Vision Sciences Society

9th Annual Meeting, May 8-13, 2009
Naples Grande Resort & Club, Naples, Florida

Abstracts

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Program and Abstracts cover design by Kevin Guckes
T-shirt and tote bag design by Alan Stubbs and Simone Gori

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Abstract Numbering System

Each abstract is assigned a unique 4 to 5 digit number based on when and where it is to be presented. The format of the abstract numbering is DT.RN (where D is the Day, T is the Time, R is the Room and N is the Presentation number).

First Digit - Day	Second Digit - Time Period	Third Digit - Room	Fourth/Fifth Digits - Number
1 Friday	1 Early AM talk session	1 Royal Palm Ballroom 1-3	1, 2, 3... For talks
2 Saturday	2 Late AM talk session	2 Royal Palm Ballroom 4-5	01, 02, 03... For posters
3 Sunday	3 AM poster session	3 Royal Palm Ballroom 6-8	
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Examples:
21.16 Saturday, early AM talk in Royal Palm Ballroom 1-3, 6th talk
36.513 Sunday, PM poster in Vista Ballroom, poster board 513
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Note: Two digits after the period indicates a talk, three digits indicates a poster (and is also the number of the poster board).

Meeting Schedule

Friday, May 8

9:00 am – 8:30 pm	Registration Open	Royal Palm Foyer
1:00 – 3:00 pm	Symposia Session 1	Royal Palm Ballrooms 1-3, 4-5 & 6-8
3:00 – 3:30 pm	Coffee Break	Royal Palm Foyer
3:30 – 5:30 pm	Symposia Session 2	Royal Palm Ballrooms 1-3, 4-5 & 6-8
5:30 – 7:30 pm	Opening Night Reception	Sunset Deck, Vista Deck
6:30 – 9:00 pm	Evening Poster Session	Vista Ballroom

Saturday, May 9

7:30 am – 7:30 pm	Registration Open	Royal Palm Foyer
8:00 – 8:30 am	Coffee	Royal Palm Foyer
8:30 – 10:00 am	Talk Sessions	Royal Palm Ballrooms 1-3 & 4-5
8:30 am – 12:30 pm	Poster Sessions	Royal Palm Ballroom 6-8, Orchid Ballroom, Vista Ballroom
8:30 am – 6:45 pm	Exhibits Open	Orchid Foyer
11:00 am – 12:45 pm	Talk Sessions	Royal Palm Ballrooms 1-3 & 4-5
12:45 – 2:45 pm	Lunch Break	Purchase a lunch at VSS Marketplace and head to the beach!*
1:30 – 2:30 pm	Funding Opportunities in Vision Research at NEI & NIH	Royal Palm Ballroom 1-3
2:45 – 4:15 pm	Talk Sessions	Royal Palm Ballrooms 1-3 & 4-5
2:45 – 6:45 pm	Poster Sessions	Royal Palm Ballroom 6-8, Orchid Ballroom, Vista Ballroom
4:30 – 5:00 pm	Coffee Break	Royal Palm Foyer
5:15 – 7:00 pm	Talk Sessions	Royal Palm Ballrooms 1-3 & 4-5
7:30 – 9:00 pm	Keynote Address and Awards Ceremony	Royal Palm Ballroom 4-5

Sunday, May 10

8:00 – 8:30 am	Coffee	Royal Palm Foyer
8:00 am – 6:45 pm	Registration Open	Royal Palm Foyer
8:30 – 10:00 am	Talk Sessions	Royal Palm Ballrooms 1-3 & 4-5
8:30 am – 12:30 pm	Poster Sessions	Royal Palm Ballroom 6-8, Orchid Ballroom, Vista Ballroom
8:30 am – 6:45 pm	Exhibits Open	Orchid Foyer
11:00 am – 12:45 pm	Talk Sessions	Royal Palm Ballrooms 1-3 & 4-5
12:45 – 2:45 pm	Lunch Break	Purchase a lunch at VSS Marketplace and head to the beach!*
1:00 – 2:30 pm	Python & Vizard User Group Meeting	Royal Palm Ballroom 1-3
2:45 – 4:15 pm	Talk Sessions	Royal Palm Ballrooms 1-3 & 4-5
2:45 – 6:45 pm	Poster Sessions	Royal Palm Ballroom 6-8, Orchid Ballroom, Vista Ballroom
4:30 – 5:00 pm	Coffee Break	Royal Palm Foyer
5:15 – 7:00 pm	Talk Sessions	Royal Palm Ballrooms 1-3 & 4-5
7:00 – 9:00 pm	The 5th Annual Best Visual Illusion Contest	Philharmonic Center for the Arts
10:00 pm – 1:00 am	VVRC-CVS Social	Vista Ballroom & Sunset Deck

Monday, May 11

8:00 – 8:30 am	Coffee	Royal Palm Foyer
8:00 am – 1:45 pm	Registration Open	Royal Palm Foyer
8:30 – 10:00 am	Talk Sessions	Royal Palm Ballrooms 1-3 & 4-5
8:30 am – 12:30 pm	Poster Sessions	Royal Palm Ballroom 6-8, Orchid Ballroom, Vista Ballroom
8:30 am – 1:00 pm	Exhibits Open	Orchid Foyer
11:00 am – 12:45 pm	Talk Sessions	Royal Palm Ballrooms 1-3 & 4-5
1:00 – 1:45 pm	Business Meeting	Royal Palm Ballroom 4-5
6:00 – 8:00 pm	Demo Night Dinner	Sunset Deck & Vista Deck
7:00 – 9:00 pm	Demo Night Demos	Royal Palm Ballroom 4-5 & Acacia Meeting Rooms

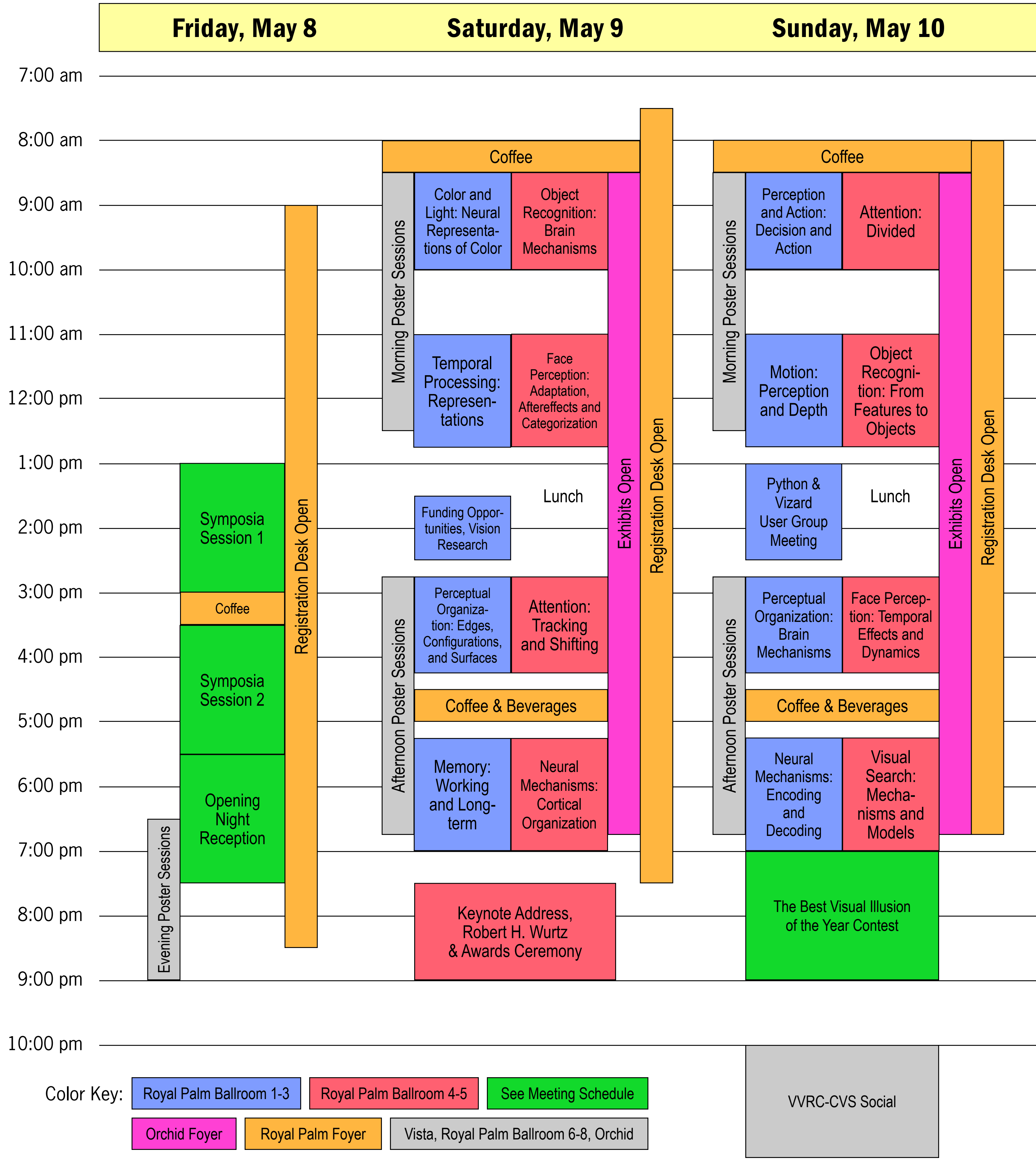
Tuesday, May 12

8:00 – 8:30 am	Coffee	Royal Palm Foyer
8:00 am – 6:45 pm	Registration Open	Royal Palm Foyer
8:30 – 10:00 am	Talk Sessions	Royal Palm Ballrooms 1-3 & 4-5
8:30 am – 12:30 pm	Poster Sessions	Royal Palm Ballroom 6-8, Orchid Ballroom, Vista Ballroom
8:30 am – 6:45 pm	Exhibits Open	Orchid Foyer
11:00 am – 12:45 pm	Talk Sessions	Royal Palm Ballrooms 1-3 & 4-5
12:45 – 2:45 pm	Lunch Break	Purchase a lunch at VSS Marketplace and head to the beach!*
2:45 – 4:30 pm	Talk Sessions	Royal Palm Ballrooms 1-3, & 4-5
2:45 – 6:45 pm	Poster Sessions	Royal Palm Ballroom 6-8, Orchid Ballroom, Vista Ballroom
4:30 – 5:00 pm	Coffee Break	Royal Palm Foyer
5:15 – 7:00 pm	Talk Sessions	Royal Palm Ballrooms 1-3 & 4-5
9:30 pm – 1:30 am	Club Vision Dance Party	Vista Ballroom, Sunset Deck & Vista Deck

Wednesday, May 13

8:00 – 8:30 am	Coffee	Royal Palm Foyer
8:00 am – 12:45 pm	Registration Open	Royal Palm Foyer
8:30 – 10:00 am	Talk Sessions	Royal Palm Ballrooms 1-3 & 4-5
8:30 am – 12:30 pm	Poster Sessions	Royal Palm Ballroom 6-8, Orchid Ballroom, Vista Ballroom
11:00 am – 12:45 pm	Talk Sessions	Royal Palm Ballrooms 1-3 & 4-5
12:45 pm	Meeting Ends	

* Salads, sandwiches, and snacks are available for purchase at the VSS Marketplace in the Aura Bar/Chill-out Lounge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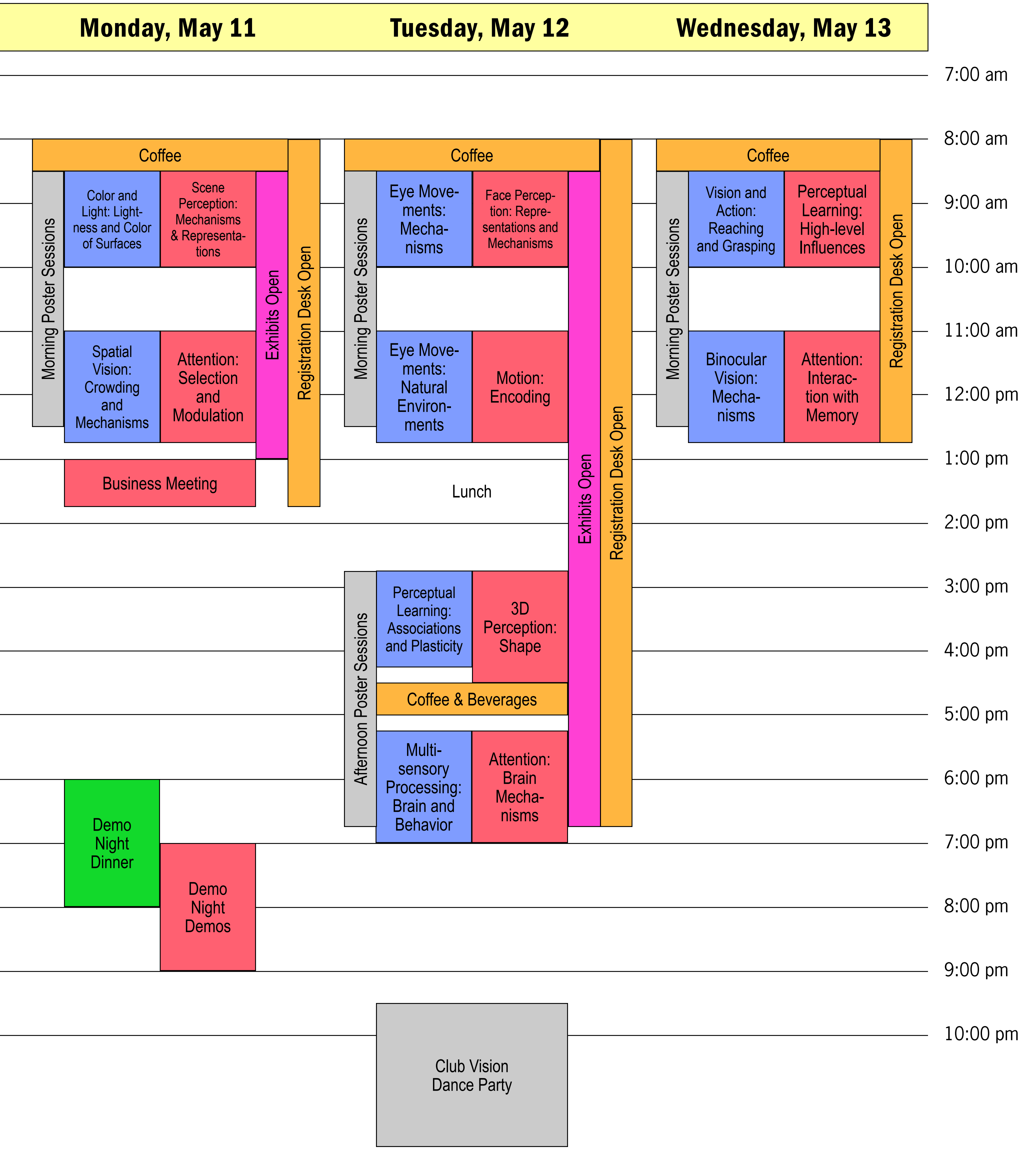
Symposia Session 1
Coffee
Symposia Session 2
Opening Night Reception
Evening Poster Sessions
Registration Desk Open
Coffee
Morning Poster Sessions
Color and Light: Neural Representations of Color
Object Recognition: Brain Mechanisms
Temporal Processing: Representations
Face Perception: Adaptation, Aftereffects and Categorization
Funding Opportunities, Vision Research
Lunch
Afternoon Poster Sessions
Perceptual Organization: Edges, Configurations, and Surfaces
Attention: Tracking and Shifting
Coffee & Beverages
Memory: Working and Long-term
Neural Mechanisms: Cortical Organization
Keynote Address, Robert H. Wurtz & Awards Ceremony
Exhibits Open
Registration Desk Open
Coffee
Morning Poster Sessions
Perception and Action: Decision and Action
Attention: Divided
Motion: Perception and Depth
Object Recognition: From Features to Objects
Python & Vizard User Group Meeting
Lunch
Afternoon Poster Sessions
Perceptual Organization: Brain Mechanisms
Face Perception: Temporal Effects and Dynamics
Coffee & Beverages
Neural Mechanisms: Encoding and Decoding
Visual Search: Mechanisms and Models
The Best Visual Illusion of the Year Contest
VVRC-CVS Social
Exhibits Open
Registration Desk Open
Color Key:
Royal Palm Ballroom 1-3
Royal Palm Ballroom 4-5
See Meeting Schedule
Orchid Foyer
Royal Palm Foyer
Vista, Royal Palm Ballroom 6-8, Orchid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10:00 pm
Coffee
Morning Poster Sessions
Color and Light: Lightness and Color of Surfaces
Scene Perception: Mechanisms & Representations
Exhibits Open
Registration Desk Open
Spatial Vision: Crowding and Mechanisms
Attention: Selection and Modulation
Business Meeting
Demo Night Dinner
Demo Night Demos
Coffee
Morning Poster Sessions
Eye Movements: Mechanisms
Face Perception: Representations and Mechanisms
Eye Movements: Natural Environments
Motion: Encoding
Lunch
Exhibits Open
Registration Desk Open
Afternoon Poster Sessions
Perceptual Learning: Associations and Plasticity
3D Perception: Shape
Coffee & Beverages
Multisensory Processing: Brain and Behavior
Attention: Brain Mechanisms
Club Vision Dance Party
Coffee
Morning Poster Sessions
Vision and Action: Reaching and Grasping
Perceptual Learning: High-level Influences
Registration Desk Open
Binocular Vision: Mechanisms
Attention: Interaction with Memory

Poster Schedule

Poster Setup and Takedown

All poster sessions are held in the Royal Palm Ballrom 6-8 and Orchid Ballroom on the Ballroom level, and Vista Ballroom on the Lobby level. The last three digits of your poster number indicate the number of your poster board.

Posters should be put up at the beginning of a session and taken down at the end. Authors of even numbered posters are expected to be present at their posters during the entire “Even Author Presents” time; and authors of odd numbered posters during the entire “Odd Author Presents” time. Authors may be present longer if desired.

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.

Friday Afternoon, May 8

Setup: 6:00 – 6:30 pm
Session: 6:30 – 9:00 pm
Even Authors Present: 6:30 – 7:30 pm
Odd Authors Present: 7:30 – 8:30 pm
Room: Vista Ballroom
- Face Perception: Emotion
- Attention: Models
- Eye Movements: Cognitive Mechanisms
- Neural Mechanisms: Visual and Visuomotor Function

Take down: 9:00 – 9:15 pm

Saturday Morning, May 9

Setup: 8:00 – 8:30 am
Session: 8:30 am – 12:30 pm
Even Authors Present: 9:30 – 10:30am
Odd Authors Present: 10:30 – 11:30 am
Room: Royal Palm 6-8
- Motion: Local and Global Processing
- Perceptual Learning: Models and Mechanisms

Room: Orchid Ballroom
- Neural Mechanisms: Receptive Fields
- Perceptual Organization: Contours
- Spatial Vision: Crowding and Peripheral Vision
- Multisensory Processing: Visual and Auditory Perception

Room: Vista Ballroom
- Attention: Capture
- Attention: Temporal Selection and Modulation
- Spatial Vision: Natural Scenes
- Special Populations: Disorders and Disease

Take down: 12:30 – 1:00 pm

Saturday Afternoon, May 9

Setup: 2:00 – 2:45 pm
Session: 2:45 – 6:45 pm
Even Authors Present: 3:45 – 4:45 pm
Odd Authors Present: 4:45 – 5:45 pm
Room: Royal Palm 6-8
- Color and Light: Lightness and Brightness
- Eye Movements: Cognition and Social Cognition

Room: Orchid Ballroom
- Spatial Vision: Mechanisms
- Motion: Biological
- Face Perception: Development and Disorders

Room: Vista Ballroom
- 3D Perception: Shape, Shading and Contours
- Binocular Vision: Depth, Bistability, and Memory
- Attention: Spatial Selection and Modulation
- Visual Search: Attentional Mechanisms

Take down: 6:45 – 7:00 pm

Sunday Morning, May 10

Setup: 8:00 – 8:30 am
Session: 8:30 am – 12:30 pm
Even Authors Present: 9:30 – 10:30am
Odd Authors Present: 10:30 – 11:30 am
Room: Royal Palm 6-8
- Scene Perception: Categorization and Memory
- Face Perception: Wholes, Parts, Configurations and Features

Room: Orchid Ballroom
- Attention: Brain Mechanisms
- Perceptual Organization: Segmentation
- Memory: Visual Learning and Memory
- Object Recognition: Reading

Room: Vista Ballroom
- Vision and Action: Posture, Wayfinding, and Whacking
- Binocular Vision: Brain and Behavior
- Multisensory Processing: Cross-modal Perception

Take down: 12:30 – 1:00 pm

Sunday Afternoon, May 10

Setup: 2:00 – 2:45 pm
Session: 2:45 – 6:45 pm
Even Authors Present: 3:45 – 4:45 pm
Odd Authors Present: 4:45 – 5:45 pm
Room: Royal Palm 6-8
- 3D Perception: Space
- Memory: Working and Short-term Memory

Room: Orchid Ballroom
- Attention: Endogenous and Exogenous
- Object Recognition: Objects and Categories
- Color and Light: Color Appearance

Room: Vista Ballroom
- Motion: Depth and Optic Flow
- Vision and Action: Hand Movements
- Spatial Vision: Adaptation and Masking

Take down: 6:45 – 7:00 pm

Monday Morning, May 11

Setup: 8:00 – 8:30 am
Session: 8:30 am – 12:30 pm
Even Authors Present: 9:30 – 10:30am
Odd Authors Present: 10:30 – 11:30 am
Room: Royal Palm 6-8
- Perceptual Learning: Specificity and Transfer
- Motion: Representations

Room: Orchid Ballroom
- Eye Movements: Pursuit and Fixation
- Attention: Inattention and Blindness
- Attention: Linguistic, Motivational and Affective Factors
- Face Perception: Brain Mechanisms

Room: Vista Ballroom
- Vision and Action: Locomotion
- Vision and Action: Reaching
- Spatial Vision: Mechanisms and Special Populations

Take down: 12:30 – 1:00 pm

Tuesday Morning, May 12

Setup: 8:00 – 8:30 am
Session: 8:30 am – 12:30 pm
Even Authors Present: 9:30 – 10:30am
Odd Authors Present: 10:30 – 11:30 am
Room: Royal Palm 6-8
- Object Recognition: Objects and Visual features
- Binocular Vision: Rivalry and Bistability

Room: Orchid Ballroom
- Attention: Tracking
- Attention: Feature- and Object-based
- Eye Movements: Saccade Selection
- Perceptual Organization: Grouping

Room: Vista Ballroom
- Temporal Processing: Mechanisms
- Perception and Action: Decisions and Frames of Reference
- Visual Search: Context and Attention

Take down: 12:30 – 1:00 pm

Tuesday Afternoon, May 13

Setup: 2:00 – 2:45 pm
Session: 2:45 – 6:45 pm
Even Authors Present: 3:45 – 4:45 pm
Odd Authors Present: 4:45 – 5:45 pm
Room: Royal Palm 6-8
- Face Perception: Inversion and Viewpoint Effects
- Face Perception: Face Space, Categorization and Representation

Room: Orchid Ballroom
- Perceptual Organization: 2D Shape
- 3D Perception: Disparity and Other Depth Cues
- Scene Perception: Spatiotemporal Factors
- Color and Light: Chromatic Mechanisms

Room: Vista Ballroom
- Special Populations: Lifespan Development
- Motion: Mechanisms
- Attention: Interaction with Memory

Take down: 6:45 – 7:00 pm

Wednesday Morning, May 13

Setup: 8:00 – 8:30 am
Session: 8:30 am – 12:30 pm
Even Authors Present: 9:30 – 10:30am
Odd Authors Present: 10:30 – 11:30 am
Room: Royal Palm 6-8
- Neural Mechanisms: Visual Representations
- Face Perception: Experience, Learning and Expertise

Room: Orchid Ballroom
- Attention: Resource Competition
- Eye Movements: Mechanisms
- Visual Search: Mechanisms and Special Populations

Take down: 12:30 – 12:45 pm

Talk Schedule

Saturday, May 9

Time	Royal Palm 1-3	Royal Palm 4-5
8:30 – 10:00 am	Color and Light: Neural Representations of Color	Object Recognition: Brain Mechanisms
11:00 am – 12:45 pm	Temporal Processing: Representations	Face Perception: Adaptation, Aftereffects and Categorization
2:45 – 4:15 pm	Perceptual Organization: Edges, Configurations, and Surfaces	Attention: Tracking and Shifting
5:15 – 7:00 pm	Memory: Working and Long-term	Neural Mechanisms: Cortical Organization

Sunday, May 10

Time	Royal Palm 1-3	Royal Palm 4-5
8:30 – 10:00 am	Perception and Action: Decision and Action	Attention: Divided
11:00 am – 12:45 pm	Motion: Perception and Depth	Object Recognition: From Features to Objects
2:45 – 4:15 pm	Perceptual Organization: Brain Mechanisms	Face Perception: Temporal Effects and Dynamics
5:15 – 7:00 pm	Neural Mechanisms: Encoding and Decoding	Visual Search: Mechanisms and Models

Monday, May 11

Time	Royal Palm 1-3	Royal Palm 4-5
8:30 – 10:00 am	Color and Light: Lightness and Color of Surfaces	Scene Perception: Mechanisms and Representations
11:00 am – 12:45 pm	Spatial Vision: Crowding and Mechanisms	Attention: Selection and Modulation

Tuesday, May 12

Time	Royal Palm 1-3	Royal Palm 4-5
8:30 – 10:00 am	Eye Movements: Mechanisms	Face Perception: Representations and Mechanisms
11:00 am – 12:45 pm	Eye Movements: Natural Environments	Motion: Encoding
2:45 – 4:30 pm	Perceptual Learning: Associations and Plasticity	3D Perception: Shape
5:15 – 7:00 pm	Multisensory Processing: Brain and Behavior	Attention: Brain Mechanisms

Wednesday, May 13

Time	Royal Palm 1-3	Royal Palm 4-5
8:30 – 10:00 am	Vision and Action: Reaching and Grasping	Perceptual Learning: High-level Influences
11:00 am – 12:45 pm	Binocular Vision: Mechanisms	Attention: Interaction with Memory

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 8, 1:00 – 3:00 pm

S1 Common Mechanisms in Time and Space Perception, Royal Palm Ballroom 1-3

S2 ARVO@VSS: Advances in Understanding the Structure and and Function of the Retina, Royal Palm Ballroom 4-5

S3 Is number visual? Is vision numerical? Investigating the relationship between visual representations and the property of magnitude, Royal Palm Ballroom 6-8

Friday, May 8, 3:30 – 5:30 pm

S4 Retinotopic and Non-retinotopic Information Representation and Processing in Human Vision, Royal Palm Ballroom 1-3

S5 Dynamic Processes in Vision, Royal Palm Ballroom 4-5

S6 Modern Approaches to Modeling Visual Data, Royal Palm Ballroom 6-8

S1

Common Mechanisms in Time and Space Perception

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

Organizer: David Eagleman (Baylor College of Medicine)

Presenters: David Eagleman (Baylor College of Medicine), Concetta Morrone (Università di Pisa, Pisa, Italy), Jonathan Kennedy (University of Cardiff), Alex Holcombe (University of Sydney)

Symposium Summary

Most of the actions we carry out on a daily basis require timing on the scale of tens to hundreds of milliseconds. We must judge time to speak, to walk, to predict the interval between our actions and their effects, to determine causality and to decode information from our sensory receptors. However, the neural bases of time perception are largely unknown. Scattered confederacies of investigators have been interested in time for decades, but only in the past few years have new techniques been applied to old problems. Experimental psychology is discovering how animals perceive and encode temporal intervals, while physiology, fMRI and EEG unmask how neurons and brain regions underlie these computations in time. This symposium will capitalize on new breakthroughs, outlining the emerging picture and highlighting the remaining confusions about time in the brain. How do we encode and decode temporal information? How is information coming into different brain regions at different times synchronized? How plastic is time perception? How is it related to space perception? The experimental work of the speakers in this symposium will be shored together to understand how neural signals in different brain regions come together for a temporally unified picture of the world, and how this is related to the mechanisms of space perception. The speakers in this symposium are engaged in experiments at complementary levels of exploring sub-second timing and its relation to space.

Presentations

A neural model for temporal order judgments and their active recalibration: a common mechanism for space and time?

David M. Eagleman, Mingbo Cai, Chess Stetson

Human temporal order judgments (TOJs) dynamically recalibrate when participants are exposed to a delay between their motor actions and sensory effects. We here present a novel neural model that captures TOJs and their recalibration. This model employs two ubiquitous features of neural systems: synaptic scaling at the single neuron level and opponent processing at the population level. Essentially, the model posits that different populations of neurons encode different delays between motor-sensory or sensory-sensory events, and that these populations feed into opponent processing neurons that employ synaptic scaling. The system uses the difference in activity between populations encoding for 'before' or 'after' to obtain a decision. As a consequence, if the network's 'motor acts' are consistently followed by sensory feedback with a delay, the network will automatically recalibrate to change the perceived point of simultaneity between the action and sensation. Our model suggests that temporal recalibration may be a temporal analogue to the motion aftereffect. We hypothesize that the same neural mechanisms are used to make perceptual determinations about both space and time, depending on the information available in the neural neighborhood in which the module unpacks.

Space-time in the brain

Concetta Morrone, David Burr

The perception of space and time are generally studied separately and thought of as separate and independent dimensions. However, recent research suggests that these attributes are tightly interlinked: event timing may be modality-specific and tightly linked with space. During saccadic eye movements, time becomes severely compressed, and can even appear to run backwards. Adaptation experiments further suggest that visual events of sub-second duration are timed by neural visual mechanisms with spatially circumscribed receptive fields, anchored in real-world rather than retinal coordinates. All these results sit nicely with recent evidence implicating parietal cortex with coding of both space and sub-second interval timing.

Adaptation to space and to time

Jonathan Kennedy, M.J. Buehner, S.K. Rushton

Human behavioural adaptation to delayed visual-motor feedback has been investigated by Miall and Jackson (2006: Exp Brain Res) in a closed-loop manual tracking task with a semi-predictably moving visual target. In intersensory, open-loop and predictable sensory-motor tasks, perceptual adaptation of the involved modalities has been demonstrated on several occasions in recent years, using temporal order judgments and perceptual illusions (e.g. Stetson, Cui, Montague, & Eagleman, 2006: Neuron; Fujisaki, Shimojo, Kashino, & Nishida, 2004: Nature Neuroscience).

Here we present results from two series of experiments: the first investigating perceptual adaptation in Miall and Jackson's tracking task, by adding visual-motor temporal order judgments; and the second investigating the localization of perceptual adaptation across the involved modalities.

We will discuss these results in the light of recent developments in modeling adaptation to misalignment in spatial (Witten, Knudsen, & Sompolinsky, 2008: J Neurophysiol) and temporal (Stetson et al, 2006) domains, and consider their implications for what, if any, common mechanisms and models may underlie all forms of adaptation to intersensory and sensory-motor misalignment.

A temporal limit on judgments of the position of a moving object

Alex Holcombe, Daniel Linares, Alex L. White

The mechanisms of time perception have consequences for perceived position when one attempts to determine the position of a moving object at a particular time. While viewing a luminance-defined blob orbiting fixation, our observers report the blob's perceived position when the fixation point changes color. In addition to the error in the direction of motion (flash-lag effect), we find that the standard deviation of position judgments increases over a five-fold range of speeds such that it corresponds to a constant 70-80 ms of the blob's trajectory (also see Murakami 2001). This result is in sharp contrast to acuity tasks with two objects moving together, for which thresholds vary very little with velocity. If the 70 ms of temporal variability is dependent on low-level factors, we would expect a different result when we triple the eccentricity, but this had little effect. If the variability is due to uncertainty about the time of the color change, then we should be able to reduce it by using a sound as the time marker (as the auditory system may have better temporal resolution) or by using a predictable event, such as the time a dot moving at a constant velocity arrives at fixation. Although average error differs substantially for these conditions, in both the reported positions still spanned about 70-80 ms of the blob's trajectory. Finally, when observers attempt to press a button in time with arrival of the blob at a landmark, the standard deviation of their errors is about 70 ms. We theorize that this temporal imprecision originates in the same mechanisms responsible for the poor temporal resolution of feature-binding (e.g. Holcombe & Cavanagh 2001; Fujisaki & Nishida 2005).

S2

ARVO@VSS: Advances in Understanding the Structure and Function of the Retina

Friday, May 9, 1:00 – 3:00 pm, Royal Palm Ballroom 4-5

Organizer: Donald Hood (Columbia University)

Presenters: Dennis Dacey (University of Washington), Paul R Martin (National Vision Research Institute of Australia & Department of Optometry and Vision Sciences & University of Melbourne, Australia.), Austin Roorda (University of California, Berkeley), Donald C Hood (Columbia University)

Symposium Summary

This symposium was designed in conjunction with Steve Shevell to bring the latest advances presented at ARVO to the VSS audience. There will be four talks covering the following topics. I will moderate it and speak last on. "Advances in structural imaging of the human retina." Before me the speakers and topics will be: D. Darcy (Advances in retinal anatomy); P. Martin (Advances in retinal physiology); and A. Roorda (Advances in optical imaging of the human retina). The speakers are all experienced researchers and lectures use to speaking to diverse audiences. Thus the level should be appropriate for all attendees at VSS from students to experts in vision or cognition.

Presentations

Advances and challenges in understanding the normal retina

Dennis Dacey

The vertebrate retina is one of the most accessible parts of the central nervous system for clarifying the links between neural circuits and visual coding. Advanced imaging methods are already revealing fundamental features of retinal organization and function previously inaccessible to study. As a background for considering future directions I will review our current understanding of the cellular architecture of the primate retina. On the one hand, the retina is an elegantly simple structure at the periphery of the visual system where mosaics of receptor cells transmit signals to interneurons and ganglion cells whose axons project a representation of the visual world to the brain. However, the retina is also an amazingly complex neural machine that contains at least 80 anatomically and physiologically distinct cell populations. The interactions among most of these cell types are precisely arranged in a microlaminated sheet that provides the scaffold for ~ 20 separate visual pathways. In the primate, much attention has been focused in the so-called 'midget pathway', yet these cells, despite their numerosity, only account for two anatomically distinct visual pathways. By contrast, the great majority of visual pathways exists at relatively low density and subserves diverse functions ranging from color vision and motion detection to the pupil reflex and setting biological rhythms. Microdissecting the structure and function of each of these diverse low-density pathways remains a key challenge for retinal neurobiology.

Advances in understanding circuits serving colour vision

Paul R Martin, Ulrike Grunert, Sammy CS Lee, Patricia R Jusuf

The theory of trichromatic human colour vision was proposed over 200 years ago and the existence of three types of cone photoreceptors was confirmed in the 1980s. I will summarise current views of how the signals from cone photoreceptors are organised into "blue-yellow" and "red-green" pathways in the subcortical visual system. These pathways can be distinguished at the first synapse in the visual pathway, between cone photoreceptors and cone-contacting bipolar cells, and remain segregated in the subcortical afferent visual pathway. I will review evidence from molecular biology, anatomy, and physiology showing that the blue-yellow pathway likely forms a primordial colour vision system common to most diurnal mammals, whereas the red-green pathway is unique to primates and evolved together with high-acuity spatial vision.

Advances in optical imaging of the human retina

Austin Roorda

Adaptive optics (AO) is a technique to correct for the aberrations in the eye's optics, and offers non-invasive, optical access to the retina in living eyes on an unprecedented scale. The technology is very useful for ophthalmic imaging and is being used for basic and clinical imaging, but the scope of applications goes well beyond. By coupling scanning laser technology with adaptive optics, we are able to track and deliver light to the retina with the precision and accuracy of single cones and can simultaneously record either perceptual (human) or electrical responses (monkey). These measurements are helping to reveal basic properties of the human visual system.

Advances in structural imaging of the human retina

Donald C Hood

With recent advances in the structural imaging, it is now possible to visualize individual retinal layers of the human retina in vivo. After a short summary of the technique of optical coherence tomography (OCT), its application to understanding the structure and function of the normal and diseased eye will be considered. First, measurements of the thickness of the normal human receptor, inner nuclear, and ganglion cell layers will be presented and the possibilities of using this technique to study normal human vision discussed. Next, data from patients with diseases that affect the receptors (e.g. retinitis pigmentosa) and retinal ganglion cells (e.g. glaucoma) will be presented and discussed in terms of tests of hypotheses about the relationship between behavior (i.e. visual loss) and structural (i.e. anatomical) changes in these layers.

S3

Is number visual? Is vision numerical? Investigating the relationship between visual representations and the property of magnitude

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

Organizer: Michael C. Frank (Massachusetts Institute of Technology)

Presenters: David Burr (Dipartimento di Psicologia, Università Degli Studi di Firenze and Department of Psychology, University of Western Australia), Michael C. Frank (Massachusetts Institute of Technology), Steven Franconeri (Northwestern University), David Barner (University of California, San Diego), Justin Halberda (Johns Hopkins University)

Symposium Summary

The ability to manipulate exact numbers is a signature human achievement, supporting activities like building bridges, designing computers, and conducting economic transactions. Underlying this ability and supporting its acquisition is an evolutionarily-conserved mechanism for the manipulation of approximate quantity: the analog magnitude system. The behavioral and neural signatures of magnitude representations have been extensively characterized but how these representations interact with other aspects of cognitive and visual processing is still largely unknown. Do magnitude features attach to objects, scenes, or surfaces? Is approximate magnitude representation maintained even for sets for which exact quantity is known? Is magnitude estimation ability altered by experience?

The goal of our symposium is to look for answers to these questions by asking both how number is integrated into visual processing and how visual processing in turn forms a basis for the acquisition and processing of exact number. We address these questions through talks on three issues: 1) the basic psychophysical properties of numerical representations (Halberda, Burr), 2) how visual mechanisms integrate representations of number (Franconeri & Alvarez), and 3) how these representations support exact computation, both in standard linguistic representations (Frank) and via alternative representations (Barner).

The issues addressed by our symposium have been a focus of intense recent interest. Within the last four years there have been a wide variety of high-profile reports from developmental, neuroscientific, comparative, and cross-linguistic/cross-cultural studies of number. Research on number is one of the fastest moving fields in cognitive science, due both to the well-defined questions that motivate research in this field and to the wide variety of methods that can be brought to bear on these questions.

The target audience of our symposium is a broad group of vision scientists, both students and faculty, who are interested in connecting serious vision science with cognitive issues of broad relevance to a wide range of communities in psychology, neuroscience, and education. In addition, the study of number provides an opportunity to link innovations in vision research methods—including psychophysical-style experimental designs, precise neuroimaging methods, and detailed computational data analysis—with deep cognitive questions about the nature of human knowledge. We anticipate that attendees of our symposium will come away with a good grasp of the current state of the art and the outstanding issues in the interface of visual and numerical processing.

Presentations

A visual sense of number

David Burr

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, by measuring Weber fractions with a series of techniques, and by adaptation. The Weber fraction measurements suggest that number estimation and “subitizing” share common mechanisms. 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.

Language as a link between exact number and approximate magnitude

Michael C. Frank

Is exact number a human universal? Cross-cultural fieldwork has given strong evidence that language for exact number is an invention which is not present in all societies. This result suggests a range of questions about how learning an exact number system may interact with pre-existing analog magnitude representations. More generally, number presents a tractable case of the Whorfian question of whether speakers of different languages differ in their cognition. We addressed these questions by studying the performance of the Pirahã, an Amazonian group in Brazil, on a range of simple quantity matching tasks (first used by Gordon, 2004). We compared the performance of this group to the performance of English-speakers who were unable to use exact numerical representations due to a concurrent verbal interference task. We found that both groups were able to complete simple one-to-one matching tasks even without words for numbers and both groups relied on analog magnitude representations when faced with a more difficult task in which items in the set to be estimated were presented one at a time. However, performance between the two groups diverged on tasks in which other strategies could be used. We conclude that language for number is a “cognitive technology” which allows the manipulation of exact quantities across time, space, and changes in modality, but does not eliminate or substantially alter users’ underlying numerical abilities.

Rapid enumeration is based on a segmented visual scene

Steve Franconeri, George Alvarez

How do we estimate the number of objects in a set? One primary question is whether our estimates are based on an unbroken visual image or a segmented collection of discrete objects. We manipulated whether individual objects were isolated from each other, or grouped into pairs by irrelevant lines. If number estimation operates over an unbroken image, then this manipulation should not affect estimates. But if number estimation relies on a segmented image, then grouping pairs of objects into single units should lead to lower estimates. In Experiment 1, participants underestimated the number of grouped squares, relative to when the connecting lines were ‘broken’. Experiment 2 presents evidence that this segmentation process occurred broadly across the entire set of objects. In Experiment 3, a staircase procedure provides a quantitative measure of the underestimation effect. Experiment 4 shows that is the strength of the grouping effect was equally strong for a single thin line, and the effect can be eliminated by a tiny break in the line. These results provide the first direct evidence that number estimation relies on a segmented input.

Constructing exact number approximately: a case study of mental abacus representations

David Barner

Exact numerical representation is usually accomplished through linguistic representations. However, an alternative route for accomplishing this task is through the use of a “mental abacus”—a mental image of an abacus (a device used in some cultures for keeping track of exact quantities and doing arithmetic via the positions of beads on a rigid frame). We investigated the nature of mental abacus representations by studying children ages 7-15 who were trained in this technique. We compared their ability to read the cardinality of “abacus flashcards” (briefly presented images of abacuses in different configurations) with their ability to enumerate sets of dots after similarly brief, masked presentation. We conducted five studies comparing abacus flashcards to: (1) random dot enumeration, (2) spatially proximate dot enumeration, (3) enumeration of dots arranged in an abacus configuration without the abacus frame, (4) enumeration of dots on a rotated abacus, (5) enumeration of dots arranged on an abacus. In all conditions, participants were faster and more accurate in identifying the cardinality of an abacus than they were in enumerating the same number of beads, even when the display was physically identical. Analysis of errors suggested that children in our studies viewed the abacus as a set of objects with each separate row of beads being a single object, each with its own independent magnitude feature. Thus, the "mental abacus" draws on pre-existing approximate and exact visual abilities to construct a highly accurate system for representing large exact number.

An interface between vision and numerical cognition

Justin Halberda

While the similarity of numerical processing across different modalities (e.g., visual objects, auditory objects, extended visual events) suggests that number concepts are domain general even at the earliest ages (4 month old babies), visual processing is constrained in ways that may have constrained the numerical concepts humans have developed. In this talk I discuss how online processing of numerical content is shaped by the constraints of both object-based and ensemble-based visual processing and discuss how numerical content and vision engage one another.

S4

Retinotopic and Non-retinotopic Information Representation and Processing in Human Vision

Friday, May 8, 3:30 – 5:30 pm, Royal Palm Ballroom 1-3

Organizers: Haluk Ogmen (University of Houston) and Michael H. Herzog (Laboratory of Psychophysics, BMI, EPFL, Switzerland)

Presenters: Doug Crawford (Centre for Vision Research, York University, Toronto, Ontario, Canada), David Melcher (Center for Mind/Brain Sciences and Department of Cognitive Sciences University of Trento, Italy), Patrick Cavanagh (LPP, Université Paris Descartes, Paris, France), Shin'ya Nishida (NTT Communication Science Labs, Atsugi, Japan), Michael H. Herzog (Laboratory of Psychophysics, BMI, EPFL, Switzerland)

Symposium Summary

Due to the movements of the eyes and those of the objects in the environment, natural vision is highly dynamic. An understanding of how the visual system can cope with such complex inputs requires an understanding of reference frames, used in the computations of various stimulus attributes. It is well known that the early visual system has a retinotopic organization. It is generally thought that the retinotopic organization of the early visual system is insufficient to support the fusion of visual images viewed at different eye positions. Moreover, metacontrast masking and anorthoscopic perception show that a retinotopic image is neither sufficient nor necessary for the perception of spatially extended form. How retinotopic representations are transformed into more complex non-retinotopic representations has been long-standing and often controversial question. The classical paradigm to study this question has been the study of memory across eye movements. As we shift our gaze from one fixation to another one, the retinotopic representation of the environment undergoes drastic shifts, yet phenomenally our environment appears stable. How is this phenomenal stability achieved? Does the visual system integrate information across eye movements and if so how? A variety of theories ranging from purely retinotopic representations without information integration to detailed spatiotopic representations with point-by-point information integration have been proposed. Talks in this symposium (Crawford, Melcher, Cavanagh) will address the nature of trans-saccadic memory, the role of extra-retinal signals, retinotopic, spatiotopic, and objectopic representations for information processing and integration during and across eye movements. In addition to the challenge posed by eye movements on purely retinotopic representations, recent studies suggest that, even under steady fixation, computation of moving form requires non-retinotopic representations. This is because objects in the environment often move with complex trajectories and do not stimulate sufficiently retinotopically anchored receptive fields. Moreover, occlusions can "blank out" retinotopic information for a significant time period. These failures to activate sufficiently retinotopically anchored neurons, in turn, suggest that some form of non-retinotopic information analysis and integration should take place. Talks in this symposium (Nishida, Herzog) will present recent findings that show how shape and color information for moving objects can be integrated according to non-retinotopic reference frames. Taken together, the talks at the symposium aim to provide a recent perspective to the fundamental problem of reference frames utilized by the visual system and present techniques to study these representations during both eye movement and fixation periods. The recent convergence of a variety of techniques and stimulus paradigms in elucidating the roles of non-retinotopic representations provides timeliness for the proposed symposium. Since non-retinotopic representations have implications for a broad range of visual functions, we expect our symposium to be of interest to the general VSS audience including students and faculty.

Presentations

Cortical Mechanisms for Trans-Saccadic Memory of Multiple Objects

Doug Crawford, Steven Prime

Humans can retain the location and appearance of 3-4 objects in visual working memory, independent of whether a saccade occurs during the memory interval. Psychophysical experiments show that, in the absence of retinal cues, extra-retinal signals are sufficient to update trans-saccadic memory, but where and how do these signals enter the visual system? It is know that 'dorsal stream' areas like the parietal eye fields update motor plans by remapping them in gaze-centered coordinates, but the equivalent neural mechanisms for updating object features across saccades are less understood. We investigated the possible role of extra-retinal signals from the cortical gaze control system by applying trans-cranial magnetic stimulation (TMS) to either the human parietal eye fields or the frontal eye fields, during the interval between viewing several objects and testing their remembered orientation and location. Parietal TMS had a baseline effect on memory of one feature and reduced memory capacity from approximately three down to one feature, but only when applied to the right hemisphere near the time of a saccade. The effects of frontal cortex TMS on trans-saccadic memory capacity were similar, but were more symmetric, and did not affect baseline feature memory. In our task, the latter would occur if spatial memory were disrupted without affecting feature memory. These experiments show that cortical gaze control centers usually associated with the 'dorsal' stream of vision are also involved in visual processing and memory of object features during saccades, possibly influencing 'ventral stream' processing through re-entrant pathways.

Trans-Saccadic Perception: "Object-otopy" across Space and Time

David Melcher

Real-world perception is typically trans-saccadic: we see the same object across multiple fixations. Yet saccadic eye movements can dramatically change the location in which an object is projected onto the retina. In a series of experiments using eye tracking, psychophysics, neuroimaging and TMS, we have investigated how information from a previous fixation can influence perception in the subsequent fixation. Specifically, we have tested the idea that the "remapping" of receptive fields around the time of saccadic eye movements might play a role in trans-saccadic perception. Our results suggest that two mechanisms interact to produce "object-otopic" perception across saccades. First, a limited number of objects that are individuated in a scene (treated as unique objects potentially subject to action, as opposed to being part of the background gist) are represented and updated across saccades in a sensorimotor "saliency map" (possibly in posterior parietal cortex). Second, the updating of these "pointers" in the map leads to the remapping of receptive fields in intermediate visual areas. We have found that perception can be retinotopic, spatiotopic or even-in the case of moving objects-can involve the combination of information for the same object that is neither retinally or spatially matched. At the same time, however, the visual system must give priority to the retinal information, which tends to be most reliable during fixation of stable objects.

Spatiotopic Apparent Motion

Patrick Cavanagh, Martin Szinte

When our eyes move, stationary objects move over our retina. Our visual system cleverly discounts this retinal motion so that we do not see the objects moving when they are not. What happens if the object does move at the time of the eye movement? There is a question of whether we will see the displacement at all, but if we do see it, is the motion determined by the displacement on the retina or the displacement in space? To address this, we asked subjects to make horizontal saccades of 10°. Two dots were presented, one before and one after the saccade displaced vertically on the screen by 3° from the first. Each dot was presented for 400 msec and the first turned off about 100 msec before the saccade and the second dot turned on 100 msec after the saccade. In this basic condition, the retinal locations of the two dots were in opposite hemifields, separated horizontally by 10°. Nevertheless, subjects reported the dots appeared to be in motion vertically – the spatiotopic direction – although with a noticeable deviation from true vertical. This spatiotopic apparent motion was originally reported by Rock and Ebenholtz (1962) but for displacements along the direction of the saccade. In our experiments, we use the deviation from spatiotopic motion to estimate errors in the remapping of pre-saccadic locations that underlies this spatiotopic motion phenomenon.

Trajectory Integration of Shape and Color of Moving Object

Shin'ya Nishida, Masahiko Terao, Junji Watanabe

Integration of visual input signals along motion trajectory is widely recognized as a basic mechanism of motion detection. It is however not widely recognized that the same computation is potentially useful for shape and color perception of moving objects. This is because trajectory integration can improve signal-to-noise ratio of moving feature extraction without introducing motion blur. Indeed, trajectory integration of shape information is indicated by several phenomena including multiple-slit view (e.g., Nishida, 2004). Trajectory integration of color information is also indicated by a couple of phenomena, motion-induced color mixing (Nishida et al., 2007) and motion-induced color segregation (Watanabe & Nishida, 2007). In the motion-induced color segregation, for instance, temporal alternations of two colors on the retina are perceptually segregated more veridically when they are presented as moving patterns rather than as stationary alternations at the same rate. This improvement in temporal resolution can be explained by a difference in motion trajectory along which color signals are integrated. Furthermore, we recently found that the improvement in temporal resolution is enhanced when an observer views a stationary object while making a pursuit eye movement, in comparison with when an observer views a moving object without moving eyes (Terao et al, 2008, VSS). This finding further strengthens the connection of the motion-induced color segregation with subjective motion deblur.

A Litmus Test for Retino- vs. Non-retinotopic Processing

Michael Herzog, Marc Boi, Thomas Otto, Haluk Ogmen

Most visual cortical areas are retinotopically organized and accordingly most visual processing is assumed to be processed within a retinotopic coordinate frame. However, in a series of psychophysical experiments, we have shown that features of elements are often non-retinotopically integrated when the corresponding elements are motion grouped. When this grouping is blocked, however, feature integration occurs within retinotopic coordinates (even though the basic stimulus paradigm is identical in both conditions and grouping is modulated by spatial or temporal contextual cues only). Hence, there is strong evidence for both retino- and non-retinotopic processing. However, it is not always easy to determine which of these two coordinate systems prevails in a given stimulus paradigm. Here, we present a simple psychophysical test to answer this question. We presented three squares in a first frame, followed by an ISI, the same squares shifted one position to the right, the same ISI, and the squares shifted back to their original position. When this cycle is repeated with ISIs longer than 100ms, three squares are perceived in apparent motion. With this specific set-up, features integrate between the central squares iff integration takes place non-retinotopically. With this litmus test we showed, for example, that motion processing is non-retinotopic whereas motion adaptation is retinotopic. In general, by adding the feature of interest to the central square, it can be easily tested whether a given stimulus paradigm is processed retino- or non-retinotopically.

S5
Dynamic Processes in Vision

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

Organizer: Jonathan D. Victor (Weill Medical College of Cornell University)

Presenters: Sheila Nirenberg (Dept. of Physiology and Biophysics, Weill Medical College of Cornell University), Diego Contreras (Dept. of Neuroscience, University of Pennsylvania School of Medicine), Charles E. Connor (Dept. of Neuroscience, The Johns Hopkins University School of Medicine), Jeffrey D. Schall (Department of Psychology, Vanderbilt University)

Symposium Summary

The theme of the symposium is the importance of analyzing the time course of neural activity for understanding behavior. Given the very obviously spatial nature of vision, it is often tempting to ignore dynamics, and to focus on spatial processing and maps. As the speakers in this symposium will show, dynamics are in fact crucial: even for processes that appear to be intrinsically spatial, the underlying mechanism often resides in the time course of neural activity. The symposium brings together prominent scientists who will present recent studies that exemplify this unifying theme. Their topics will cover the spectrum of VSS, both anatomically and functionally (retinal ganglion cell population coding, striate cortical mechanisms of contrast sensitivity regulation, extrastriate cortical analysis of shape, and frontal and collicular gaze control mechanisms). Their work utilizes sophisticated physiological techniques, ranging from large-scale multineuronal ex-vivo recording to intracellular in vivo recording, and employs a breadth of analytical approaches, ranging from information theory to dynamical systems.

Because of the mechanistic importance of dynamics and the broad range of the specific topics and approaches, it is anticipated that the symposium will be of interest to physiologists and non-physiologists alike, and that many VSS members will find specific relevance to their own research.

Presentations

How neural systems adjust to different environments: an intriguing role for gap junction coupling

Sheila Nirenberg

The nervous system has an impressive ability to self-adjust - that is, as it moves from one environment to another, it can adjust itself to accommodate the new conditions. For example, as it moves into an environment with new stimuli, it can shift its attention; if the stimuli are low contrast, it can adjust its contrast sensitivity; if the signal-to-noise ratio is low, it can change its spatial and temporal integration properties. How the nervous system makes these shifts isn't clear. Here we show a case where it was possible to obtain an answer. It's a simple case, but one of the best-known examples of a behavioral shift - the shift in visual integration time that accompanies the switch from day to night vision. Our results show that the shift is produced by a mechanism in the retina - an increase in coupling among horizontal cells. Since coupling produces a shunt, the increase causes a substantial shunting of horizontal cell current, which effectively inactivates the cells. Since the cells play a critical role in shaping integration time (they provide feedback to photoreceptors that keeps integration time short), inactivating them causes integration time to become longer. Thus, a change in the coupling of horizontal cells serves as a mechanism to shift the visual system from short to long integration times. The results raise a new, and possibly generalizable idea: that a neural system can be shifted from one state to another by changing the coupling of one of its cell classes.

Cortical network dynamics and response gain

Diego Contreras

The transformation of synaptic input into spike output by single neurons is a key process underlying the representation of information in sensory cortex. The slope, or gain, of this input-output function determines neuronal sensitivity to stimulus parameters and provides a measure of the contribution of single neurons to the local network. Neuronal gain is not constant and may be modulated by changes in multiple stimulus parameters. Gain modulation is a common neuronal phenomenon that modifies response amplitude without changing selectivity. Computational and in vitro studies have proposed cellular mechanisms of gain modulation based on the postsynaptic effects of background synaptic activation, but these mechanisms have not been studied in vivo. Here we used intracellular recordings from cat primary visual cortex to measure neuronal gain while changing background synaptic activity with visual stimulation. We found that increases in the membrane fluctuations associated with increases in synaptic input do not obligatorily result in gain modulation in vivo. However, visual stimuli that evoked sustained changes in resting membrane potential, input resistance, and membrane fluctuations robustly modulated neuronal gain. The magnitude of gain modulation depended critically on the spatiotemporal properties of the visual stimulus. Gain modulation in vivo may thus be determined on a moment-to-moment basis by sensory context and the consequent dynamics of synaptic activation.

Dynamic integration of object structure information in primate visual cortex

Charles E. Connor

Object perception depends on extensive processing of visual information through multiple stages in the ventral pathway of visual cortex. We use neural recording to study how information about object structure is processed in intermediate and higher-level ventral pathway cortex of macaque monkeys. We find that neurons in area V4 (an intermediate stage) represent object boundary fragments by means of basis function tuning for position, orientation, and curvature. At subsequent stages in posterior, central, and anterior inferotemporal cortex (PIT/CIT/AIT), we find that neurons integrate information about multiple object fragments and their relative spatial configurations. The dynamic nature of this integration process can be observed in the evolution of neural activity patterns across time following stimulus onset. At early time points, neurons are responsive to individual object fragments, and their responses to combined fragments are linearly additive. Over the course of approximately 60 ms, responses to individual object fragments decline and responses to specific fragment combinations increase. This evolution toward nonlinear selectivity for multi-fragment configurations involves both shifts in response properties within neurons and shifts in population activity levels between primarily linear and primarily nonlinear neurons. This pattern is consistent with a simple network model in which the strength of feedforward and recurrent inputs varies continuously across neurons.

Timing of selection for the guidance of gaze

Jeffrey D. Schall

Time is of the essence in the execution of visually guided behavior in dynamic environments. We have been investigating how the visual system responds to unexpected changes of the image when a saccade is being planned. Performance of stop signal or double-step tasks can be explained as the outcome of a race between a process that produces the saccade and a process that interrupts the preparation. Neural correlates of dynamic target selection and these race processes have been identified in the frontal eye field and superior colliculus. The timecourse of these processes can provide useful leverage for understanding how early visual processing occurs.

S6
Modern Approaches to Modeling Visual Data

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

Organizer: Kenneth Knoblauch (Inserm, U846, Stem Cell and Brain Research Institute, Bron, France)

Presenters: Kenneth Knoblauch (Inserm, U846, Bron, France), David H. Foster (University of Manchester, UK), Jakob H Macke (Max-Planck-Institut für biologische Kybernetik, Tübingen), Felix A. Wichmann (Technische Universität Berlin & Bernstein Center for Computational Neuroscience Berlin, Germany), Laurence T. Maloney (NYU)

Symposium Summary

A key step in vision research is comparison of experimental data to models intended to predict the data. Until recently, limitations on computer power and lack of availability of appropriate software meant that the researcher’s tool kit was limited to a few generic techniques such as fitting individual psychometric functions. Use of these models entails assumptions such as the exact form of the psychometric function that are rarely tested. It is not always obvious how to compare competing models, to show that one describes the data better than another or to estimate what percentage of ‘variability’ in the responses of the observers is really captured by the model. Limitations on the models that researchers are able to fit translate into limitations on the questions they can ask and, ultimately, the perceptual phenomena that can be understood. Because of recent advances in statistical algorithms and the increased computer power available to all researchers, it is now possible to make use of a wide range of computer-intensive parametric and nonparametric approaches based on modern statistical methods. These approaches allow the experimenter to make more efficient use of perceptual data, to fit a wider range of perceptual data, to avoid unwarranted assumptions, and potentially to consider more complex experimental designs with the assurance that the resulting data can be analyzed. Researchers are likely familiar with nonparametric resampling methods such as bootstrapping (Efron, 1979; Efron & Tibshirani, 1993). We review a wider range of recent developments in statistics in the past twenty years including results from the machine learning and model selection literatures. Knoblauch introduces the symposium and describes how a wide range of psychophysical procedures (including fitting psychophysical functions, estimating classification images, and estimating the parameters of signal detection theory) share a common mathematical structure that can be readily addressed by modern statistical approaches. He also shows how to extend these methods to model more complex experimental designs and also discusses modern approaches to smoothing data. Foster describes how to relax the typical assumptions made in fitting psychometric functions and instead use the data itself to guide fitting of psychometric functions. Macke describes a technique---decision-images--- for extracting critical stimulus features based on logistic regression and how to use the extracted critical features to generate optimized stimuli for subsequent psychophysical experiments. Wichmann describes how to use “inverse” machine learning techniques to model visual saliency given eye movement data. Maloney discusses the measurement and modeling of super-threshold differences to model appearance and gives several examples of recent applications to surface material perception, surface lightness perception, and image quality. The presentations will outline how these approaches have been adapted to specific psychophysical tasks, including psychometric-function fitting, classification, visual saliency, difference scaling, and conjoint measurement. They show how these modern methods allow experimenters to make better use of data to gain insight into the operation of the visual system than hitherto possible.

Presentations

Generalized linear and additive models for psychophysical data

Kenneth Knoblauch

What do such diverse paradigms as classification images, difference scaling and additive conjoint measurement have in common? We introduce a general framework that permits modeling and evaluating experiments covering a broad range of psychophysical tasks. Psychophysical data are considered within a signal detection model in which a decision variable, d, which is some function, f, of the stimulus conditions, S, is related to the expected probability of response, E[P], through a psychometric function, G: E[P] = G(f(d(S))). In many cases, the function f is linear, in which case the model reduces to E[P] = G(Xb), where X is a design matrix describing the stimulus configuration and b a vector of weights indicating how the observer combines stimulus information in the decision variable. By inverting the psychometric function, we obtain a Generalized Linear Model (GLM). We demonstrate how this model, which has previously been applied to calculation of signal detection theory parameters and fitting the psychometric function, is extended to provide maximum likelihood solutions for three tasks: classification image estimation, difference scaling and additive conjoint measurement. Within the GLM framework, nested hypotheses are easily set-up in a manner resembling classical analysis of variance. In addition, the GLM is easily extended to fitting and evaluating more flexible (nonparametric) models involving arbitrary smooth functions of the stimulus. In particular, this approach permits a principled approach to fitting smooth classification images.

Model-free estimation of the psychometric function

David H. Foster, K. Zychaluk

The psychometric function is central to the theory and practice of psychophysics. It describes the relationship between stimulus level and a subject's response, usually represented by the probability of success in a certain number of trials at that stimulus level. The psychometric function itself is, of course, not directly accessible to the experimenter and must be estimated from observations. Traditionally, this function is estimated by fitting a parametric model to the experimental data, usually the proportion of successful trials at each stimulus level. Common models include the Gaussian and Weibull cumulative distribution functions. This approach works well if the model is correct, but it can mislead if not. In practice, the correct model is rarely known. Here, a nonparametric approach based on local linear fitting is advocated. No assumption is made about the true model underlying the data except that the function is smooth. The critical role of the bandwidth is explained, and a method described for estimating its optimum value by cross-validation. A wide range of data sets were fitted by the local linear method and, for comparison, by several parametric models. The local linear method usually performed better and never worse than the parametric ones. As a matter of principle, a correct parametric model will always do better than a nonparametric model, simply because the parametric model assumes more about the data, but given an experimenter's ignorance of the correct model, the local linear method provides an impartial and consistent way of addressing this uncertainty.

Estimating Critical Stimulus Features from Psychophysical Data: The Decision-Image Technique Applied to Human Faces

Jakob H. Macke, Felix A. Wichmann

One of the main challenges in the sensory sciences is to identify the stimulus features on which the sensory systems base their computations: they are a pre-requisite for computational models of perception. We describe a technique---decision-images--- for extracting critical stimulus features based on logistic regression. Rather than embedding the stimuli in noise, as is done in classification image analysis, we want to infer the important features directly from physically heterogeneous stimuli. A Decision-image not only defines the critical region-of-interest within a stimulus but is a quantitative template which defines a direction in stimulus space. Decision-images thus enable the development of predictive models, as well as the generation of optimized stimuli for subsequent psychophysical investigations. Here we describe our method and apply it to data from a human face discrimination experiment. We show that decision-images are able to predict human responses not only in terms of overall percent correct but are able to predict, for individual observers, the probabilities with which individual faces are (mis-) classified. We then test the predictions of the models using optimized stimuli. Finally, we discuss possible generalizations of the approach and its relationships with other models.

Non-linear System Identification: Visual Saliency Inferred from Eye-Movement Data

Felix A. Wichmann, Wolf Kienzle, Bernhard Schölkopf, Matthias Franz

For simple visual patterns under the experimenter's control we impose which information, or features, an observer can use to solve a given perceptual task. For natural vision tasks, however, there are typically a multitude of potential features in a given visual scene which the visual system may be exploiting when analyzing it: edges, corners, contours, etc. Here we describe a novel non-linear system identification technique based on modern machine learning methods that allows the critical features an observer uses to be inferred directly from the observer's data. The method neither requires stimuli to be embedded in noise nor is it limited to linear perceptive fields (classification images). We demonstrate our technique by deriving the critical image features observers fixate in natural scenes (bottom-up visual saliency). Unlike previous studies where the relevant structure is determined manually---e.g. by selecting Gabors as visual filters---we do not make any assumptions in this regard, but numerically infer number and properties them from the eye-movement data. We show that center-surround patterns emerge as the optimal solution for predicting saccade targets from local image structure. The resulting model, a one-layer feed-forward network with contrast gain-control, is surprisingly simple compared to previously suggested saliency models. Nevertheless, our model is equally predictive. 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.

Measuring and modeling visual appearance of surfaces

Laurence T. Maloney

Researchers studying visual perception have developed numerous experimental methods for probing the perceptual system. The range of techniques available to study performance near visual threshold is impressive and rapidly growing and we have a good understanding of what physical differences in visual stimuli are perceptually discriminable. A key remaining challenge for visual science is to develop models and psychophysical methods that allow us to evaluate how the visual system estimates visual appearance. Using traditional methods, for example, it is easy to determine how large a change in the parameters describing a surface is needed to produce a visually discriminable surface. It is less obvious how to evaluate the contributions of these same parameters to perception of visual qualities such as color, gloss or roughness. In this presentation, I'll describe methods for modeling judgments of visual appearance that go beyond simple rating methods and describe how to model them and evaluate the resulting models experimentally. I'll describe three applications. The first concerns how illumination and surface albedo contribute to the rated dissimilarity of illuminated surfaces in three-dimensional scenes. The second concerns modeling of super-threshold differences in image quality using difference scaling, and the third concerns application of additive conjoint measurement to evaluating how observers perceive gloss and meso-scale surface texture ('bumpiness') when both are varied.

Friday Sessions

Face Perception: Emotion

Friday, May 8, 6:30 – 9:00 pm
Poster Session, Vista Ballroom

16.501

Emotional expression perception in facial parts

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Numerous studies exemplify the holistic processing of faces. When a stimulus is recognized as a face, their parts become integrated into a whole representation. Two effects have been widely used to provide evidence for face holistic processing; the composite face effect (Young, Hellawell, & Hay, 1987) and the whole/part advantage (Tanaka & Farah, 1993). In recent years, several studies provided evidence showing the inversion effect and the composite face effect suggested that the holistic process worked in the recognition of facial expressions (Calder, et al., 2000; Calder & Jansen, 2005; Fallshore & Bartholow, 2003; White, 1999). These previous studies suggest that the recognition of a local face part is affected by the other facial part(s). This suggestion raises the possibility that the holistic emotional representation of face may illusory shift the neutral face part (such as neutral mouth, eyes or eyebrows) into expressive one. Here, we aimed at clarifying this question. At first, we created a stimulus by embedding face part expressing an emotion on the whole face expressing another emotion in two manners; a congruent emotional expression (e.g., neutral face and neutral mouth) and an incongruent emotional expression (e.g., neutral face and happy mouth). Participants were seven healthy adults. First, they were presented with a target face stimulus displaying either a congruent emotional expression or an incongruent emotional expression and then presented with either one part from the target face (e.g., neutral eyes) or a foil part displaying a different emotion (e.g., neutral-happy 50% morphing eyes). Participants were instructed to make same/different judgment (e.g., emotional expression of target's eyes or not). In the result, we found that participants were mistaken to recognize a neutral facial part in a whole face as a part expressing emotion. This result is consistent with the previous studies which showed facial expressions are recognized holistically.

16.502

Discriminating fleeting facial expressions using featural and configural information

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Humans are adept at discriminating fleeting emotional expressions. We investigated how the type of expression and duration of presentation influenced discrimination accuracy. Observers viewed two sequentially presented facial expressions, one neutral and the other emotional (fearful, angry, or happy), in a two-interval forced-choice task with stimulus duration varied across trials (10, 20, 30, 40, or 50 ms). All faces were masked by a face with a surprised expression. On each trial, observers attempted to select the face with the emotional expression, and to name the expression. Discrimination against neutral was above chance at all durations, and more accurate for happy than for angry or fearful expressions. Emotional expressions that displayed teeth yielded the highest accuracy. To evaluate discrimination among emotional expressions during expression naming, we calculated d' using 'hits', 'misses', 'false alarms', and 'correct rejections' specific to each expression pair (e.g., responding 'angry' or 'happy' on angry and happy trials). Discrimination between angry and happy expressions was better than discrimination between fearful and happy expressions, and both pairs were discriminated above chance even when presented for only 20 ms. In contrast, discrimination between fearful and angry expressions was near chance at all durations. Discrimination between these expressions was also near chance in an experiment in which emotional faces were all negative in valence (fearful, angry, or disgusted), suggesting that discrimination between fleeting fearful and angry expressions is difficult, and not merely a deficit incurred from simultaneously discriminating expressions with negative and positive valence. With inverted faces, only discrimination between angry and happy expressions was impaired, which suggests a contribution of configural processing in this particular discrimination. Together, these results demonstrate that surprisingly brief presentations are sufficient for discriminating emotional expressions from neutral expressions. However, discriminating emotional expressions is difficult and depends on information from individual features and from their configurations.

16.503

Different Mechanism for processing Emotional Faces at the Segregation Level from the Background

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Recent investigations of processing emotional faces have revealed a faster mechanism for processing faces with emotional content compared to neutral ones thereby indicating the evolutionary importance of these stimuli possibly related to the need for the motor system to react rapidly to emotional signals. But it is presently unknown whether there is already a difference at the face detection level for emotional versus neutral faces. This unclarity is mainly related to the fact that detection has a short time course and control the interacting parameters in the available object detection paradigms has so far proven difficult. We have developed an experimental design based on the adaptation phenomenon which occurs in neural systems due to overactivation of a network involved in coding repeatedly the same features of the incoming stimuli. To implement adaptation in a face detection task, we first overflow the face detection system by presenting hundreds of different neutral faces rapidly following each other and appearing at random places around a central fixation point. In the immediately following test phase, we measure the detection performance at different levels of uncertainty (derived from different levels of noise added to faces) for two conditions of neutral versus emotional using a forced-choice upcoming flash of two stimuli one of which containing a noise masked face and the other one pure noise. Results indicate that processing emotional and neutral faces diverge at the very first (detection) level.

16.504

Varieties of perceptual independence in the processing of facial identity and expression

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Three approaches to addressing the hypothesis of perceptual independence (Garner & Morton, 1969) were applied to the facial dimensions of identity and expression: (1) Garner's speeded classification task (Garner, 1974), (2) measures derived from systemsfactorial technology (SFT, Townsend and Nozawa, 1995), and (3) measures derived from general recognition theory (GRT, Ashby and Townsend, 1986). The overall goals of this effort were to (a) relate three theories of perceptual independence, and (b) provide a strong test of the dual-route hypothesis (Bruce & Young, 1980), for which independence is a central construct. Identity and expression appeared as integral dimensions inthe Garner test (see also, Ganel & Goshen-Gottstein, 2004). Violations of perceptual and decisional separability, but not perceptual independence, were found in the GRT tests. A parallel,self-terminating, unlimited-to super-capacity, system with dependencies in the rates of

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processing was revealed in the SFT tests. Taken together, these results are provocative with respect to the conceptual relations among the theoretical persepctive, and with respect to the integrity of the dual-route hypothesis.

16.505

Mixed emotions: Holistic and analytic perception of facial expressions

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It is well established that recognition of facial identity relies more on Holistic Processing (HP) of the entire face than analytic processing of its constituent parts. HP of faces has been measured in experiments where participants selectively attend to the top or bottom half of faces in a same-different judgment task and either the alignment of face halves or the congruency of information across face halves are manipulated (e.g., the composite face effect, Young, Hellawell, & Hay, 1987).

In contrast to identity, it is unclear whether the identification of facial expressions is holistic or analytic, as studies to date have produced conflicting results. In part this may be due to a lack of appropriate baseline measures. To measure processing of emotional expressions, we created two sets of composite faces in which top and bottom face halves displayed incongruent (e.g., angry top/happy bottom) or congruent (e.g., happy top/happy bottom) expressions and two baseline sets where expression halves were paired with halves of neutral expression, or presented in isolation. In Experiment 1, participants were asked to report the expression in the cued half of the face and ignore information in the uncued half. Relative to baseline conditions, it was found that in an incongruent expression, conflicting information in the uncued half interfered with speed and accuracy of identifying the cued half. However, in a congruent face, the uncued portion had no effect on speed and accuracy. A manipulation of the exposure duration in Experiment 2 revealed that while stimuli were equivalently identified at brief exposures, this pattern of holistic interference without facilitation emerged by 60 ms.

Collectively, the results suggest that holistic face processes are engaged given both a) conflicting or ambiguous facial expression information and b) a minimum amount of processing. In contrast, unambiguous or briefly viewed facial expressions are processed analytically.

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16.506

How efficient are the recognition of dynamic and static facial expressions?

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Recently, Ambadar, Schooler and Cohn (2005) compared facial expression recognition performance with static and dynamic stimuli. To control for task difficulty, the researchers equated the information content in their dynamic and in their so-called “multi-static” condition, in which the frames of the dynamic stimuli were separated by noise masks and were played very slowly. Observers were better at discriminating dynamic than multi-static stimuli but only when the facial expressions were subtle. This result, however, might be due to low-level masking or to some high-level memory decay rather than to observer’s sensitivity to facial expression movement per se. Here, we factored out task difficulty by measuring the calculation efficiency for the static vs. dynamic recognition of eight facial expressions (happiness, fear, sadness, disgust, surprise, anger, and pain). Contrary to sensitivity measures, such as the d’, efficiency measures are directly comparable across tasks. Twenty naïve observers will participate to the experiment. We will extract their energy thresholds for the recognition of static and dynamic facial expressions (drawn from sets of 80 static and 80 dynamic stimuli) in five levels of external noise using the method of constant stimuli (5-10 levels of energy per noise level). Calculation efficiencies will be computed by dividing the slopes of the lines that best fit the energy thresholds of ideal and human observers. Preliminary results obtained on three observers yield efficiencies of about 20.43%, 11.46%, 11.95% and 10.4%, 8.76%, 7.36%, respectively, for the recognition of static and dynamic facial expressions.

16.507

Individual differences in attentional distraction and facilitation by emotional faces

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Research suggests that individual differences in personality variables like anxiety (e.g., Fox et al., 2007) and self-esteem (e.g., Wilkowski et al., 2008) have a powerful effect on attentional processes, especially when emotional faces are used as stimuli. The current study (N = 78) examined relationships between empathy, self-esteem, self-monitoring, state and trait anxiety and attentional distraction/facilitation to targets flanked by happy, fearful, and angry facial distractors (with direct gaze). Overall, significant facilitation was observed for happy faces relative to neutral and angry faces, supporting the notion that happy faces elicit approach-related behaviors (e.g. Canli et al., 2002). No significant differences between distraction/facilitation were found for angry and fearful faces relative to neutral faces. However, there was considerable variability in distraction/facilitation across individuals and emotional expressions. Regression analyses were conducted to determine if distraction/facilitation to different emotional expressions was related to individual differences in personality variables. Facilitation for happy faces was associated with greater perspective taking scores and higher levels of state anxiety. In contrast, distraction/facilitation to angry and fearful faces was associated with self-esteem such that individuals who scored highly in self esteem experienced greater distraction by these negative emotional expressions. Surprising, differences in trait anxiety were not significantly related to attentional capture by negative facial expressions. These results corroborate the notion that individual differences in various personality variables do contribute to attentional capture by and disengagement from emotional facial expressions. However, the nature of these relationships may be dependent upon the valence of the facial expression and the task(s) used to assess attentional processing.

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16.508

Visual search for emotional faces in neurodevelopmental disorders

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Threatening facial expressions are potent social signals and are processed rapidly and efficiently. Studies on normal development have shown that angry faces “pop-out” in a crowd, compared to happy faces. This “anger-superiority” supports the idea that social threat automatically captures attention and seems to involve amygdala circuits. The current study aimed at investigating whether atypical social functioning disrupts this intriguing potential of facial threat in capturing attention. Children with contrasting social functioning – autism spectrum disorders (ASD) and Williams syndrome (WS) – were compared to typically developing individuals using a “face-in-the-crowd” visual search paradigm. Both the emotion of the target face (happy or angry) and the size of the matrix were manipulated.

In line with previous studies, typically developing children showed an advantage for detecting angry relative to happy faces in a crowd, with a pop-out effect for the former and rather a matrix size influence for the latter. By contrast, this “anger-superiority” was absent for both ASD and WS groups. These groups rather processed anger and happy faces similarly, with matrix size decreasing performance. Taken together, these findings suggest a link between atypical social functioning and impoverished threat detection mechanisms, possibly related to the underlying amygdala dysfunctions in these neurodevelopmental disorders.

16.509

Increasing variance in emotional expression in a crowd of faces reduces sensitivity to the average face

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We often encounter groups of objects that are featurally similar and difficult to distinguish. For example a tree contains thousands of leaves that produce an average 'leafiness' texture. Instead of coding every leaf individually, it is more efficient for the visual system to quickly extract the mean of the group, in essence driving texture perception. We use this process, known as ensemble coding, to perceive the mean size of a group of circles (Ariely, 2001; Chong & Treisman, 2003), average orientation (Parkes, et al., 2001), the average speed (Watamaniuk & Duchon, 1992) and location (Alvarez & Oliva, 2008) of a set of moving dots, and even the mean emotion of a group of faces (Haberman & Whitney, 2007; 2008). A question remains, however, as to how increased variance within the set affects our ability to extract summary statistics; that is, what happens when some of the leaves' colors start to turn? We explored this by manipulating the variance in sets of faces. In each trial, observers saw a set of 16 faces that varied in emotional expression, nominally separated from one another by emotional units. We manipulated set variance by increasing or decreasing the emotional units separating set members. Using method-of-adjustment, observers adjusted a subsequent test face to the mean emotion of the set of 16. We measured how far, on average, observers' responses were from the mean; the smaller the average difference, the more precise the set mean representation. As set variance increased, mean representation precision decreased. The process of extracting a mean representation breaks down at high levels of set variance because the mean no longer functions as a reliable summary representation.

16.510

Modulating observer's pain by manipulating the diagnosticity of face stimuli for the recognition of the expression of pain

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Recent findings suggest that the emotional valence of visual stimuli can modulate pain perception (Rhudy et al. 2005); unpleasant images increase pain reports, while pleasant images has the opposite effect. Here, we modulated the observer's perception of acute shock-pain by varying the information provided to recognize the pain facial expression (unpleasant stimuli). Last year at VSS, Roy et al. (Abstract 710) described the visual information subtending the recognition of the facial expression of pain. Based on these results, we created two masks: one revealing the more useful (top 5 %) information for the identification of pain expression (optimal mask) and one revealing the less useful information (bottom 5% — neutral mask). Twenty stimuli were created by applying these masks to ten different static facial expression of pain. A pilot study ensured that the optimally-masked stimuli led to the perception of negative emotions while the neutrally-masked stimuli led to the perception of positive emotions. Twenty-four normal volunteers received transcutaneous electrical stimulation of the sural nerve (30 ms) at the offset of each visual stimulus (1 s), and were asked to rate the intensity and the unpleasantness of shock-pain on visual analog scales. Preliminary results show that pain intensity and unpleasantness are judged less intense when the shock is given after the neutrally-masked stimuli than after the optimally-masked stimuli. These results are consistent with an effect of emotional valence on pain perception and may explain the hyperalgesic effects induced by the perception of pain in others reported in studies on pain empathy.

16.511

Early, rapid processing of fearful facial expression in a patient with bilateral amygdala lesions

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The amygdala is thought to be essential for rapid, pre-conscious detection of fear through a putative subcortical pathway. Some fMRI studies have suggested such a pathway by showing amygdala activation to fear faces that were not consciously perceived (although this is debated), whereas electrophysiological studies generally demonstrate rather long response latencies in the amygdala. We tested subject SM, who has complete bilateral lesions of the amygdala, on three psychophysical tasks to characterize the stage of her impairment in visual processing of fear. First, we tested SM's ability to rapidly detect a fearful face in speeded spatial 2AFC and 4AFC tasks. While SM detected a fearful face as rapidly and accurately as controls on discrimination of fear/anger/threat from neutral stimuli in the 2AFC task, she was much slower in the 4AFC task, where a target fearful face was embedded among happy, sad, and neutral faces. Analysis of eye movements indicated that controls terminated search at the fearful face, while SM needed to inspect all faces, perhaps indicative of identifying fear by exclusion from any other emotion. Second, we investigated visual search among face morphs between fearful vs. neutral/happy/sad expressions. When asked to detect a more fearful morph among less fearful morphs, all subjects, including SM, detected the fearful face faster when the physical morph difference spanned a perceptual category boundary for fear. Finally, using Continuous Flash Suppression to suppress conscious perception of faces, we found that SM became aware of fearful faces more quickly than happy faces, just like has been reported for healthy subjects (Yang et al 2007 Emotion). We conclude that early, rapid, and pre-conscious processing of fearful faces might rely on visual cortex rather than the amygdala.

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16.512

Deciding to approach other people: The influence of face and body expressions

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Emotional expressions play an important role in facilitating our social interactions. While a great deal of research conducted over the past two decades has investigated the brain regions and cognitive mechanisms involved in the recognition of facial expressions, few studies have investigated the way in which emotional expressions are used to guide our social behaviour. This study examined whether emotional expressions are used to determine which people we should approach and which we should avoid. In Experiment 1, we found that faces with happy expressions were rated the most approachable, followed by faces that were neutral, fearful and sad. Faces displaying angry and disgusted expressions were considered the least approachable. In Experiment 2, we then examined whether body expressions would influence approachability in the same manner as facial expressions. Bodies with happy and neutral expressions were rated the most approachable, followed by bodies that were sad and disgusted, with angry and fearful bodies rated the least approachable. In Experiment 3, we investigated approachability ratings given to images of people comprised of both a face and a body. The face and body expressions could be congruent (e.g., angry face and angry body) or incongruent (e.g., happy face and angry body). Consistent with findings from Experiments 1 and 2, people displaying congruent angry face and body expressions were less approachable than people with happy face and body expressions. The approachability judgements given to people comprising incongruent face and body expressions revealed that facial expressions exerted a larger impact on a

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person's perceived approachability than did their body expressions. These findings demonstrate that both face and body expressions influence judgements of approachability. However, the decision to approach another person is influenced to a greater extent by their facial expression than their body expression.

16.513

The role of the amygdala in orienting attention to eyes within complex social scenes

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For years, the amygdala has been implicated as a brain structure dedicated to rapidly processing emotionally salient stimuli in the environment. Recently, it has been proposed that the amygdala has a more general role in orienting attention to socially salient stimuli. For instance, Adolphs et al. (Nature, 2005) found that SM, a patient with rare bilateral lesions of the amygdala, was unable to recognize fearful facial expressions because she failed to fixate the eyes of the faces. The eyes are particularly informative social stimuli, and therefore may be ones that the amygdala is particularly biased to detect. The present study examined whether this same patient (SM) fails to fixate the eyes of people when they are presented within complex social scenes. We also investigated the role of context in which the scene occurs on SM's pattern of fixations. We presented a variety of real world social scenes (Birmingham, Bischof & Kingstone, Visual Cognition, 2008) under three task conditions: one asking viewers to report where people in the scene were directing their attention, a second asking viewers to describe the scene, and a third asking viewers to describe what kind of room the scene was taking place in. Across all three conditions, SM looked less often at the eyes relative to control participants. Comparing the different tasks, we found that both SM and controls looked more often at the eyes when asked to report on the social attention in the scene. These results suggest that amygdala damage may lead to a specific reduction of exploration of other people's eyes, but that task instructions can modulate this bias to some extent. The findings extend our prior work with isolated faces and corroborate the view that the amygdala helps orient attention to certain socially salient stimuli, notably and perhaps specifically, the eyes.

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16.514

MDMA ('Ecstasy') impairs categorization of brief fearful expressions

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MDMA (±3,4-methylenedioxymethamphetamine, 'Ecstasy') is said to have unique effects including increased empathy and sociability. However, the perceptual and emotional effects of MDMA have not been well-studied in a controlled laboratory setting. We conducted a within-subjects placebo-controlled study in which 16 participants (8 male, 8 female) received 1.5 mg/kg oral MDMA and placebo in separate sessions. We measured categorization of emotional facial expressions using a 4-alternative forced choice task where a face with a neutral expression briefly displayed either a happy, sad, angry, or fearful expression. Self-report sociability and plasma oxytocin were also measured. MDMA impaired categorization of brief fearful facial expressions, decreasing accuracy and a signal-detection measure of discrimination (d-prime). MDMA also increased plasma oxytocin concentrations and self-report sociability. MDMA may not increase empathic accuracy, but may instead decrease response to threat-related stimuli while increasing sociability.

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Attention: Models

Friday, May 8, 6:30 – 9:00 pm
Poster Session, Vista Ballroom

16.515

Spatially cued visual attention for precise discriminations may narrow the template as well as excluding external noise: An elaborated perceptual template model

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Spatially cued visual attention allows an observer to more effectively select the information relevant to a discrimination. Attention has been measured in external noise for contrast-limited rather than precision-limited discriminations, where external noise exclusion is the primary reported mechanism of attention. What role can attention play when discriminations are precision- as well as contrast-limited? In four observers, we measured the effect of validly cuing one of four locations at 5 deg in the periphery compared to invalid cuing for orientation discriminations of four different precisions (±4, 8, 16, or 45 deg) in zero external noise and in high external noise. This generates 16 9-point contrast psychometric functions per observer. The effects of judgment precision and of attention were assessed within the context of an elaborated perceptual template model (ePTM, Jeon, Lu, & Dosher, 2008), an observer model that integrates the effects of non-orthogonal discriminations, contrast, and external noise. Validity of attentional cuing allowed the exclusion of external noise, as previously reported (Dosher & Lu, 2000). The precision of judgment also had very large effects on performance – systematically shifting the contrast-psychometric functions to the right (higher 75% thresholds), lowering the slope and reducing the asymptotic accuracies of performance of the psychometric functions. The effects of attention were generally smaller in the lowest-precision ±45 deg condition. For 3 of 4 observers, attention narrowed the estimated width of the tuning function, explicitly supporting the proposals of Liu, Dosher & Lu (2008) in object-attention. The ePTM provided an excellent account of the full pattern of performance across all levels of attention, precision, external noise, and signal contrast with attention-dependent factors on tuning, including effects on external noise, and (in a few cases) internal noise exclusion. This model provides distinct explanations for attention effects in a wide range of stimulus conditions.

Acknowledgement: NEI

16.516

Attending to a Feature Results in Neighboring Within-Feature Suppression

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According to the Selective-Tuning model (Tsotsos, 1990), convergence of neural input and selection of a attended feature will result in surround suppression within that feature domain: the nearby feature values in the same feature dimension will be inhibited, but not the feature values farther away in the dimension. We present three experiments that support this hypothesis. The first experiment used a feature-cue paradigm. The subjects' attention was first attracted to an orientation cue, and then subjects made a perceptual judgment about a stimulus with same or different orientation as the cue. We found that orientation attention actively suppressed the nearby orientations (5 ~ 10 degree from the cue), but did not influence far away orientations (20 ~ 90 degree from the cue), replicating the results of Tombu & Tsotsos (2008). In the second experiment we used the same paradigm but added a distractor to the cue, and the stimulus sequence became cue -> distractor -> probe. This time the subjects must actively ignore the distractor to focus their attention on the cue. By increasing the difficulty of the subjects pay attention to the cue, we found an even stronger Mexican-hat

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profile of attentional suppression. In the third experiment, we extended our findings from orientation to color. Again, we acquired a Mexican-hat profile of the feature attention in color dimension. These results further extend the evidence supporting the Selective Tuning explanation of spatial and feature attention and suggest a more general mechanism of signal-to-noise enhancement applicable to any feature dimension.

16.517

The influence of target discriminability on the time course of attentional selection

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A wealth of neurophysiological data has demonstrated that visual attention can selectively enhance target representations early in the visual processing pathway. In conjunction, behavioural evidence tells us that the extent to which irrelevant items interfere with target processing depends on their featural similarity to the target. In this context, how does target discriminability influence temporal selection? We present results from an electrophysiology study that addresses this question by investigating the neural processes underlying the temporal dynamics of target selection.

Target distinctiveness is varied across a pair of blocked conditions: In the onset condition, letter targets could be discerned simply by their visual onset. In contrast, in the RSVP condition, they were distinguishable from temporally sequential digit distractors only based on semantic identity. The results suggest that, in line with previous findings, the relatively harder category discrimination task in the RSVP condition reduces the accuracy of target identification. Our electrophysiological data suggests that there are significant differences in the perceptual processing of the target in the two conditions, as indexed by early visual ERPs. Further, in the RSVP condition, we find an increase in the latency of the P3 ERP, which indexes target consolidation.

We ground this and previous empirical evidence within a theoretical framework for understanding the mechanism of attentional selection represented in the ST2 model, a neural network model of temporal attention and working memory. The model successfully explains a broad spectrum of behavioural and electrophysiological data relating to RSVP and the attentional blink. Here, by making theoretically justified changes to the model, we extend it to simulate the onset condition. We show that the model provides a convincing explanation of the pattern of experimental results, in addition to informing questions about early vs. late selection and the cognitive equivalence of target processing in masking and RSVP experiments.

16.518

Modelling of Attentional Dwell Time

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Studies of the time course of visual attention have identified a temporary functional blindness to the second of two spatially separated targets: attending to one visual stimulus may lead to impairments in identifying a second stimulus presented between 200 to 500 ms after the first. This phenomenon is known as attentional dwell time (e.g. Duncan, Ward, Shapiro, 1994). All Previous studies of the attentional dwell time have looked at data averaged across subjects. In contrast, we have succeeded in running subjects for 3120 trials which has given us reliable data for modelling data from individual subjects.

Our new model is based on the Theory of Visual Attention (TVA; Bundesen, 1990). TVA has previously been successful in explaining results from experiments where stimuli are presented simultaneously in the spatial domain (e.g. whole report and partial report) but has not yet been extended into the temporal domain. In the neural interpretation of TVA (NTVA; Bundesen, Habekost and Kyllingsbæk, 2005), processing resources are implemented as allocation of cortical cells to objects in the visual field. A feedback mechanism is then used to keep encoded objects in VSTM alive. The proposed model of attentional dwell time extends these mechanisms by proposing that the processing resources (cells) already engaged in a feedback loop (i.e. allocated to an object) are locked in VSTM and therefore cannot be allocated to other objects in the visual field before the encoded object has been released. This confinement of attentional resources leads to the impairment in identifying the second target.

With the model, we are able to produce close fits to data from the traditional two target dwell time paradigm. A dwell-time experiment with three targets has also been carried out for individual subjects and the model has been extended to fit these data.

16.519

A model of performance in whole and partial report experiments

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Performance in whole and partial report experiments is described well by Bundesen's Theory of Visual Attention (TVA, Bundesen, 1990) and the later neural TVA (nTVA, Bundesen, Habekost and Kyllingsbaek, 2005). TVA assumes that perceptual processing of objects occurs in parallel and is constrained by a limited processing capacity or rate, which is distributed among target and distractor objects. A race model describes encoding into a limited visual short term memory (VSTM) following perceptual processing. The model employs the two capacity limits, a temporal delay before perceptual processing starts and a filtering parameter quantifying the difference in perceptual processing for target and distractor objects in order to model performance in whole and partial report experiments with varying number of targets and distractors. Here we show that the distribution of processing capacity among objects in TVA is equivalent to probability summation of a limited number of independent channels. We also introduce a simpler model of encoding into VSTM. Rather than assuming a race between objects, so that the order in which objects completes perceptual processing determines which objects are encoded, this new model simply conditions the probability of encoding a number of objects on the constraint that the capacity of VSTM is not exceeded. This new model reduces the algebraic complexity of TVA and fits data from previous whole and partial report experiments (Shibuya and Bundesen, 1988) better using the same number of free parameters.

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16.520

Modulation of Auditory and Visual Motion Aftereffects by Selective Attention to Opposite-Moving Spectral Components: Psychophysics and Computational Models

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Background: Jain et al. [VSS 2008] showed that attending to one of two competing motion signals with different frequency components can modulate within-modality Motion Aftereffects (MAE). The auditory MAE duration was strongly modulated, while there was only a weak modulation of visual static MAE duration and no modulation of visual dynamic MAE duration.

Goals: In the current study we examined whether a more sensitive measure would reveal a modulation of dynamic visual MAE. Further, we developed neurophysiologically relevant computational models to explore possible mechanisms for the observed effects.

Methods: The adaptation stimulus comprised two sinusoidal gratings moving in opposite directions; the test stimulus was a fixed-duration counterphase flickering grating at an intermediate frequency. On each trial, subjects attended to the motion signal carried by low/high frequencies during adaptation and continuously reported their perceived motion direction during both adaptation and test phase. The percentage direction dominance during test phase was taken as a measure of MAE. The computational model was based on the biased-competition model used by Reynolds et al. [J. of Neuroscience 1999]. The effects of attention were modeled by biasing the weights of neuronal connections in favor of the attended spectral features. The same model structure was used to explain results within both modalities with the spatial frequency tuning in the visual modality replaced with temporal frequency tuning in the auditory modality.

Results and Conclusions: We observed significant modulation of dynamic MAE when we used a more sensitive measure. Overall, the effects were strongest for auditory MAE, moderate for static MAE and weakest for dynamic MAE, which is in decreasing order of spectral specificity. The model had an excellent correlation (99.63%) with the behavioral data and was also able to incorporate the frequency contingency of the visual MAE as observed by Shioiri and Matsumiya [VSS 2006].

16.521

Gist Based Top-Down Templates for Gaze Prediction

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People use focal visual attention and rapid eye movements to analyze complex visual inputs in a manner that highly depends on current scene's properties. Here we propose a top-down attention model which exploits visual templates associated with different types of scenes. During training, an image set has been manually classified into several scene categories and for each category we define a corresponding top-down map which highlights locations likely to be of interest empirically. Then "gist" feature vectors of each category's images are computed to generate a Gaussian gist feature distribution, or signature of that category. During testing, the input image's gist feature vector is computed first, based on this feature vector and the already generated scene categories' gist feature distributions, a group of corresponding weights are computed using the probability density functions. The top-down map is then the weighted summation of those predefined templates. Finally, the top-down map is combined with a bottom-up saliency map (Itti & Koch 2001) to generate a final attention guidance map. In eye-tracking validation experiments, two video types are adopted as testing data, one is an original set of captured video clips and the other one is built by cutting the original clips into 1-3s small clips and re-assembling. Results show that in the original clips, the area under curve (AUC) score and the KL distance of the standard bottom-up saliency map is 0.665 and 0.185 (higher is better) while the attention guidance map result is 0.688 and 0.242, respectively; with the re-assembled clips, the standard bottom-up model result is 0.648 and 0.145 while the combined model result is 0.718 and 0.327. Our results suggest that the attention selection can be more accurate with the proposed top-down component.[1] Itti, L. and Koch, C. 2001 Computational Modeling of Visual Attention, Nature Reviews Neuroscience, 2(3), 194-203

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16.522

What the Searchlight saw: revealing the extent of natural image information that passes through bottom-up visual attention mechanisms to higher visual processing

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In order to optimize information utilization and prevent bottlenecking during visual processing, bottom-up information is triaged by selectively gating image features as they are observed. Here we demonstrate for the first time a biologically-plausible, information-theoretic model of the visual gating mechanism which works efficiently with natural images. From this, we give a neurophysiological preview of what image information is passing to higher levels of processing. We do this by processing information given in a natural image Rapid Serial Visual Presentation (RSVP) task by its spatio-temporal statistical surprise (Einhäuser,Mundhenk,Baldi,Koch & Itti,2007). From this, we obtain an attention-gate mask over each of the RSVP image frames derived from the map of attentional capture provided by the surprise system. The mask itself accounts for the degree to which distracter images that proceed or follow a target image are able to take attention away from it and vice versa. Attention is also accounted for within an image so that targets need to be salient both across frames and within the target image in order to be detected. Additionally, stronger target capture leads to better masking of rival information decreasing later visual competition. The surprise-based attention-gate is validated against the performance of eight observers. We find that 29 unique RSVP targets from 29 different sequences which are easy to detect precisely overlap to a far greater extent with open regions in the attention gate compared with 29 unique targets which are difficult to detect (P<.001). This means that when a target is easy to detect, more target regions are passing through the attention-gate increasing the availability of relevant features to visual recognition facilities. Additionally, this allows us to surmise what parts of any given image in an RSVP task can plausibly be detected since regions which are gated at this stage cannot be processed any further.

16.523

Attention Prioritization as a Mechanism Underlying Context-Guided Learning in Visual Search

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Previous studies showed that contextual cueing expedited visual search. Tseng and Li (2004, Perception & Psychophysics) demonstrated that the decrease in search time occurred as a result of the reduction in the number of saccadic eye movements during an ineffective search phase. Context has no effect in the effective search phase in which successive fixations move closer to the target. In the present study we explored in computational modeling how three alternative factors mediate eye movements during context-guided visual search: attention prioritization, the rate of visual resolution decline in the periphery, and magnitude of inhibition of return (IOR). The selection of successive fixation location is based on the optimal information gain hypothesis: the search model evaluated each possible location and selected one that will maximize information gain from surrounding stimuli. The stimulus expected information gain increases by attention prioritization but declined with increase of eccentricity, and the rate of the decline was contingent on a scaling constant. If a stimulus had been examined, its information decreased by the magnitude of IOR. The model parameters were calibrated by the observed distribution of the amplitude of saccade in no-cued condition and then tested in cued condition. The results showed that both the change of the decline rate of visual resolution and the magnitude of IOR lead to a shortening of the ineffective search phase and a change in the slope of the effective search phase, in disagreement with the empirical data. On the other hand, attention prioritization shortened the duration of the ineffective search phase but left the slope of the effective search phase unaltered. These simulation results suggest that attention prioritization can occur during our visual search paradigm in which the salient task-irrelevant contextual cues serve as a causal venue through which context-guided learning takes place.

16.524

Visual Routines for Sketches: A Computational Model

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We present Visual Routines for Sketches (VRS), a system which is being developed to compute symbolic, qualitative representations of sketches drawn by users. VRS models early to mid-level human vision in a simple line-drawing environment. Its primary purpose is to provide the user with a set of elementary operations that can be combined to construct visual routines, i.e., programs that extract some symbolic information about a sketch, as described in Ullman's (1984) seminal paper. Elementary operations include the spreading of covert attention through curve tracing and region coloring, and inhibiting or locating elements in a visual scene that contain a particular basic feature, such as a color or orientation.

The strength of VRS over other visual routine implementations is that rather than using a small set of routines to perform a particular task, VRS provides a wide open environment, in which the user can combine operations to create any number of routines, depending on the desired information about the sketch. This approach has two key advantages: a) there is a great deal of flexibility in what information can be computed, and thus the system can compute representations that serve as the input for many different visuospatial tasks; and b) the system can serve as a sandbox in which to evaluate and compare different computational models for how people compute visual features and spatial relations. In particular, we focus on two types of two-dimensional relations: positional relations and topological relations. We show how simple routines can be written in VRS to compute these relations, and how the output of VRS can be used to evaluate those routines as models of human perceptual processing.

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16.525

The effect of experience on visual capture in a virtual environment

Katherine Snyder[1] (ksnyder@mail.utexas.edu), Brian Sullivan[1], Richard Revia[1], Mary Hayhoe[1]; [1]Psychology Department, The University of Texas at Austin

One mechanism for controlling the deployment of eye movements is attentional capture. Such capture may depend on the history of experience in the environment. Itti & Baldi (2006) have suggested that the visual system is sensitive to 'Surprise', that is, the deviation of the current image statistics from the distribution of prior experience. In the present study, we tested how prior experience influences eye movements to a novel object. Subjects walked in a virtual environment while their eye gaze was tracked. All subjects walked 20 laps, ~20m long, along a oval sidewalk in a virtual environment containing 13 prominent objects placed along the path. On a critical trial, a novel object was inserted next to the path. Additionally, 2 virtual pedestrians started walking against the subject on the critical trial and remained for the duration of the experiment. For subjects in the 'Inexperienced' condition (n=9) this change occurred on the second lap. For those in the 'Experienced' condition (n=8) it occurred on the sixteenth lap. Eye movements were manually coded for four of the objects in the scene, including the novel object. Fixation durations and probabilities and saccade latencies were calculated. Across both conditions, subjects fixated both novel and non-novel objects about 2/3 of the time on any given lap for about 200-600ms. Fixation durations and saccade latencies did not differ for the novel object for different levels of experience. We found little evidence to suggest that the novel object captured gaze more than other objects in the scene independent of the subject's level of familiarity with the scene. Thus Surprise with respect to a familiar image sequence may not be a universally effective mechanism for attracting gaze. Rather, task constraints may dominate Surprise in many situations.

Itti,L; Baldi, PF; Bayesian Surprise Attracts Human Attention; NIPS, 19, 547-554, 2006.

16.526

Investigating the Link Between Visual Attention and Emotion: A TVA-Based Computational Approach

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Although visual attention and emotion appear to be radically different processes, they are closely related in an adaptive, functional sense. The visual world presents a vast amount of information (over ten million bits) in any given second. However, human visual resources (processing and storage capacities) are limited and therefore must be directed to the most significant parts of the visual field. An important measure of significance is emotional relevance: i.e., relevance to the observer's goals and concerns.

This paper will investigate the link between visual attention and emotion by presenting a computational model based on the results from a range of empirical studies. The computational framework is provided by the Theory of Visual Attention (Bundesen, 1990; Bundesen, Habekost, and Kyllingsbæk, 2005). TVA proposes that visual attention comprises two waves of processing. First, each object in the visual field is assessed for 'pertinence' values and given a corresponding attentional weight. Second, each object is categorised according to certain 'bias' values; those objects/categories which have the greatest weight and bias are most likely to win the race for entry into visual short-term memory. In order to link visual attention to emotion, both schematic and photographic faces were used as emotional stimuli. The first experimental paradigms used accuracy as the main response measure (identification of one or more letter targets with face distractors), whereas the second paradigms measured reaction time (variations of the Eriksen and Eriksen flanker task). In TVA terms, the results suggest that negative emotional stimuli have high pertinence values and attentional weights, in comparison with either positive or neutral stimuli. However, significant effects are only observable if the number of stimuli exceeds VSTM capacity of around four items (accuracy paradigms), or if targets and distractors come from the same stimulus class and bias values are set constant (RT paradigms).

Eye Movements: Cognitive Mechanisms

Friday, May 8, 6:30 – 9:00 pm
Poster Session, Vista Ballroom

16.527

Stability of Eccentric Attention

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Purpose: Patients with macular degeneration develop eccentric fixation by directing objects of interest and attention to preferred retinal locus (PRL). This study explores the relationship between PRL eccentricity and fixation stability. We hypothesized that fixation stability would decrease as the deviation between gaze and attention increased.

Method: An experienced low vision observer with two PRLs and a normal observer performed a fixation stability task. Fixation was tracked monocularly. The low vision observer was calibrated using his primary PRL and instructed to "look at" the 1 º fixation cross with one of his two PRLs. The fixation target flickered when eye position deviated beyond a set tolerance, providing feedback and requiring attention. Practice trials were performed by the normal observer before fixation stability was measured. The normal observer was required to hold their gaze at a 10 º or 15 º to the left of the feedback target, forcing the decoupling of gaze and attention. Fixation stability was computed with the bivariate contour ellipse area (BCEA) for a set of fixations (Bellman, et. al., Opt 2004).

Results: The low vision patient produced an average BCEA value of 1.88 º for his primary PRL. The patient described some difficulty switching to his secondary PRL, and BCEA values were much larger. The normal subject produced average BCEA values of 1.19 and 0.92 for 10 º and 15º respectively.

Conclusion: The normally subject achieved better stability with few practice trials as compared to the more experienced low vision subject. This effect may be due to practice with the specific stimulus instead of more extended real-world objects. The increase in stability with eccentricity may reflect a lesser need for attention to detect flickering stimuli in the periphery. Letter or shape discrimination would likely require a more "eccentric" attention, possibly reversing the effect.

16.528

Simulation of human eyes in three dimensions

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To understand human vision it is important to appreciate the challenges faced by the brain in acquiring stable images of natural three dimensional (3D) scenes and controlling eye movements. Recent advances in computer simulation now make it possible to create realistic models of these essential peripheral processes of human vision. Specifically, we describe physically based models for simulating eye movements controlled by extraocular muscles (EOMs) and image formation on a curved retina.

We simulate 3D eye movements using a new biomechanical simulation framework. Most previous models simplify the nonlinearities of the oculomotor plant's geometry and EOM mechanics, and are limited to static simulation. We model EOMs as a collection of "strands," which are modeling elements for musculotendon dynamics based on splines with inertia. Each strand represents a part of the musculotendon aligned with the fibers; depending on the level of detail needed, a strand can be as fine as a single fascicle or as coarse as an entire muscle. Anatomical variations in EOM and globe geometry across individuals can be taken into account. The resulting model generates realistic gaze positions and trajectories from brainstem control signals.

We can simulate image formation on the retina by tracing a large number of rays from 3D objects as they pass through the optics of the eye to form an image on the curved retina. Most existing models use a pin-hole camera model, with images formed on a planar surface. A more realistic model is useful for understanding basic questions of vision science such as binocular alignment and transsaccadic perception. Recent advances in computer graphics hardware make it possible to efficiently compute these retinal images at interactive rates.

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URL: http://www.cs.ubc.ca/~pai/

16.529

Latency/accuracy trade-offs during sequences of saccades

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For many motor behaviors, the more time devoted to planning a movement, the higher the spatial accuracy. To determine whether latency/accuracy trade-offs apply to saccadic eye movements, subjects made saccades in sequence to 4 target circles (diameter 15′-180′) located at the corners of an imaginary square (corner separation 90′-520′). Subjects were instructed to look at each target in sequence at either a fast or slow pace.

In the "fast" condition, the time to complete the sequences increased with increasing target separation and with decreasing target size, in keeping with Fitts's Law (1954). The increase in scanning time was due mainly to a greater frequency of secondary saccades, needed to correct the landing errors of the primary saccades. Secondary saccades were preferred over a strategy of increasing the latency of primary saccades in an attempt to improve accuracy.

Why were subjects reluctant to increase primary saccadic latency? Under the "slow" condition, where increases in latency were encouraged, the fixation pause duration increased by about 50%. The increase in pause duration was due to both a higher occurrence of smaller secondary saccades during the pauses, as well as to longer saccadic latencies. Yet despite the longer latencies in the "slow" condition, the scatter of saccadic landing positions did not change.

These results show that increasing the time available for saccadic planning did not improve the spatial precision of saccades. In our visual display, with fixed target locations and no distracters, latency/accuracy trade-offs did not apply. Saccades thus differ from other motor behaviors, where optimal performance depends on trading off the duration of primary movements with the occurrence of corrections (Meyer et al., 1988). For saccades, the only apparently viable strategy to improve accuracy is to issue more corrections.

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16.530

Cognitive expectation and repetitive priming contribute to probabilistic encoding in frontal cortex

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Previous work demonstrated that lateral intraparietal cortex (LIP) neurons encode the probability that a given stimulus set predicts an appropriate response (Yang & Shadlen, 2007). Similarly, neurons in the supplementary eye field (SEF) probabilistically encode stimulus configurations that predict appropriate responses in a go-nogo smooth pursuit task (Heinen et al., 2008). While these neurons might calculate stimulus probabilities to form a cognitive expectation of the appropriate response, a low-level memory of recent trials (priming) could alternatively explain the result. Here, we test between these alternatives. Single neurons were recorded from the SEF in monkeys performing the ocular baseball smooth pursuit task (Kim et al., 2005). In "strike" trials, the monkey pursued targets that intersected a visible zone (plate). In "ball" trials, the monkey maintained fixation when the target did not intersect the plate. Three conditions were used, one where a block contained only strike trials or only ball trials - it allowed both the expectation and priming alternatives. In another, strikes and balls were randomized, nulling expectation, but allowing priming. Finally, strikes and balls were alternated, nulling repetitive priming, but allowing expectation. Neurons were most active during the first condition when either strategy was allowed. Activity in the other two conditions was similar, but lower than in the first condition, consistent with both expectation and priming contributing to their response. Direct assessment of activity modulation by previous trials validated the priming result. The results suggest that SEF neurons encode stimulus probabilities which signal appropriate behavior using both a cognitive expectation and a transient memory of previous trials.

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16.531

Differential Effects of Partial Foreknowledge on Efficiency and Switch Costs of Saccadic Eye Movements

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Foreknowledge can be used to optimize behavioural responses to stimuli. Most previous reports have studied the effects of complete foreknowledge, in which all aspects of an upcoming trial are known. However, these have left open the question of which aspects of a trial are most useful to know in advance, in terms of reducing error rate and latency. In the current study we systematically investigated different types of 'partial foreknowledge' – that is, for stimulus, task or response, but not all three - in a saccade paradigm. Partial foreknowledge blocks contained predictable 'ABBA' sequences of either stimulus location, task-set (prosaccade or antisaccade) or response direction, while the other two trial parameters followed a random sequence. These blocks were compared to blocks with no foreknowledge or complete foreknowledge of all three parameters. 10 healthy subjects performed the experiment. As output variables we measured saccadic inverse efficiency score (reaction time divided by accuracy rate) and switch cost, which is the difference in scores between trials in which a parameter value changed and trials in which it was repeated. The results showed that the effects on saccadic efficiency of prosaccades and antisaccades were not equivalent for all three types of foreknowledge. While stimulus foreknowledge had no effect on efficiency, task foreknowledge had some effect and response foreknowledge was as effective as complete foreknowledge. Foreknowledge effects on switch costs followed a similar pattern in general, but were not specific for switching of the trial attribute for which foreknowledge was available. We conclude that partial foreknowledge shows a 'distal-to-proximal' gradient effect on efficiency, most consistent with preparatory activation of a motor schema in advance of the stimulus, with consequent benefits for both switched and repeated trials.

16.532

The influence of prior experience and task-demands on visual search for a pop-out target

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During visual search, a “pop-out” stimulus can capture attention, and either interfere with or facilitate search, depending on whether it is a target or distracter. Horstmann [1] demonstrated that these influences depended on subjects’ expectations for the amount of color variation in the scene. We performed a similar experiment, but additionally quantitatively manipulated the variance of colored patches on which letters were superimposed. We hypothesized that the influence of the pop-out stimulus should be greatest when the variance of color experience was small, and consequently more deviant with respect to the experienced distribution. Eye movements were recorded while subjects searched for one of two target letters in a circular array of letters placed on colored tiles. Subjects were given experience in one of two conditions, where the variance of the background color tiles was either high or low. On a critical trial, subjects in all conditions were presented with an identical array containing a color pop-out stimulus. For critical and post-critical trials, the singleton was either the target letter or a distracter letter, depending on condition. Across all conditions, during experience trials subjects’ reaction times were between 1-2s and they took 3-5 fixations to locate the target. Regardless of prior experience, during critical and post-critical trials subjects had faster reaction times, 0.6-1s, and took 1-3 fixations to find the pop-out target. Crucially, it took ~5 trials to asymptote in performance for finding the pop-out target. We found no evidence for gaze capture or performance impairment in the pop-out distractor condition. Overall we found little evidence for strong gaze capture in any condition, instead it appears that subjects must learn the relevance of a pop-out feature to guide search.

1. Horstmann G.; JEP:HPP. 2005 Oct;31:1039-60.

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16.533

Task-driven Saliency Using Natural Statistics (SUN)

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Based on an assumption that one main goal of the visual attention system is to direct attention towards objects of interest, we have derived a probabilistic model of salience. The resulting model, Saliency Using Natural Statistics (SUN), is grounded in probabilities learned through the experience of the natural world. These probabilities decompose into three parts: knowledge about what features are rare or novel, the visual appearance of particular objects of interest, and where those objects are likely to occur in a scene. Bottom-up saliency is defined by SUN as rare combinations of features, and an implementation of this component of the SUN model has been shown to achieve state-of-the-art performance predicting human eye-movement fixations when free viewing static images (Zhang et al., in press) and video. SUN’s bottom-up saliency model also predicts visual search asymmetries that other models of bottom-up salience based only on the current image fail to capture. However, when interacting with the world, we do so with a focus. Models of visual attention likewise need to be driven by the task at hand. Here we implement the remaining portions of SUN, a location prior which guides attention to likely locations of the target and a probabilistic appearance model in the spirit of the Guided Search (Wolfe, 1994) and Iconic Search (Rao et al., 1996) models. We evaluate our model on the publicly available dataset of Torralba et al. (2006) that contains eye-tracking data collected from subjects asked to count people, cups, or paintings in indoor or outdoor scenes. We show that the full SUN model achieves superior performance in predicting human fixations, suggesting that learned knowledge of targets’ appearance, location, and the rarity of features play a role in determining where to fixate.

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16.534

The role of visual saliency and subjective-value in rapid decision making

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Imagine that you are in front of a vending machine with a few seconds available to purchase a food item. The available items vary both in subjective value - how much you like each - and in their visual attractiveness or saliency. What is the nature of the interaction between value and saliency? In our recent eye-tracking study, subjects made a choice between two food items with different subjective values, as indicated by a priori subject’s liking ratings for each item (Milosavljevic, et al. 2008). The results from 7 subjects indicate that simple value-based choices can be made accurately (85.7%), with a mean reaction time of 582ms. To study the extent to which these choices are influenced by their value versus their saliency, we followed the same procedure (Milosavljevic, et al. 2008) while manipulating the saliency of the food items. We did so by embedding the items in a background with 1/f2 noise in spatial frequency – meant to simulate naturalistic backgrounds with clutter – while matching the background color to the mean color of one of the two food items presented. To further decrease the saliency of the item, we also decreased its contrast. Preliminary results show that when one item has much higher value than the other, choices are driven by the value and are independent of saliency. In particular, on trials where one item has the highest subjective value but the other item is very salient, the conflict is resolved in favor of the high-value option. However, saliency plays a strong role in the choices when the two food items have similar values – the more salient item is chosen faster and more often than the less-salient item.

16.535

I like what I see: Using eye-movement statistics to detect image preference

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The preferential looking paradigm is most commonly used with participants such as infants who are unable or unwilling to express their preference consciously. The immediacy of eye-movements as a measure of preference offers the potential to explore typically noisy subjective evaluations, such as aesthetic preference with reliable objective measures in normal adults (Schirillo, 2007, Perception, 36:19). We presented a variety of simple (geometric shapes) and complex (everyday objects, buildings and commercial products) images in sets of 2, 4 or 8 items and recorded oculomotor statistics such as dwell time, returns to location and fixation sequence while participants searched for their preferred image. After eye-tracking for 1500, 2500 or 5000ms, we asked participants to indicate their preference using a button press. The amount of time spent looking at an image correlates increasingly well with preference over the three presentation durations. For short presentations the first and last fixation provide a more reliable predictor of image preference. All statistics become increasingly noisy as the amount and complexity of images presented are increased. By combining the information from these measures the signal to noise ratio can be significantly improved to provide a reliable predictor, which could be used for the subjective evaluation of stimuli in visual psychophysics. Its role as a fitness function in visually driven evolutionary algorithms (Holmes & Zanker, 2008, Perception, 37:148) and potential for application to commercial product testing is discussed.

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 See page 3 for Abstract Numbering System

16.536

What eye-movements tell us about online learning of the structure of scenes

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We have recently proposed that representations of novel multi-element visual displays learned and stored in visual long-term memory encode the independent chunks of the underlying structure of the scenes (Orban et al. 2008 PNAS). Here we tested the hypothesis that this internal representation guides eye movement as subjects explore such displays in a memory task. We used scenes composed of two triplets of small black shapes randomly selected from an inventory of four triples and arbitrarily juxtaposed on a grid shown on a 3'x3' screen. In the main part of the experiment, we showed 112 trials with two scenes for 2 sec each with 500 msec blank between them, where the two scenes were identical except for one shape that was missing form the second scene. Subjects had to select from two alternatives the missing shape, and their eye movements were recorded during the encoding phase while they were looking at the first scene. In the second part of the experiment, we established the subject's confusion matrix between the shapes used in the experiment in the given configurations. We analyzed the amount of entropy reduction with each fixation in a given trial based on the individual elements of the display and based on the underlying chunk-structure, and correlated these entropies with the performance of the subject. We found that, on average, the difference between the entropy reduction between the first and last 10 trials was significantly increased and correlated with improved performance when entropy was calculated based on chunks, but no such reduction was detected when entropy calculation was based on individual shapes. These findings support the idea that subjects gradually learned about the underlying structure of the scenes and their eye movements were optimized to gain maximal information about the underlying structure with each new fixation.

16.537

Looking away from faces: Influence of high level visual processes on saccade programming

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Human faces capture attention more than other visual stimuli. Normal observers notice changes in faces more rapidly than changes to other visual objects and brain damaged patients suffering from visual neglect show sensitivity to faces in their neglected hemifield. Here we investigated whether such face specific biases rely on automatic (involuntary) or voluntary orienting responses. To this end, we used an anti-saccade paradigm, which requires the ability to inhibit a reflexive automatic response and to generate a voluntary saccade to the opposite direction of the target. To control for potential low-level confounds in the eye-movement data, we manipulated the high-level visual properties of the stimuli while normalizing their low-level visual properties. Stimuli consisted of faces and cars (normalized for amplitude and contrast spectra), as well as noise patterns generated by randomizing the phase-spectrum of the normalized face and car images. We recorded the eye movements of 20 participants while performing either pro- or anti-saccades to a face, car or noise pattern randomly presented to the left or right of a fixation point. For each trial, a symbolic cue randomly instructed the observer to generate either a pro-saccade or an anti-saccade. We report a significant increase in anti-saccade error rates for faces compared to cars and noise patterns, as well as faster pro-saccades to faces and cars in comparison to noise patterns. Moreover, the fixation duration after the first saccade was much shorter for pro-saccades to faces compared to other stimuli, suggesting a more efficient processing for faces. These results indicate that human faces generate a stronger involuntary orienting response than other visual objects in line with an automatic processing for faces. Importantly, this involuntary processing cannot be accounted for by low-level visual factors.

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16.538

Tracking the Visual Attention of Novice and Experienced Drivers

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We investigated deployment of visual attention of 12 novice and 19 experienced drivers while they examined projected photographs of road scenes, which ranged from congested urban streets to open rural roads. Scenes were selected to represent a range of risk-levels based on prior ratings (1-7) by experienced drivers. Participants viewed 52 pairs of photographs. In each pair of photos, one scene scored a higher risk-level than the other scene (e.g., a merging vehicle, pedestrian, construction activities, etc.). Importantly, the difference in risk-level of some stimulus pairs was great and, therefore, "easy" to assess quickly, whereas the difference of risk-level of other pairs was relatively small and, therefore, "difficult" to assess quickly. The task was to decide as quickly and accurately as possible which of the two road scenes posed greater risk and to press a button indicating whether the riskier scene appeared on the right or left. Eye movements were recorded simultaneously to determine which elements of each scene attracted the participant's fixation. Analyses of eye movement records indicated that, compared with novice drivers, the fixations of experienced drivers tended to cluster more heavily on elements of potential risk. Moreover, reaction time (RT) data showed that experienced drivers took significantly longer to respond when the risk-levels of the two scenes were similar ("Difficult") than when the risk-levels were different ("Easy"). In contrast, novices responded quickly to all comparisons, with no difference between "Difficult" and "Easy" combinations. These findings indicate that, compared to novices, experienced drivers recognize and attend more thoroughly to risky elements in realistic road scenes. This difference in deployment of attention may help to account for the fact that, for at least a year after licensure, new drivers, independent of their age, are at greater risk of causing a collision.

Acknowledgement: Supported by grants from Franklin & Marshall College.

Neural Mechanisms: Visual and Visuomotor Function

Friday, May 8, 6:30 – 9:00 pm
Poster Session, Vista Ballroom

16.539

Insect visual learning: Drosophila melanogaster can discriminate and generalize the shapes of a circle and a cross

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Purpose. Using a flight simulator for Drosophila melanogaster, Ernst & Heisenberg (1999) reported that several parameters like size, color, and vertical compactness could be used as cues for visual discrimination in tethered flies. However, a puzzling result was found in their original study--flies failed in conditioned discrimination between a cross (+) and a circle (O), but showed spontaneous preferences towards the circle. Using a T-maze like apparatus (Tully & Quinn, 1985), we previously re-examined Ernst & Heisenberg's (1999) finding and found that flies could in fact learn to discriminate between a circle and a cross (Chien, Lin, Chen, & Lai, APCV 2008). In the present study, we further investigated whether flies can recognize luminance-defined shapes and generalize them to the same shapes that were defined by the law of continuity.

Methods. The same T-maze like device was used as the main training/testing apparatus. The stimuli were printed paper and were back illuminated by LED lights. We first trained flies to discriminate between a circle and a cross sequentially with one being associated with heat (aversive conditioning). In the test phase, flies were presented with the two stimuli located on the opposite arms. The rationale was that if the flies did learn which stimulus was unsafe (i.e. the heated one), we expected to see significantly fewer flies would stay in the unsafe arm than in the safe arm.

Results. Tested with about 500 flies in each experimental condition, our data indicated that, when trained with luminance-defined shapes, flies were able to show statistically significant learning behavior for the same pair of shapes but were made of dots (the law of continuity) instead of solid lines. This finding supports the notion that free flying Drosophila can learn to recognize and generalize simple shapes. Further control experiments are in progress.

Acknowledgement: This project was supported by Grant# NSC 97-2410-H-039-006 to Dr. Sarina H. L. Chien.

16.540

Spatial representation during saccade adaptation in macaque areas V1 and V4

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The saccadic system is capable of rapidly adapting to changes in the oculomotor system (e.g. changes in the mechanics of the eyeball) that otherwise would lead to movement inaccuracy and poor vision - an effect usually referred to as saccade adaptation. This adaptation challenges the mechanisms that guarantee visual perceptual stability across eye-movements – the neural basis of which is currently unknown. We hypothesized that perceptual stability during saccade adaptation would require a modulation of the visual RFs with respect to the fovea to compensate for the mismatch between sensory and motor signals. In our current study we therefore mapped visual receptive fields (RFs) in areas V1 and V4 of the macaque monkey during a saccade adaptation task.

RFs were mapped by presenting Gaussian luminance patches at random positions under three different conditions: during fixation, in a classical saccade task and during saccade adaptation. Saccade adaptation was elicited by a perisaccadic displacement of the saccade target against the direction of the eye movement (Backward adaptation). To obtain spatiotemporal RFs we analyzed multi-unit activity using a stimulus response correlation technique.

Preliminary data suggest that, in both areas RF positions were different during saccade adaptation trials as compared to fixation or non-adapted saccade trials. In adaptation trials, RF locations calculated from stimuli presented immediately after saccade offset were shifted in the direction of the saccade (i.e. opposite to the direction of the target displacement) compared to control trials. This displacement was larger for RFs mapped in V4 than in V1. In both areas, however, the magnitude of RF shift decreased slightly during the course of adaptation.

We conclude that eye movement signals do have an influence on spatial information processing in areas V1 and V4 - a mechanism probably involved in the maintenance of perceptual stability across saccadic eye movements.

16.541

Frontal eye field activity before form visual search errors

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The frontal eye field (FEF) signals the location of the target of visual search by increasing activity when the target, relative to a distractor, is inside neuronal receptive fields (RF). Here, we studied the role of FEF associated with errors of target selection during visual search by recording neuronal activity in two monkeys performing visual search for T (or L) among Ls (or Ts) in which they were required to make a single saccade to the target. When monkeys made saccades to distractors (typically followed by corrective saccades to the target), one population of neurons increased activity when the distractor, relative to the target, was inside their RF, replicating previous work (Thompson KG, Bichot NP, Sato TR (2005) Frontal eye field activity before visual search errors reveals the integration of bottom-up and top-down salience. J Neurophysiol 93, 337-351). A second population of neurons, all with visual- and movement-related activity, exhibited higher distractor-related activity early in error trials, but showed higher target-related activity later in error trials. A third population of neurons exhibited higher activity for the target than for distractors during correct and error trials. These results replicate and extend the findings of Thompson et al. (2005) and demonstrate a diversity of target selection processes in FEF.

Acknowledgement: Supported by NEI R01-EY08890, P30-EY08126 and Ingram Chair of Neuroscience

16.542

Frontal Eye Field modulation of Parieto-Occipital visual processing; an online TMS EEG study

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A single pulse of transcranial magnetic stimulation (TMS) applied over the frontal eye field (FEF) can facilitate the subsequent detection of near-threshold stimuli (Grosbras and Paus, 2003) or increase the excitability of other visual regions (Silvanto et al., 2005). How FEF TMS influences cortical processes remains elusive, however. Here we aim to combine electroencephalography (EEG) and single pulse TMS to explore the timing of the modulation of EEG as well as potential changes in the oscillatory activity.

Five subjects viewed gratings briefly flashed in their lower left or right half visual field while we recorded EEG. In some trials we applied single-pulse TMS over the right FEF or a control site (vertex) at three latencies relative to visual onset: -100, 0 and 50ms. In some trials we applied TMS without any visual stimulation. We excluded from the analysis the 30ms during which TMS

artifact occurred. We analyzed (1) Event-Related Potentials (2) Power in alpha, beta, lower gamma and upper gamma frequency bands during the 500ms before and after visual stimulus onset.

We observed higher P300 amplitude for FEF- than for vertex TMS.

When no visual stimulation was present we observed a decrease in alpha power after TMS, larger for FEF stimulation than vertex and for the right than the left hemisphere. No univoqual effect was observed in other frequency bands. When a visual stimulus was present, FEF TMS applied 50 ms after a left target specifically increased alpha synchronization.

The TMS-induced changes in evoked visual response occurred at the same time as effects of attention have been observed, and are similar to what Taylor and al (2006) reported with FEF rTMS. The reduction in background alpha synchronization in visual cortex is reminiscent of desynchronization during attention orienting and in line with a role of FEF in top-down visual control.

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16.543

Illuminating Awareness: Investigating the temporal and spatial neural dynamics of metacontrast masking using the event-related optical signal

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 See page 3 for Abstract Numbering System

It has been proposed that in order for a stimulus to reach consciousness, visual information that is relayed to higher brain areas must also be fed back to the early visual areas for a reverberatory strengthening of the representation. This theory further proposes that when these feedback signals from higher brain areas encounter new activity elicited by a different stimulus, this reactivation, and thus the conscious perception of the original target, is inhibited. The present study measured the neural correlates of conscious perception in a backwards metacontrast masking paradigm, in which the detection of a target is inhibited by a subsequent mask. After a fixation cue in the current experiment, target and mask pairs were presented at a constant SOA such that participants detected roughly half of the targets. Using the event related optical signal (EROS), a brain imaging technique with high spatial and temporal resolution, we examined not only the differential activity elicited by detected and undetected targets, but also preparatory activity prior to the target onset that might predict subsequent target detection. Preliminary analyses revealed a parietal area more active before detected targets, preceding an observed reduction in parietal alpha power measured with simultaneous EEG recording. Furthermore, the largest difference in activity in primary visual areas between detected and undetected targets occurred relativity late (+ 150 ms), after the initial feed forward processing, consistent with the dependence of visual awareness on re-entrant reverberations.

16.544

Theta-burst transcranial magnetic stimulation to the prefrontal cortex impairs metacognitive visual awareness

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Introduction

Current theories suggest that prefrontal cortex (PFC) plays an important role in visual awareness (Dehaene 2003). This hypothesis has been supported by a number of brain imaging studies (Rees 2002). However, critics have challenged that there has been a lack of neuropsychological demonstration of the essential role of PFC in visual awareness: PFC damage does not seem to result in cortical blindness (Pollen 1995). Here we clarify this issue by showing that bilateral transcranial magnetic stimulation (TMS) to PFC affects visual awareness and metacognition.

Methods and Results

We used a recently developed TMS protocol, theta-burst stimulation, to bilaterally depress activity in dorsolateral PFC as subjects performed a visual discrimination task. We found that this stimulation impaired subjects' ability to discriminate between correct and incorrect stimulus judgments. After TMS, subjects reported lower visibility for correctly (but not incorrectly) identified stimuli, suggesting that visual awareness of effective information processing was selectively suppressed. A signal detection theoretic analysis confirmed that these results were not merely due to a change in response bias, but rather reflected a reduction of metacognitive sensitivity. The effect was specific to metacognition; TMS did not impair performance in the stimulus discrimination task, which undermines alternative explanations such as TMS impairing visual attention.

Discussion

These results suggest that activations in PFC accompanying visual awareness in brain imaging experiments are not epiphenomena, but rather may reflect a critical metacognitive process. Disruption of PFC selectively impairs visual awareness of correctly processed stimuli.

References:

Dehaene S, Sergent C, Changeux J (2003) A neuronal network model linking subjective reports and objective physiological data during conscious perception. Proc Natl Acad Sci U S A 100:8520-5
Pollen DA (1995) Cortical areas in visual awareness. Nature 377:293-5
Rees G, Kreiman G, Koch C (2002) Neural correlates of consciousness in humans. Nat Rev Neurosci 3:261-70

16.545

Alteration of visuomotor processing following left-right prism adaptation

Brian Barton[1] (bbarton@uci.edu), Ling Lin[1], Christian Herrera[1], Alyssa A. Brewer[1]; [1]Department of Cognitive Sciences, University of California, Irvine

Several studies have examined the role of primate parietal cortex in visuomotor tasks involving grasping, reaching, and saccadic eye movements (e.g., Hagler et al., Neuroimage, 2007). One especially useful way to study that role is to measure how motor systems adapt to alterations in visual input. Neuroimaging measurements in humans have begun to reveal a cluster of visual field maps in posterior parietal cortex that may be involved in visuomotor integration and adaptation (Swisher et al., J. Neuroscience, 2007). Here, we examine the alterations in these parietal maps in an example of extreme visuomotor adaptation during a 14 day period of continuous left-right visual field reversal.

We combined psychophysical and neuroimaging measurements of subjects wearing left-right reversing prisms and compared them to baseline and post-experimental measurements. Throughout this adaptation period, subjects performed a daily battery of visuomotor behavioral tasks in which we tracked changes in error rates and reaction times (e.g., Richter et al., Exp. Brain Res., 2002; Sekiyama et al., Nature, 2000). In the neuroimaging experiments, we used standard retinotopic stimuli to define the posterior and dorsal visual field maps. These data were then compared across time points to the organization of these maps as defined by a delayed-saccade paradigm. Additionally, we compared the responses to a variety of visual spatial tasks across these maps. These data increase our understanding of cortical regions that underlie visuomotor adaptation to continuous, long-term left-right visual field reversal.

Acknowledgement: Supported in part by a Grant-in-Aid of Research from Sigma Xi, The Scientific Research Society and by a Graduate Student Summer Fellowship from the UCI Center for Cognitive Neuroscience.

16.546

Visual Field Mapping of Visuomotor Adaptation to Prisms

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Stratton (Psych. Rev., 1897) first described visuomotor adaptation to altered visual input by wearing inverting prism spectacles. A number of studies (e.g., Miyauchi et al., J. Physio., 2004) have tried to confirm his findings and further examine the question of how responses in visual cortex change during this adaptation process. There is evidence from these studies that changes occur in parieto-occipital cortex. Recently, several human visual field maps have been described in parietal cortex that are thought to be involved in visuomotor integration (Swisher et al., J. Neurosci., 2007). Here, we further investigate the adaptation of these cortical maps to an extreme alteration of visuomotor processing.

Our study specifically measured the changes in parietal visual field maps throughout a 14 day continuous adaptation period to left-right reversing prism spectacles. We first defined the baseline organization of the posterior and dorsal visual field maps using retinotopic stimuli comprised of wedges, rings, and bars. At multiple pre-prism, with-prism and post-prism time points, we measured the alterations in the occipital and parietal visual field maps. We also compared the population receptive fields within these maps across the time points (Dumoulin and Wandell, Neuroimage, 2008). Throughout the adaptation period, subjects practiced a daily battery of visuomotor behavioral tasks (e.g. Richter et al., Exp. Brain Res., 2002).

These measurements allowed us to identify the cortical regions subserving the dynamic remapping of visuomotor representations and altered visual perception following adaptation to the prisms. These data add to our current understanding of the visual pathways and the neural mechanisms for visuomotor processing.

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16.547

Dissociation of feature-based motion and 'objectless' motion energy for direction discrimination within the sighted and blind-sighted visual fields of a hemianope

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The detection of motion direction is one of the visual capabilities spared by damage to the striate cortex (or pathways leading to the striate cortex) that is sufficient to eliminate conscious awareness. We have found that the discrimination of motion direction within such a cortically blind visual field is not attributable to the detection of changes in position (i.e., feature tracking), as proposed by Azzopardi and Cowey (2001), but is due instead to the detection of 1st-order motion energy (spatiotemporal changes in luminance). The experiments demonstrating this were based on a version of the line motion illusion (Hikosaka, Miyauchi & Shimojo 1993) entailing reverse-phi motion (Anstis & Rogers1975). Opposing motion directions were simultaneously cued by changes in motion energy and changes in stimulus shape. In forced-choice tests, our blindsighted test subject always selected the motion direction cued by shape when the stimulus was presented in his intact field, and reliably selected the motion direction cued by motion energy when the stimulus was presented in his cortically blind field, where it also was shown that relevant position information either was inaccessible or invalid. The dissociation of motion direction by visual field (cortically blind vs. intact) provides evidence for parallel neural pathways to cortical Area MT/V5, a brain area specialized for the perception of motion: A motion energy pathway originating in the superior colliculus and bypassing Area V1 that is not affected by striatal damage, and an object motion pathway originating in the lateral geniculate nucleus and passing through Area V1 before projecting onto Area MT. Motion energy has been characterized as 'objectless' by Sperling and Lu (1998), so its detection is consistent with the severely impaired access to shape information in blindsight.

Acknowledgement: Funded by a European Network Grant from the Oxford McDonnell Network for Cognitive Neuroscience to PA.

Saturday Sessions

Color and Light: Neural Representations of Color

Saturday, May 9, 8:30 – 10:00 am
Talk Session, Royal Palm Ballroom 1-3
Moderator: Sophie Wuerger

21.11, *8:30 am*

Decoding and reconstructing color from responses in human visual cortex

Gijs Joost Brouwer[1] (gbrouwer@cns.nyu.edu), David Heeger[1]; [1]New York University, Department of Psychology and Center for Neural Science

Introduction

How is color represented by the distributed spatial patterns of activity in visual cortex? We determined the accuracy with which stimulus color could be decoded and reconstructed from fMRI measurements of activity in visual cortex.

Methods

We used eight isoluminant colors, equally spaced in the CIE L*a*b color space, surrounding and equidistant from a central gray point. Each stimulus was a concentric grating modulating from central gray to one of the eight colors, presented in pseudo-randomized order (1.5 s duration, 3-6 s ISI). fMRI responses were analyzed with multivariate techniques: pattern classification and principal component analysis (PCA).

Results

Stimulus color was accurately decoded from spatially distributed patterns of responses within areas V1, V2, V3, V4 and VO, but not LO1, LO2, V3A/B or MT. In a complementary analysis, we used PCA to reconstruct a color space from activity in each visual area. PCA extracted the covariation between voxels' responses to the different colors. In V4, the first two principal components (the main source of variation) of the responses constituted a vector space that resembled perceptual color space, with similar colors evoking the most similar responses. By contrast, although decoding was more accurate in V1 than V4, the PCA of V1 activity did not reveal a similar progression. The mean responses, averaged across voxels in each visual area, were the same for all colors. Although voxels in each visual area exhibited different color preferences, no consistent spatial organization or topography was found.

Conclusion

Each stimulus color was associated with a unique spatially distributed pattern of activity within early visual areas. We assume that this reflects the color-selectivity of the neurons in those areas. If so, activity in V4 (but not V1) appears to depend primarily on the responses of color-selective neurons with color tuning that reflects perceptual color space.

Acknowledgement: Supported by: NIH R01-EY16752 (DJH) and NWO Rubicon Fellowship (GJB)

21.12, *8:45 am*

Multivoxel Pattern Analysis of chromatic responses in LGN and V1

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Behavioural measurements have repeatedly shown that the four unique hues are different from the chromatic mechanisms found in the Lateral Geniculate Nucleus (LGN), a sub-cortical structure involved in visual processing: the cone-opponent LGN mechanisms (i.e. cardinal directions 'L-M' and 'S-(L+M)') do not map onto the colours human observers usually label as red, green, yellow, and blue. Unique hues must therefore be encoded at a later processing stage, in the primary visual cortex or in the extrastriate visual areas. We use multi-voxel pattern analysis (MVPA) to study the spatial clustering of color-selective neurons in the human brain. Our main objective was to investigate whether MVPA reveals the spatial arrangements of color-selective neurons in LGN and in human primary visual cortex (V1). We measured the distributed fMRI activation patterns for different color stimuli (Experiment 1: cardinal colors (to which the LGN is known to be tuned), Experiment 2: unique hues) in LGN and V1. Our main findings were: (i) In LGN, cone-opponent cardinal directions produce unique activation patterns for each of the three cardinal colour directions. (ii) Cone-opponent cardinal color modulations produce highly reproducible patterns of activity in V1, but these were not unique to each color. These results suggests that V1 neurons with tuning characteristics similar to those found in LGN are not spatially clustered. (iii) Unique activation patterns for perceptual (unique) hues in V1 support current evidence for a spatially clustered hue map.

Acknowledgement: Supported by the Wellcome Trust and Cambridge Research Systems

21.13, *9:00 am*

The significance of Whittle's experiments on luminance discrimination and brightness scaling for the multiplicative-versus-additive contrast-noise question

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Aim: A question that continues to engage vision researchers is whether contrast transduction noise is additive (fixed with respect to stimulus contrast) or multiplicative (increases with stimulus contrast). Previous attempts to answer this question have been based on an analysis of contrast discrimination thresholds, i.e. JNDs. JNDs however are determined by both the slope of the transducer function as well as the magnitude of internal noise at the point of discrimination. It is difficult to tease these two factors apart, even when employing both the threshold and slope of the psychometric function. One solution is to measure the shape of the transducer function directly using a suprathreshold scaling procedure that is robust to whether internal noise is additive or multiplicative. This will result in a set of contrasts defined at equal perceptual intervals, or 'equal-perceived-differences' (EPDs). If the functions relating JNDs and EPDs to contrast magnitude superimpose when suitably scaled this suggests that transduction noise is additive, whereas if the JNDs increase more rapidly than EPDs, this suggests that transduction noise is multiplicative. Method and Results: Whittle (Vis. Res., 32, p1493-1507, 1992) asked subjects to adjust the luminances of a series of patches on a uniform background to form an equal-interval brightness scale, i.e. a set of EPDs. Although not aiming to address the additive-versus-multiplicative noise question, Whittle compared the EPDs with JNDs obtained from a previous study (Whittle, Vis. Res., 26, p1677-1691, 1986). He found that when the JNDs were suitably scaled they neatly superimposed on the pattern of EPDs. Conclusion: Contrast transduction noise for incremental and decremental patches on uniform backgrounds is additive not multiplicative.

Acknowledgement: Supported by a Canadian Institute of Health Research (CIHR) grant # MOP-11554 given to F.K.

21.14, *9:15 am*

Producing non-Hering Hue Combinations Using Complementary Chromatic Induction

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Perceiving opponent hues (e.g., red and green) as components of a uniformly colored region of space cannot be explained within Hering's opponent theory. Here we demonstrate that the classical formulation of this theory cannot account for perception of colors resulting from certain

Saturday Sessions

chromatic contrasts. In a series of stimuli generating a continuum of colors produced by complementary chromatic induction, our subjects were asked to set bounds along the continuum on when they first (or no longer) saw "redness" or "greenness." The results demonstrate an overlap between the set of colors in which a red component is perceived and the set of colors in which a green component is perceived. This overlap constitutes perception of opponent mixtures explicitly forbidden by the opponent theory. In a control stimulus sequence, in the absence of complementary chromatic induction, the two sets of colors do not overlap, which is consistent with the classical prediction of red and green being mutually exclusive. Our finding and previous results (Crane & Piantanida, 1983, Science, 221:1078-1080; Billock et al. 2001, JOSA A, 18, 2398-2403) support a revision of Hering's theory. We conclude that the opponent structure of classical perceptual color space results not from opponent hues occupying polar positions of a single perceptual dimension, but rather from a projection of the four-dimensional unipolar chromatic hyperspace onto a subspace whose dimensions emerge in response to the visual environment. Such a space allows any unique hue combinations but typically gets reduced to unipolar two-dimensional chromatic percepts. Showing that "forbidden" hue combinations, previously reported only under artificial image stabilization and in our own lab using neon color spreading, can be present in normal viewing conditions opens a new paradigm in the experimental study of the dimensionality and structure of perceptual color space.

Acknowledgement: supported in part by NSF SBE-0354378 at Boston University.

21.15, *9:30 am*

Both Monocular and Binocular Mechanisms Underlie Perceived Temporal Modulation of Color

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The perceived color of light in one region of visual space depends on light in surrounding regions. Perception of a central light that varies in chromaticity over time is strongly affected by a surround that also has a temporally-varying chromaticity. Both monocular and binocular neural processes are shown here to mediate the percept of the temporally-varying light. METHODS: Observers viewed a central test stimulus (1 deg. diameter) with the l chromaticity of Macleod-Boynton space varying over time. This stimulus had a surround (6 deg. diameter) that also varied in l chromaticity at the same temporal frequency. Center and surround were separated by a thin dark gap (0.2 deg.); they were either presented to the same eye (monocular condition) or to opposite eyes (dichoptic condition) at the same frequency (3.125, 6.25, or 9.375 Hz). Relative phase between center and surround was varied. Observers adjusted the modulation depth of a separate temporally-varying field to match the perceived modulation depth in the central test area. RESULTS & CONCLUSIONS: In both the monocular and dichoptic conditions, the perceived modulation depth of the central light depended on the relative phase of the surround; this could be modeled as a linear combination of center and surround modulation. At the lowest temporal frequency, 3.125 Hz, the surround's influence was virtually identical for monocular and dichoptic conditions, suggesting at this frequency that the surround's influence was mediated by only a binocular neural mechanism. At the two higher frequencies, the surround's influence was greater for the monocular condition than the dichoptic condition, and this difference increased with temporal frequency. These results are consistent with a linear combination of responses from two separate neural mechanisms that mediate the influence of the surround, one binocular and dominant at lower frequencies (<4 Hz) and one monocular and predominant at higher frequencies (6-10 Hz).

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21.16, *9:45 am*

Visual search for colors as a test of the Sapir-Whorf hypothesis

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The Sapir-Whorf "linguistic relativity" hypothesis holds that language controls other cognitive processes, especially perception. Specifically, observers perceive color categorically because of the color names in their language. Consistent with the Sapir-Whorf hypothesis, Gilbert et al. (PNAS, 2006) reported that visual search for a colored target stimulus was ~30 msec faster when it was categorically different from its distractors (e.g., a blue target among green distractors) than when the target and distractor were categorically the same (green target, green distractors or blue target, blue distractors). Furthermore, this effect was restricted to the right visual field, suggesting that it is related to language. Here, we replicated and extended this result.

We measured saccadic latency (Tobii eyetracker) on right-handed observers, who viewed 12 disks (one target, 11 distractors) arrayed around a circle, starting in the center and looking at the target color quickly but accurately. The colors were at 170°–225° in CIELAB color space, at constant maximum saturation; targets and distractors were separated by ΔE~11 (15° in CIELAB color space). We measured each observer's green-to-blue color boundary using color naming and MLDS, a perceptual scaling method.

Globally, we found a large effect of color on search time. Discrimination between our bluest stimuli (210°–225° in color space) was slowest (~0.9 sec), and discrimination throughout our range of greenish colors (170°–200°) was ~400 msec faster (~0.5 sec). The broad global minimum was ~192° ("green", according to our subjects). There was a small (~40 msec) cross-category advantage near Gilbert's green-blue boundary, compared to Gilbert's neighboring colors. However, that effect was not reliable across our observers, it did not correspond reliably to individual observers' blue-to-green boundaries, and it was not reliably larger in the right visual field.

We did not find any reliable support for Whorfian categorical perception of colors near the blue-green boundary.

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Object Recognition: Brain Mechanisms

Saturday, May 9, 8:30 – 10:00 am
Talk Session, Royal Palm Ballroom 4-5
Moderator: Nikolaus Kriegeskorte

21.21, *8:30 am*

Heads, Shoulders, Knees and Toes: Body Representations in Human Extrastriate Visual Cortex

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Human fMRI studies have shown that the extrastriate body area (EBA) responds more strongly when people view body parts than other objects and may play a specific role in body part recognition. However, the average response in EBA is similar for different body parts, suggesting little sensitivity to body part category. Here, we conducted a multi-voxel pattern analysis to investigate whether the spatial pattern of response across EBA contains information about body part category.

Specifically, we conducted a category (face, shoulder, elbow, hand, knee, foot) x side of body (left, right) x visual field (left, right, 2° from fixation) event-related fMRI experiment. On each trial, participants fixated while a single body part was presented from an allocentric point of view. We used a split-half correlation technique (Haxby et al., 2001) to compare the pattern of activation across voxels in an independently localized EBA.

We found stronger within than between body part correlations in EBA demonstrating the presence of body part category information. Furthermore there was a strong interaction between side of body and visual field, such that there was more information about body parts in their commonly experienced locations. Specifically, in the left visual field, EBA contained infor-

mation about the category of body parts from the right side of the body, but not the left side. In the right visual field, the converse was true (more information about body parts from the left than the right side), although in general the correlations were weaker. These effects were specific to EBA. In FFA, only faces showed strong within body part correlations and no information about the category of non-face body parts. We conclude that EBA contains information about body part category, but this information is specific to body parts presented in their commonly experienced positions.

21.22, *8:45 am*

Relating neural object representations to perceptual judgments with representational similarity analysis

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Human inferior temporal cortex (hIT) has been shown to be involved in the representation of visual objects. Recent studies have begun to investigate the relationship between perceived object similarity and similarity of response patterns in hIT. These studies often used a small set of (novel) stimuli from a few a priori defined categories. Here, we use a stimulus set consisting of 96 object images from a wide range of object categories including faces, body parts, animals, places, and artificial objects. We compare the neural and perceptual similarity structure of these 96 object images using representational similarity analysis.

We performed BOLD fMRI measurements at high resolution (voxel size 1.95x1.95x2 mm3). Activity in response to 96 different object photos was measured in four subjects. hIT was defined at a range of sizes by selecting the most visually responsive voxels, based on independent data. The neural similarity structure of hIT response patterns was constructed by computing the dissimilarity (1-correlation distance) between each pair of object activity patterns. Subjects were asked to arrange the 96 object images in 2D to report perceptual similarity.

The neural and perceptual similarity structures were significantly correlated ($r = 0.46$, $p<0.0001$). This indicates that objects that are perceived as similar tend to elicit similar response patterns in hIT. In addition, both structures showed a categorical organization, with the main clusters being animate and inanimate objects. These findings suggest that, for a wide range of real-world objects, similarity of neural object representations in hIT reflects perceived object similarity.

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21.23, *9:00 am*

Decoding top-down information: imaging prior knowledge in the visual system

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The visual system is exquisitely good at recognizing images, even when presented with obstructed, noisy, or degraded stimuli. To solve such a complex problem, people use prior information – or, knowledge of the fully coherent image – to aid recognition of noisy stimuli. Is this purely a cognitive effect, or can we find where and how this facilitation interacts with the feed-forward visual system? Using machine learning algorithms and a multivariate approach we can quantify the amount of information a given brain region contains about the stimuli, as a function of prior knowledge. Here we show how distinct regions from prefrontal to retinotopic cortex contain more information about degraded stimuli with prior knowledge, and that the gain in information is correlated with the strength of the behavioral effect – indicating that prior knowledge increases stimulus-specific information throughout the visual system. Interestingly, this form of priming 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. Furthermore, this effect cannot be seen in regions modulated by the recognition of any degraded image, indicating that standard univariate analyses, like the GLM, may reveal a set of regions distinct from those regions involved in distinguishing between images.

21.24, *9:15 am*

Reading the mind's eye: Decoding object information during mental imagery from fMRI patterns

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Studies have shown that category information for visually presented objects can be read out from fMRI patterns of brain activation spread over several millimeters of cortex. What is the nature and reliability of these activation patterns in the absence of any bottom-up visual input, for example, during visual imagery? Previous work has shown that the BOLD response under conditions of visual imagery is lower and limited to a smaller number of voxels, suggesting that activation patterns during imagery could be substantially different from those observed during actual viewing. We here ask first, how well category information can be read-out for imagined objects and second, how the representations of imagined objects compare to those obtained during actual viewing.

These questions were addressed in an fMRI study where four categories were used – faces, buildings, tools and vegetables – in two conditions. In the V-condition, subjects were presented with images and in the I-condition they imagined them. Using pattern classification techniques we found, as previously, that object category information could be reliably decoded in the V-condition, both from category selective regions (i.e. FFA and PPA), as well as more distributed patterns of fMRI activity in object selective voxels of ventral temporal cortex. Good classification performance was also observed in the I-condition indicating that object representations in visual areas in the absence of any bottom-up signals provide information about imagined objects. Interestingly, when the pattern classifier was trained on the V-condition and tested on the I-condition (or vice-versa), classification performance was comparable to the I-condition suggesting that the patterns of neural activity during imagery and actual viewing are surprisingly similar to each other.

Overall these results provide strong constraints for computational theories of vision suggesting that in the absence of bottom-up input, cortical backprojections can selectively re-activate specific patterns of neural activity.

21.25, *9:30 am*

The sum of its parts? Decoding the representation of multiple simultaneous stimuli objects in the human brain using fMRI

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Studies of visual recognition have traditionally focused on neural responses to single, isolated objects. In the real world, however, objects are almost always surrounded by other objects. Although previous fMRI studies have shown that the category identity of single objects can be extracted from patterns of activity in human object selective cortex, little is known about how multiple, simultaneous objects are represented. Here we use multi-voxel pattern analysis to examine this issue. Specifically, we tested whether patterns evoked by pairs of objects showed an ordered relationship to patterns evoked by their constituent objects when presented alone. Subjects viewed four categories of objects (brushes, chairs, shoes, and cars), presented either singly or in different-category pairs, while performing a one-back task that required attention to all items on the screen. Response patterns in the lateral occipital complex (LOC) reliably discriminated between all object pairs, suggesting that LOC populations encode information about object

Saturday Sessions

pairs at a fine grain. We next performed a voxel-by-voxel analysis of the relationship between responses evoked by each pair and responses evoked by its component objects. Applying a "searchlight" classification approach to identify voxels with the highest signal-to-noise ratios, we found that individual voxels' responses to object pairs were well-predicted by the mean of responses to the corresponding component objects. We validated this relationship by successfully classifying patterns evoked by object pairs based on synthetic patterns derived from the averages of patterns evoked by single objects. These results indicate that the representation of multiple objects in LOC is governed by response normalization mechanisms similar to those reported in non-human primates. They also suggest a coding scheme in which patterns of population activity preserve information about multiple objects under conditions of distributed attention, facilitating fast object and scene recognition during natural vision. Supported by NIH grant EY-016464 to R.E.

21.26, *9:45 am*

Where do objects become scenes?

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A pair of objects can be depicted side-by-side or interacting. W. Epstein et al. (1960) showed that the depiction of interacting objects (e.g., a pipe on a clock) facilitated cued recall compared to when the same images were shown side-by-side. The saliency of object interactions, readily described by prepositions or gerunds, is immediately appreciated. What are the neural loci of these interactions? Does novelty of the interaction matter? In an fMRI block-design, subjects viewed a series of minimal scenes, each consisting of a pair of objects. The objects were presented either side-by-side (e.g., a bird and a birdhouse) in some blocks or interacting with each other (e.g., the bird perched on the birdhouse) in other blocks. To examine the effects of novelty, on some blocks one of the objects in each pair was switched with an object from another pair (e.g., an ear for the birdhouse) so now the interaction would depict the bird on the ear. Interactions produced greater BOLD activity both in the lateral occipital cortex (LOC) and, only under some conditions, in the parahippocampal place area (PPA) as well. Novelty of the interactions magnified this gain, an effect that was absent in the side-by-side depictions. Controls ruled out eccentricity, relative size, task influences, or feed-forward activity from earlier visual areas as possible sources of the interaction effect. The results thus suggest that objects can become scenes as early as LOC. The distinctive relation of each interacting pair likely elicited additional associations—more so for novel relations—and it is that activity that might have magnified the BOLD responses in these higher visual areas.

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Temporal Processing: Representations

Saturday, May 9, 11:00 am – 12:45 pm
Talk Session, Royal Palm Ballroom 1-3
Moderator: Shin'ya Nishida

22.11, *11:00 am*

The Visual System Discounts Temporal Artifacts Introduced by its Eye Movements During Reading

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Objective: Saccadic eye movements abruptly update the retinal image every 200 msec or so during reading. We examine how these dynamic images affect visual sensitivity with an adaptation paradigm.

Methods: Text from common novels was presented on a computer screen in c.10 second passages. Observers either actively read the text or passively fixated a stationary point while the text was updated at 0.25, 1 or 4 times typical reading speeds. Between passages, observers detected spatio-temporal frequency band-pass filtered noise in a 2AFC task with feedback.

Results: Contrast detection thresholds were elevated following the presentation of text, but less so after active reading than passive text viewing. For spatial frequency, there were two peaks that corresponded approximately to the periodicity of lines and letters. For temporal frequency, threshold elevations reciprocated the temporal contrast sensitivity function, with minimum threshold elevations around 9.0 Hz.

Conclusions: The results are consistent with adaptive changes in contrast sensitivity that arise from a second-order model of temporal processing in which the $1/\omega$ temporal amplitude spectrum attributed to natural scenes is itself modulated by the expected dynamics of eye movements.

22.12, *11:15 am*

Age-related changes in the temporal modulation transfer function (TMTF) assessed with a novel optical device in the fovea and parafovea

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Purpose: The temporal modulation transfer function (TMTF) is a measure of dynamic properties of the visual system and reflects age- and disease-related changes in visual function. Whether the TMTF is impacted similarly when assessed at foveal and parafoveal loci is unknown, and was the primary question of this investigation. Given the fact that macular pigment (MP) also tends to vary with disease state and that preliminary research suggests a relation between MP density and flicker sensitivity, an ancillary goal was to relate MP density to the TMTF. Methods: A novel device (Macular Metrics) was constructed that utilized LEDs to deliver a 1-deg, 660 nm target surrounded by a 10-deg, 660 nm annulus. The target was varied sinusiodally at frequencies from 2.5-32 Hz. A 3 mm artificial pupil was used to control pupil size. 61 subjects (aged 15-84 years) adjusted the percent modulation at each frequency to threshold in the fovea and at 7-degrees of eccentricity. MP density was assessed at 30-min of eccentricity via heterochromatic flicker photometry (HFP). Results: TMTF assessment with the novel device produced a function with the expected bandpass shape in fovea and parafovea. Flicker sensitivity decreased with age in the fovea ($p < 0.05$), but not the parafovea. Individuals with higher MP density showed an increased sensitivity to flicker ($p < 0.05$). Conclusions: The bandpass shape of the TMTF and the fact that relation between TMTF and age (assessed in the fovea) followed the same trend seen in past studies suggests that that the novel device provides valid measures. Given the fact that MP density also tends to vary with disease state, the relation between MP and temporal visual function warrants further investigation.

Acknowledgement: supported by Cognis

22.13, *11:30 am*

Dissociating motion-induced position illusions by the velocity dependence of both their magnitude and their variability

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Observers mislocalize a moving object's color change in the direction of its motion (Cai & Schlag 2001). One theory of this Cai effect and of the related flash-lag effect is that motion signals shift perceived position to help overcome neural latency. Others suggest perception of a transient change is delayed relative to a moving object or that the transient triggers a time-consuming process. All these theories predict that the illusory displacement should increase with speed. For the Cai effect, we used a blob orbiting fixation that suddenly changed color and asked observers to report the perceived position of the change. Contrary to the predictions, spatial shifts were nearly identical across a five-fold range of speeds. With the same stimulus configuration, we measured the flash-lag effect (by asking observers to report the position of the blob when the fixation mark changed color) and Frohlich effect (by asking observers to report the position at which the blob first appeared). Results for the Frohlich effect were similar to the Cai effect results, whereas the flash-lag effect was larger and showed a significant increase with speed. The effects also differed in their variability from trial to trial: the variability of the Cai and Frohlich shifts did not increase with speed, while the flash-lag variability increased steeply with speed. These results suggest the involvement of a process with low temporal resolution unique to the flash-lag task, perhaps one that binds the flash (here, a sudden color change) with the moving object. The Cai and Frohlich effects appear to be caused by a distinct spatial shifting mechanism, one not very useful for overcoming neural delays as it does not scale with speed. Position judgments in the flash-lag task may reflect a combination of this spatial shifting with coarse temporal binding.

Acknowledgement: supported by an Australian Research Council DP grant to AOH

URL: http://dlinares.org/

22.14, *11:45 am*

Perceptual ambiguity of bistable stimuli has little effects on perceptual latency

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Previous studies suggest that cognitive ambiguity, such as is found in categorical judgments, increases behavioral response latency. The purpose of this study is to see whether or not perceptual ambiguity for bistable stimuli, stimuli in which two perceptual interpretations are mutually competitive, also causes an increase in perceptual latency. We measured manual reaction times for the judgment of the perceived direction of a two-frame apparent motion, in which four discs located at the corners of a virtual square were rotated around the center of the square between the frames. We manipulated the angle of rotation to control the perceived direction and the magnitude of directional ambiguity. The observers had to report the perceived direction as quickly as possible by pressing one of two keys. They had to press a key again when they noticed an incorrect response, and we excluded those trials from data analysis. In comparison with the performance obtained at perceptually unambiguous angles (~20 deg), reaction time was only slightly increased at angles around 45 deg, where the magnitude of rotation angle was similar for the two directions, and either direction was seen in a bistable fashion. In contrast, reaction time was significantly increased at angles around 0 deg where the rotation angle was so small that the observer could not reliably judge the rotation direction. These findings indicate that the perceptual latency is dominated by stimulus strength, not by perceptual ambiguity. We confirmed this finding using other bistable stimuli: Rubin's vase and Ullman's cylinder. Our findings suggest that perceptual competition has little effect on the latency of the initial perception of a bistable stimulus.

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22.15, *12:00 pm*

Separate central temporal limits of cross-attribute processing revealed by binding and synchrony judgments

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The temporal resolution of phase judgments is significantly worse across different sensory attributes than within identical attributes. This suggests the involvement of slow central processors, rather than fast peripheral processors, in cross-attribute temporal judgments. However, what makes central cross-attribute processing slower remains unspecified. We found a clue to this problem in the pattern of systematic differences between synchrony and binding tasks. In both tasks, observers discriminate whether two repetitive sequences are in-phase or out-of-phase, but a slight change in stimulus structure can have a substantial effect on the style of processing. For the synchrony task (e.g., Fujisaki & Nishida, 2005), each stimulus sequence contained brief pulses presented at a given rate. The pulses of the two sequences were either synchronous or asynchronous (precisely interleaved). Observers could discriminate the two phase-conditions from the timing of stimulus changes without assessing the feature values. For the binding task (e.g., Holcombe & Cavanagh, 2001), each sequence was a repetitive alternation of two feature values. The alternation was always synchronized between the two sequences, but the feature paring was changed between the two phase-conditions. Observers have to access the feature values of the two sequences within a limited period of time. We measured how the temporal limit of each task changed for different stimulus combinations. We combined three visual (luminance, color, and orientation), one auditory (pitch), and one tactile (vibration) attributes. For synchrony judgments, there was a significant variation in temporal limits across different attribute/modality combinations. For instance, the temporal limit was ~4 Hz for visuo-tactile and audio-visual pairs, while ~10 Hz for audio-tactile pair. In contrast, for binding judgments, the temporal limit was similar (2-3 Hz) for any combinations of cross-attribute/modality judgments. These findings suggest the existence of two separate central limits in cross-attribute temporal processing, presumably each reflecting bottom-up and top-down processing.

22.16, *12:15 pm*

Using the proliferation effect to study subjective duration at brief timescales

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Brief events are sometimes perceived to last longer or shorter in duration than others of equal length. For example, if an oddball is presented within a visual train of repeated stimuli, participants report that the oddball appears longer in duration than the repeated stimulus even if they are physically of equal duration. We have hypothesized that subjective duration distortions are a consequence of differential neural responses to repeated versus novel stimuli (Eagleman, 2008; Pariyadath & Eagleman, 2007, 2008). As seen in EEG, fMRI and single-cell electrophysiology, the neural response to a stimulus diminishes with repeated presentation, an effect known as repetition suppression. We have leveraged the effects of repetition on the subjective duration of brief stimuli to develop a new psychophysical paradigm that we term the proliferation effect. When a single letter of the alphabet was serially flashed onto different locations on the screen, several letters appeared to be present on the screen simultaneously due to persistence of vision. Participants' estimates of how many letters they perceived on the screen at any instant of time were significantly lower when the same letter was flashed repeatedly than when different, randomized letters were used for each flash. This result suggests that the persistence of vision contracts for repeated stimuli. Because of their very rapid time scale, these experiments demonstrate that subjective duration can be computed without explicit temporal judgments. Finally, the proliferation effect gives us a rapid, non-invasive tool to test the integrity of repetition suppression in patient populations with repetition deficits such as schizophrenia.

22.17, *12:30 pm*

Probabilistic nature of time perception

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We use our internal sense of time to identify temporal relationships between events and to make time-sensitive responses. The accuracy with which we can exploit temporal contingencies derives from two important factors: the temporal regularities between external stimuli and the reliability of our internal sense of time.

We used a "Ready, Set, Go" paradigm to examine how these two forms of uncertainty influence timing behavior. Human subjects were presented with two brief peripheral flashes, a "Ready" cue followed by a "Set" cue. These cues demarcated a reference interval (RI) that varied randomly from trial to trial. Subjects were instructed to reproduce RI by making a key press RI time units after "Set". Subjects' timing accuracy were tested in three separate blocks of trials in which RIs were sampled from three partially overlapping Uniform distributions, which varied between 493–847, 670–1024, and 847–1200 ms, respectively. These distributions constitute different prior probability distributions of RI.

Behavioral responses exhibited three characteristic features. (1) Production times increased with RI. (2) Production times were systematically biased towards the mean of the prior distribution over RI. Thus, in different blocks with different prior distributions, production times associated with the same RI were biased differently. (3) The magnitude of the bias increased for longer RIs – both within and across blocks.

These observations were naturally explained in a Bayesian framework in which subjective estimates of RIs were assumed to derive from the probabilistic fusion of the likelihood information associated with a sample RI, and the prior distribution over RI. Our analysis suggests that (i) subjects were able to evaluate the uncertainty associated with the likelihood information on a trial-by-trial basis, and (ii) subjects' estimate of the prior information (i.e. "subjective prior") depended on both the experimentally imposed prior and the subjects' timing uncertainty.

Acknowledgement: HHWF, HHMI, NIH Grant EY11378

Face Perception: Adaptation, Aftereffects and Categorization

Saturday, May 9, 11:00 am – 12:45 pm
Talk Session, Royal Palm Ballroom 4-5
Moderator: Adam Anderson

22.21, *11:00 am*

The face aftereffect spreads over changes in position, orientation and size in retinotopic, not space- or object-based coordinates

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We examined the coordinate frame of face aftereffects (FAE) by measuring the FAE following eye movement, head movement, head rotation, or stimulus movement. 1) Following adaptation to a face at one location, subjects made a saccade. A test face was then presented either at the same location as the adaptor on the screen, the same retinal location as the adaptor or a different location with the same eccentricity as the adaptor. 2) Subjects tilted their head 45 deg to the right during adaptation, then tilted their head 45 deg to the left to view the test. The test was displayed with various orientations including the same retinal angle as the adaptor or the same angle on the screen as the adaptor. 3) Following adaptation, subjects moved their head and halved their distance to the monitor. The test face was then presented at various sizes including the same screen size and the same retinal size (half of the screen size) as the adaptor. 4) The adapting face turned around after adaptation, showing the blank back of the head, and moved to a new location. The test face was then presented at various locations including the original and the new location of the adaptor (where only the back of the head had been presented). In all experiments, the face aftereffect was strongest at the retinal position/angle/size of the adaptor. There was substantial spread of the FAE across location, size and orientation but no additional benefit was found for test locations, sizes or orientations fixed in display-based or object-based coordinates (spatiotopy or object-otopy) rather than retinal coordinates. Our findings suggest that face analysis is grounded in a retinotopic coordinate frame and that spatiotopy across head and eye movements is not constructed at the level of visual feature/object analysis.

22.22, *11:15 am*

Solving the upside-down puzzle: Inverted face aftereffects derive from shape-generic rather than face-specific mechanisms

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Given the robust perceptual processing differences between upright and inverted faces (e.g. holistic effects), a somewhat peculiar finding in the face perception literature has been the consistent observation that inverted faces produce adaptation aftereffects very similar to those for upright faces. Although there is evidence that the specific neural populations supporting upright and inverted face aftereffects are partially separable (Rhodes et al., 2006), these different neural populations have produced, to date, no known qualitative differences between aftereffects for upright and inverted faces. Indeed, large inverted aftereffects occur not only for general shape distortions (Webster & Maclin, 1999) but also for distortions that might potentially be more face-specific, including gender (Watson & Clifford, 2006), identity relative to the average face (Leopold et al., 2001), and a 'second-order relational' distortion of eye height (Robbins et al., 2007); further, last year (Susilo, McKone, Edwards, VSS 2008) we reported that aftereffects for inverted faces, just like those for upright, comply with predictions of opponent neural coding. So, are there any important differences between aftereffects for upright and inverted faces? Here, we show there are. We tested whether the origin of the face aftereffects is face-specific or shape-generic. We manipulated eye heights (eyes up/down) and T-shape forms (vertical bar up/down), and compared the magnitude of the aftereffects following adaptation in same-stimuli conditions (adapt-face/test-face, adapt-T/test-T) with that in across-stimuli conditions (adapt-T/test-face, adapt-face/test-T). Our rationale was that the magnitude of adaptation transfer between faces and shapes reflects the degree of their shared neural representation. We found limited transfer of adaptation between eye heights and T-shapes when the stimuli were upright, but almost complete transfer when they were upside-down. Results argue that, while upright face aftereffects derive from high-level face-specific representations, inverted face aftereffects derive from shape-generic neural populations (possibly mid-level in origin).

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22.23, *11:30 am*

Cross-category adaptation of faces

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Adaptation is a critical attribute of perceptual systems, allowing them to alter their response with changing demands. Recent results demonstrate that adaptation is not only occurs for low-level stimulus properties, but can also occur for high-level properties of a face, such as gender and identity. These face-adaptation effects suggest that the brain contains neurons tuned to specific features critical for determining these properties. However, it is unknown whether these networks are face-specific or the result of adapting neurons more broadly tuned to gender or identify.

To address this question, pictures of either male or female bodies from the neck down (i.e., without a visible face) and pictures of males and females photographed from behind were presented, followed by a target face (Experiment 1a and 1b). Face perception was biased away from the gender of the adapting bodies (a gender face adaptation aftereffect was found with faceless bodies used as the adapting stimuli; $p < .05$ for experiment 1a and $p < .001$ for experiment 1b). These results indicate that gender-related body images can adapt the perceptual processes involved in identifying the gender of a face. In Experiment 2, we found that the magnitude of this body-to-face adaptation effect increased logarithmically with increasing adaptation duration (main effect of adaptation duration $p < .05$), as in traditional adaptation. In Experiment 3, we explored the limits of this face gender aftereffect by using gender connotative objects such as men's and women's shoes as the adapting stimuli. In this case, no perceptual bias for faces was seen ($p > .2$). Taken together, these results demonstrate that face adaptation can be elicited by information conveyed by human bodies, but not by any gender-related information. More generally, these results suggest that adaptation can cross categorical boundaries for intrinsically-related objects.

22.24, *11:45 am*

A contrast-based adaptation study of the contribution of gender to face representations

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Face adaptation has been used recently to infer the organization of representation space for faces. Previous face adaptation studies have suggested both distinct and common underlying mechanisms for faces of different gender. We used a new technique that measures the effect of an adapting face on recognition contrast thresholds for subsequent test faces, to determine if adaptation aftereffects are influenced by gender.

We used two female and two male faces in a four-alternative forced-choice paradigm. An ideal observer analysis was used to select a set of four faces in which the physical differences between faces of the same gender were equivalent to the differences between faces of a different gender. During a 100ms adapting period subjects viewed one of five stimuli: one of the four faces, or a blank for the unadapted baseline condition. After a mask, a test face was presented for 150ms, following which the subject indicated which one of the four faces they saw. We used a staircase procedure to determine recognition thresholds for all 20 adapt-test pairs (5 adaptor stimuli x 4 test faces). Nine subjects participated.

The three main conditions were same-face, same-gender (different face of the same gender), and different-gender. We calculated threshold elevation ratios for each main condition by dividing thresholds by the corresponding baseline threshold. We found a significant main effect of condition (Kruskal-Wallis one-way ANOVA, $p<0.05$). Adapting to the same-face decreased recognition thresholds, indicating facilitation, while adapting to a different face elevated thresholds. Adapting to a different-gender face increased thresholds more than adapting to a same-gender face, despite our controlling for physical similarity. This result suggests that gender is a factor in representational face-space that cannot be accounted for by simple physical resemblance.

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22.25, *12:00 pm*

Emotional anti-faces reveal contrastive coding of facial expressions

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It is widely thought that facial expressions are recognized in relation to one of six or more basic prototypes, with cross cultural and neuropsychological studies supporting these prototypes as the fundamental building blocks of emotional representation (Ekman, 1999). However, little work has examined directly whether there is a non-arbitrary underlying logic based on physical movements of the face that can explain why expressions look the way they do. Why do we raise our brows in fear and wrinkle our noses in disgust? According to evolutionary accounts, facial movements serve adaptive functions to regulate an organism's interaction with the environment. Confirming this view, we recently demonstrated that production of fear and disgust expressions has opposing effects on sensory intake, with fear increasing and disgust decreasing visual field size, saccadic velocity, and nasal inspiration (Susskind et al, 2008, Nature Neuroscience 11, 843-850). We reasoned that these opposing physical actions have come to represent important social cues for recognizing emotions in the face. Specifically, we hypothesized that the brain would represent expressions as perceptual opposites through opponent neural coding. Employing a computational model of facial appearance, we created a set of photorealistic expression prototypes and their visual-statistical opposites (i.e., emotional anti-faces). Categorization data revealed that not only do emotional anti-faces physically oppose basic emotion prototypes, but subjectively convey opposing emotional meanings. We next tested the effects of perceptually adapting to emotional faces and anti-faces on expression discrimination. As predicted by opponent coding, adapting to facial expressions impaired expression discrimination, and adapting to their anti-faces enhanced expression discrimination. Analogous results were found for discrimination of fear, disgust, happiness, and sadness. These results provide evidence for a new theory that emotional expressions are decoded not only as discrete categories, but by opponent representations that highlight contrasting facial actions.

22.26, *12:15 pm*

Neural basis of contextual modulation on categorical face perception

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The ability to categorize patterns is crucial for making sense of the visual world as an orderly collection of discrete objects. Contextual information often facilitates perceptual categorization to disambiguate and organize visual input. In last year's VSS, we demonstrated neural correlates of categorization in the domain of faces. Our experimental strategy involved compiling 300 images that spanned a range of facial similarity from non-faces to genuine faces. Using fMRI, we found that the pattern of activity in the left fusiform changed in a graded fashion as the image stimuli became increasingly face-like, while the pattern of activity in the right fusiform showed a step-like response corresponding to a categorical difference between faces and non-faces. Here we investigated how contextual information can modulate brain activation patterns that are evoked by these stimuli. Behaviorally, we verified that subjects were more accurate at the face/non-face classification task when the 300 images were shown with surrounding context. Consistent with our previous finding, brain activation patterns in the right fusiform correlated with the perceived face categoricity. More interestingly, the pattern of activity in the left fusiform and right inferior occipital gyrus also became categorical in correspondence to the behavioral step-like difference between faces and non-faces. Particularly in the left fusiform, the surrounding context on one hand enhanced activation patterns induced by genuine faces, and on the other hand suppressed the activation patterns induced by the non-face stimuli that happened to look face-like. By contrast, the effect of contextual modulation was not significant in the left inferior occipital gyrus and the calcarine sulcus, ruling out activation change induced by bottom-up effects. These results suggest a categorically selective neural mechanism of contextual modulation and have important implications for models of real-world face-processing.

22.27, *12:30 pm*

Where is kinship information in the child's face? Signal detection study finds no evidence for lateralization

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Purpose. Dal Martello & Maloney (2006, JOV) report signal detection experiments measuring the amount of kinship information in the upper and lower halves of children's faces. They found that the upper and lower halves each contained significant information about kinship with the upper half of the face containing considerably more than the lower. The information in the two halves was statistically independent.

Previous work has shown that information about age, attractiveness, gender, identity, expression and lip-reading tends to be left-right lateralized. We test whether this is the case for kinship.

Methods. Stimuli: 30 pairs of photographs, each photograph portraying a child's face with background removed. Half were of siblings, half, unrelated. The children's ages spanned 14 years. Observers: 124 adult observers who judged each pair as siblings or not. We summarized performance in each condition by signal detection estimates d' and β. Conditions: Full Face visible (FF); Right Half visible (RH); Left Half visible (LH). Different observers participated in each condition.

Results. Performance in FF ($d' = 1.079$) did not differ significantly (p = n.s.) from performance in RH condition ($d' = 1.024$) or from performance in LH ($d' = 1.004$). Performance in RH and LH did not differ significantly (p = n.s.). The beta values of FF ($\beta = 0.888$) and RH ($\beta = 0.896$) did not differ (p = n.s.) and indicated an equal bias towards saying related. The beta for LH ($\beta = 1.102$) differed significantly ($p = 0.0001$) from betas on the other conditions.

Saturday Sessions

Conclusion. Kinship cues appear to be evenly distributed across the vertical halves of the face and completely redundant. There is no superiority of one or the other side of the observed face for kinship. Observers have a bias against saying ‘related’ when the right half of the face is masked.

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Motion: Local and Global Processing

Saturday, May 9, 8:30 am – 12:30 pm
Poster Session, Royal Palm Ballroom 6-8

23.301

Interaction of first- and second-order signals in global one-dimensional motion pooling

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It has previously been argued that first-order (FO) and second-order (SO) signals are kept independent up to and including the global-motion level (Edwards & Badcock, Vis Res 1994). That study found that contrast-modulated noise dots had no effect on the ability to extract a signal carried by a subset of luminance-defined dots, while luminance-modulated noise dots impaired the ability to extract a signal carried by contrast-modulated dots. It was argued that this asymmetry was due to the luminance-modulated dots being both a FO and SO stimulus. Here we address the question of whether the same degree of independence occurs in the pooling of one-dimensional local-motion signals, which are pooled via an intersection-of-constraints (IOC) process, rather than the vector-average process used for two-dimensional stimuli (Nishida, et.al. VSS, 2006). We used stimuli consisting of static Gabor patches that had moving carriers which were either luminance (FO) or contrast (SO) modulated. These stimuli were used to determine the effectiveness of one kind of noise (FO or SO) in disrupting the extraction of a global-motion signal carried by the other type of signal (SO or FO). Results were the same as the original study by Edwards and Badcock: SO noise did not mask FO signal extraction, but FO noise masked SO extraction. Additionally, given that the luminance-defined stimulus in this experiment was a pure FO stimulus, the asymmetry in the masking cannot be due to a SO signal in the luminance-defined (FO) stimulus. Taken together, these results suggest that FO and SO interactions are the same for both IOC and vector-average pooling.

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23.302

Pooling of one dimensional motion signal across different spatial frequencies

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Object motion is first detected by direction selective sensors, each tuned to a given combination of orientation and spatial frequency (SF). To recover the true 2D direction of the object, the visual system should integrate 1D motion signals across different orientations. Is this computation carried out separately for different SFs? This basic issue has yet to be resolved. SF selective pooling is suggested by the perception of motion transparency in plaid motion whose component motions have separate SFs. Even in this case, however, coherent motion can be perceived under specific orientation conditions (Kim & Wilson, 1993). Furthermore, masking effects in Global Gabor motion suggest a broadband interaction among 1D motion signals (Nishida et al., 2007). We tried to find a systematic explanation that addresses this question using a simple global motion stimulus (Lorenceau & Zago, 1999). The stimulus consisted of four Gabors oriented orthogonally with respect to the radial direction whose carrier gratings, oscillating in sine and cosine phase opposing pairs, generate a rotational global motion. The observer's task was to judge the rotation direction. Direction judgments became harder with increasing difference in carrier SF between component Gabors, and became almost impossible for many observers for 3-octave differences. However, direction discrimination could be restored without reducing the SF difference, by presenting the stimulus in peripheral vision, or, more dramatically, by thinning the envelope of high SF Gabors to form “good” contours. These results suggest that 1D motion pooling across different SFs is not impossible within the motion processing system, but SF differences could stop motion integration by way of introducing form cues against grouping (Lorenceau & Alais, 2001; McDermott et al., 2001). In agreement with this hypothesis, we found it easy to see coherent motion even between first-order and second-order motions particularly when they were similar in appearance.

23.303

Extracting motion contours with simultaneous local and global processing mechanisms

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Dynamic visual scenes present an observer with motion contours that indicate the location of the boundaries of moving objects. Because motion contours are useful for figure-ground discrimination and for the analysis of depth structure, their fast and accurate identification is ecologically significant. Visibility depends on the difference between motion vectors on either side of the contour, each of which has a speed and a direction. The relative contribution of speed and direction in determining the visibility of a motion-defined contour can provide important clues about the neural mechanisms underlying the perception of motion discontinuities. Here, we explore the computational requirements of detecting motion contours for stimuli that we previously investigated with psychophysical methods in a study which found that speed and direction are detected independently by human observers and combined such as to optimise perceptual performance (Durant and Zanker 2008, Vision Research 48, 1053-1060). We simulate the detection of motion contours by computing local motion signals using correlation detectors and deriving global motion patterns from the local signal distributions. From histograms of local motion signals, clusters corresponding to different regions of uniform motion are identified. The clusters are used to group local motion signals in order to segment the images and identify contours. This process is based on a hierarchical structure with forward and backward connectivity computing an initial local detection, then computing global motion to support a subsequent segmentation. The reliability of separating clusters attributable to the different stimulus regions is used as an indicator of the visibility of the contours. In computer simulations, we find that differences in direction are more reliably detected than differences in speed. We discuss this result and the general structure of the model in relation to the previous psychophysical findings.

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23.304

Global not local motion direction tuning of curvature encoding mechanisms

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Aim. The shape-frequency and shape-amplitude after-effects, or SFAE and SAAE, are phenomena in which adaptation to a sine-wave-shaped contour causes a shift in respectively the apparent shape-frequency and shape-amplitude of a test contour in a direction away from that of the adapting stimulus. SFAEs and SAAEs are useful for probing curvature encoding in human vision. Here we have investigated motion direction selectivity of curvature-encoding mechanisms as a function of temporal frequency. We have examined whether curvature encoding mechanisms are tuned for: (i) global motion direction, (b) local motion direction, and (c) the local motion of texture-surround inhibition. Methods. SFAEs and SAAEs were measured as a function of temporal frequency for adapting and test contours that were either the same or different in motion direction, the rationale being that if the after-effects were smaller when adaptor and test differed in their motion direction then curvature encoders must be selective for motion direction. Results. SFAEs and SAAEs (i) show selectivity to global motion direction; (ii) increase in magnitude with global temporal frequency; (iii)

show no selectivity to local motion direction; (iv) show no tuning for local motion of texture-surround inhibition. Conclusion. Curvature is encoded by mechanisms that are selective to global not local motion direction.

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23.305

Motion-induced position shifts are based on global motion estimates

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Visual motion interacts with spatial location to produce several phenomena in which static or moving objects are mislocalized in space. Motion is processed in several stages from local estimates to global percepts. Previous studies have used drifting gratings or Gabors (drifting sinusoids windowed by a stationary Gaussian) in which the local and global velocities are necessarily the same. It is therefore not clear at which stage motion information affects perceived position. If the spatial shift is a property of cortical simple cells in primary visual cortex (Fu et al. Journal of Neuroscience, 2004. 24(9): 2165-2171), where only local motion information is represented, we would expect motion shifts to be determined by local motion signals. Rectangular grids of Gabor patches were generated with either vertical gratings and equal drift speeds (3 °/sec) or randomly oriented gratings with drift speeds that vary with the sine of the angle between carrier orientation and the global motion direction. Patches above fixation drifted leftward and below fixation rightward, or vice versa. The rectangular grids (7 high; 7, 3 or 1 element wide) were offset horizontally and subjects reported whether the top array was shifted to the right relative to the bottom array. The offset was varied systematically from trial to trial to generate a psychometric function. The 50% point provided a measure of the perceived spatial shift. We found no significant difference in the magnitude of the shift for the parallel and random Gabor arrays that might indicate a direct influence of the local velocities. We also found that a larger area of motion tends to induce a larger shift in position. Our results indicate that motion information affects perceived position only after motion integration has taken place.

23.306

Motion drag induced by global motion Gabor arrays

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The position of stationary flashed objects can be shifted in the direction of a moving object (Whitney and Cavanagh, 2000). However it is not known whether motion drag is induced by local motion or object motion resulting from the spatial pooling of local motion estimates. Here we investigated this remote positional drag with global motion Gabor arrays (Amano, Edwards, Badcock & Nishida, in press). The arrays consisted of multiple Gabor patches with orientations between plus/minus 90 degrees of the global motion direction. Each 1D Gabor was assigned a drift speed such that local velocities were consistent with the normal components of a single object moving in the global motion direction. Two vertically separated 29 x 9 Gabor arrays (diameter = 0.5°; spacing 0.1°) were placed above and below fixation. On any trail they moved horizontally in opposite directions with the direction chosen at random from trial to trial. During presentation of the arrays two lines were briefly flashed, one above the top array and one below the bottom array. We measured the horizontal separation needed for the two lines to be perceived as horizontally aligned using the method of constant stimuli. We compared the magnitude of the motion-induced positional drag across global motion arrays against the position shift for consistent arrays where all the Gabor's had the same global orientation and speed. We also investigated the effects of reducing the number of Gabor's in each type of array (random deletion from 261 to 87). We found that both types of array induced approximately the same amount of remote positional drag and drag remained approximately constant for both types of array across changes in the number of Gabor's, indicating motion drag is induced after the extraction of the global motion signal.

23.307

Impairment of peripheral motion perception in the elderly

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Previous research has shown that sensitivity to basic aspects of foveally-viewed motion, such as direction and speed, declines with age (e.g., Norman et al., 2003; Snowden & Kavanagh, 2006; Bennett et al., 2007). Although sensitivity to peripheral motion has been studied extensively in younger observers, relatively little is known about the effects of aging on peripheral motion perception, despite its importance for navigation and balance. The current experiment tested peripheral direction discrimination in three groups of 8 observers: younger (<30, mean age =22.8) junior-seniors (60-70, mean age =66.4), and senior-seniors (> 70, mean age=74). Stimuli were 500 ms presentations of random dot kinematograms that drifted coherently to the right or left at 5 deg/sec, displayed within a 3 deg wide annulus with its inner radius at an eccentricity of 5.5 deg. The subject's task was to identify the direction of motion of 25 target dots while fixating centrally, and thresholds were estimated by varying target contrast across trials. Target dots were embedded within a mask comprising 475 dots that moved in random directions on each frame. The contrast of the mask dots was varied across blocks. A 3 (Group) x 4 (Contrast) ANOVA found significant main effects of Group and Contrast, and a significant Group x Contrast interaction. Post-hoc tests showed that, at each mask contrast, younger subjects had lower thresholds than seniors, but the two senior groups did not differ. Our preliminary analyses suggest that the effects of aging on peripheral motion sensitivity do not differ significantly from the effects found with similar foveally-viewed stimuli (Tsotsos et al., 2008). We are expanding this result by examining the effects of attention and varying the eccentricity of our stimuli.

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23.308

Repulsion of Perceived Direction in Superimposed Surfaces

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Under the proper conditions, two moving gratings that are superimposed are perceived as a plaid moving in the vector average of the 2 grating directions. Much research has been done both psychophysically and through neuronal recordings to understand the process of integrating the two gratings into a single plaid object. A field of dots (random dot kinetograms) that moves coherently is perceived as a surface. When two dot fields are superimposed upon each other, moving in different directions, no such integration occurs. Instead, the dots are segmented into two distinct objects.

We investigated whether the perceived directions of motion of two superimposed surfaces would still be affected by the process of direction integration. Subjects fixated a central cross while an aperture containing 2 surfaces moving in different directions appeared in the lower right or lower left visual fields. After 1000 ms, the surfaces and fixation cross were removed while a white circular outline of the aperture appeared. Subjects used a mouse to click on the perceived directions of motion for each of the 2 surfaces. We expected to find that the difference in the perceived directions would be less than the actual difference between the directions, as this would be consistent with (weak) integration. Surprisingly, we found the opposite effect. The difference in perceived directions was significantly larger than the difference in actual directions.

These results suggest that unlike the integration of moving gratings into a plaid, superimposed surfaces comprised of random dot kinetograms are repulsed. The key factor is that the RDKs are automatically segmented into two objects providing a substrate for competitive interactions. Thus, the repulsion of perceived direction is likely due to competitive circuits previously identified for attentional modulation in area MT.

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23.309

Direction repulsion facilitates motion segregation

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Inhibitory connections exist between motion-sensitive neural units tuned to different directions. Such inhibitory interactions are evidenced in a well known visual illusion, direction repulsion, in which the perceived direction difference between two superimposed transparent surfaces is exaggerated. A possible functional consequence of direction repulsion is to aid the segregation of global motions. If it does facilitate motion segregation then one would expect direction repulsion to be evident at the shortest duration for which two global motions can be perceptually segregated. Two experiments investigated this question. In the first experiment observers were presented with pairs of sequentially presented stimuli – one containing two transparent motion patterns, and one containing three motion patterns. The observers' task was to judge which stimulus contained two transparent motions. In the second experiment observers were presented with stimuli containing two transparent motions, and had to make direction judgments of one of the motion components; thus providing a direction repulsion measure. Our results reveal that direction repulsion occurs at the shortest duration at which transparent motions are perceived (circa 100ms). Furthermore, direction repulsion magnitude remains constant across all stimulus durations; thus demonstrating that the underlying inhibitory activity peaks before the perceptual segregation of transparent motions. This is consistent with the view that neural inhibition facilitates motion segregation.

23.310

Temporal integration and segmentation in perceived speed

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Here we provide a unified account of the relationship between perceived speed and signal intensity in random dot kinematograms (RDKs). Previous studies have shown a mixed pattern of results with both increases and decreases in perceived speed as a response to increases in signal intensity (coherence). These differences may be accounted for by looking at the temporal characteristics of the patterns used. We demonstrate that, for speed integration over an arbitrary temporal window, reduction of update rate can have dramatic consequences on the resultant speed distribution. Low update rates result in a bimodal speed distribution. We propose that observers segment such speed distributions, choosing the higher speed dots as signal and treating the remainder as background. Our analysis reveals that this can readily account for the inverse relationship between signal intensity and perceived speed found in patterns with low update rates. In contrast, with high update rates a unimodal distribution is found that can correspondingly account for the increase in perceived speed found with increases in coherence. We support these findings by introducing the notion of "trajectory coherence" in RDKs. This allows us to titrate between RDKs in which signal dots remain as signal dots for their entire trajectory and RDKs in which a dot's allocation to signal or noise is decided on a frame-by-frame basis. This manipulation affects the speed distribution histogram of the RDK whilst holding pattern coherence and update rate constant; increasing trajectory coherence results in an increase in the bimodality in the speed distribution. In support of the analysis presented above we find that increasing trajectory coherence (and thus bimodality of the speed distribution) results in increases in perceived speed. Our results indicate that perceived speed is the result of both temporally integrative and temporally segregative processes.

23.311

Grouping impairs motion direction perception

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The literature on motion perception abounds with contextual effects, such as the induced effect where a stationary object is seen moving when surrounding objects are moving. We are here interested in contextual effects where no additional moving objects are present in the image. More specifically, we are interested in motion perception when the moving elements are grouped together. In contrast to previous work on the effects of image segmentation on speed discrimination (Verghese & Stone, 1996, Nature; Verghese & McKee, 2006, Vision Research), we are interested in grouping moving elements without changing their spatial arrangement.

Stimuli consisted in low contrast vertical lines moving left or right. Two such lines were placed on either side of a fixation point and moved either towards or away from each other. Two configurations were used: either (1) only the two vertical lines were shown, or (2) the vertical lines were connected by two horizontal lines so as to form a rectangular figure. The task of the observer was to report the direction of motion of the vertical lines (towards or away from each other). The method of constant stimuli was used to measure thresholds in both configurations.

We found that connecting two moving lines significantly increased the threshold to correctly identify their direction of motion. In other words, motion was more easily perceived when it was split across two objects than when it belonged to a single object. We propose a model based on the propagation of object motion uncertainty towards the object features to explain these results.

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23.312

The Whole Moves More than the Spin of its Parts

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Individually moving elements in the visual scene may be perceptually grouped together into a coherently moving object leading to a global motion percept. In the current experiment, we show that the perceived speed of a particular global motion percept is not completely dictated by the speed of the local moving elements. We investigate a specific stimulus that leads to bi-stable percepts in which local and global motion may be perceived in alternating fashion. Four rotating dot-pairs, when arranged into a square-like configuration may be perceived either locally, as independently rotating dot-pairs, or globally, as two large squares translating along overlapping circular trajectories. Using a modified version of this stimulus, we demonstrate that the perceptually grouped squares appear to move more slowly than the locally perceived rotating dot-pairs.

Further experiments investigate several possible explanations as to why the effect occurs, including a) the hypothesis that the illusory squares in the global percept are treated as veridical objects by the motion processing system, where larger objects are perceived as moving slower, and b) the hypothesis that the rotational motion of the dots in the local percept stimulate rotation-specific motion detectors sub-optimally, leading to an imprecise measure of speed.

These data give further evidence that speed perception is not determined solely on the basis of local speed-tuned mechanisms, but rather must receive input from operations that carry out a global analysis of form, and specifically address how certain properties of the stimuli, such as rotation or illusory lines, might contribute to the analysis of speed. This result therefore draws a clear distinction between stages of processing involved in the detection of visual information explicitly represented in the image and stages of perceptual construction that can extract and even create information that is not explicit in the image.

Acknowledgement: Stuart Anstis

23.313

Motion detection sensitivity modulated by a task-irrelevant illusory motion in an orthogonal direction: a population decoding model

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Motion in the surround is known to cause a repulsive bias in the perception of a central target motion (induced motion). For instance, a target physically moving in a horizontal direction is perceived as moving obliquely upward when embedded within a surrounding stimulus moving downward. Recently, Takemura and Murakami (VSS, 2008) reported that the detection sensitivity to the target motion can be enhanced (or degraded) by adding a slow (or fast) surrounding motion in an orthogonal direction, even though here the illusory motion component caused by the surround is not relevant to the task. The enhancement at adequate surround speeds indicates that sensory input signals are implicitly retained in early visual processing stages at a finer precision than our normal perceptual resolution, and that an optimal testing condition helps get an access to this intrinsic information. What computation makes it possible for the task-irrelevant component to modulate detection sensitivity? We modeled the neural population responses in a higher visual cortex; individual model neurons were tuned to different directions, and their trial-by-trial responses were noisy. The task was to judge the horizontal direction of the central target (leftward or rightward) from given population activities. In our model, a surrounding motion in an orthogonal direction (downward) was made to facilitate the visual responses of central neurons preferring the opposite direction (upward). As the surround speed increased, the total neuronal information as well as bias increased in the center. We found that the motion detection performance of the ideal observer was enhanced or degraded by a task-irrelevant, additive motion component, replicating the properties observed in human subjects. This means that the enhancement and degradation found in detection sensitivity can be understood as consequences of the noisy neural encoding that limits the resolution of information transmission in the cortical visual processing pathway.

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23.314

Active manipulation disambiguates local but not global motion perception

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Purpose: We ran 4 experiments to investigate whether the human visual system uses kinesthetic information to disambiguate visual motion perception.

Methods: Subjects moved a cube, tracked by an Optotrak system, behind an occluder. Randomly oriented grating patterns were rendered moving with the cube and co-aligning with its top surface. A 6-degree round aperture was rendered 10mm above the gratings. Subjects moved the cube along a randomly chosen direction for 3500ms and reported the grating motion direction by turning a dial. The hand movement direction was obtained by fitting a line to the cube positions. Experiment 1 and 2 were rendered stereoscopically and 3 monocularly. Fixation was required in Experiment 1 but not the others. Experiment 4 was similar to 2, with 200ms delay added between the hand movement and the grating motion. Four subjects participated Experiment 1, 2 and 4, respectively and 6 participated Experiment 3.

Results: Regression of the reported direction over the hand movement and grating normal direction showed that all subjects in Experiment 1, 2 and 3 perceived the grating motion being consistent with the hand movement direction. In Experiment 4, 3 subjects' perception agreed with the grating normal direction. The other subject's perception coincided with the hand movement. The results were statistically significant.

Discussions: The experiments provide strong evidence that kinesthetic information disambiguates motion direction perception, regardless which terminators the subjects attended to (fixating or not) or the nature of the terminators (extrinsic or intrinsic). Experiment 4 controlled for the possibility that the subjects simply reported the hand movement direction. We also tried actively moving a diamond shape behind 3 invisible bars and spinning ellipses with high aspect ratios. That we didn't see coherent rigid motion in both cases suggests that active manipulation doesn't help integrating local motion signals to global motion perception.

23.315

Distinct visual motion integration for high and low spatial frequency stimuli revealed by manual following response

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The visual motion normalization is known to be one of the important aspects in the early stage of visual motion processing. However, we have demonstrated that amplitude of manual following response (MFR), which is quickly elicited by a sudden background motion during arm reaching, increased progressively with stimulus size (up to 50 deg in diameter) when the stimulus area was filled with the low spatial frequency sinusoidal grating (<0.05 cpd). To clarify the stimulus size effect without any change in the number of grating cycles, in the first experiment, we have evaluated MFR amplitudes elicited by stimuli having several vertical widths (0.5, 1, 2.5, 10 deg) and a fixed horizontal length (80 deg). Participants were asked to repeatedly produce reaching movements to the center of the screen with eyes fixating on the same center location. MFR amplitude did not increase with vertical width of stimulus for the higher spatial frequency stimuli (0.2, 0.8 cpd), but progressively increased for the lower spatial frequency stimuli (0.02, 0.05 cpd) as previously observed for the circle stimuli.

To consider the stimulus location effect, we next presented the stimulus (thin or thick) on center, top, bottom, or top and bottom (50 deg apart between top and bottom). From the results, we found (1) a high sensitive feature of MFR on the visual center for each spatial frequency stimulus, (2) higher MFR sensitivity for visual motion on the bottom visual periphery with 0.05 cpd than for 0.2 cpd, (3) different local interactions within the stimulus between the visual center and periphery, and (4) strong remote interaction between top and bottom stimuli for 0.2 cpd but less for 0.05 cpd. These lines of evidence of MFR modulation suggest that spatial integration of visual motion with lower spatial frequency is distinct from that with higher spatial frequency.

23.316

Do surface features help? How the visual system disambiguates ambiguous motion

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Observations that apparent motion is robust across features changes, such as color and shape, suggest that surface features cannot serve as correspondence cues to disambiguate ambiguous apparent motion. We revisited this question using a modified Ternus display. In typical Ternus displays, three horizontally adjacent discs are presented, followed by the same discs shifted one position. These two displays are cycling continuously. For long interstimulus intervals (ISI), the discs tend to be perceived as moving together as a group. At short ISIs, one element is perceived as jumping from one end to the other, while the other discs remain stationary. We added a small dot to each disc, changing its relative position within the discs over time (Boi, Otto & Herzog, 2008). Consistent with the implied object correspondences, group motion caused the central dot to rotate within its disc, whereas element motion caused the central dot to appear as though it were moving up-and-down or side-to-side within its disc. This modified display allowed us to investigate the influence of surface features without relying on subjective judgments of motion quality. We used surface features to bias either group or element motion. If feature cues are used to solve the correspondence problem in apparent motion, then direction-of-motion reports should reflect the feature bias. If they are not, then direction-of-motion reports should reflect only ISI. All surface-feature correspondence cues yielded large differences between the element and the group bias conditions, indicating that feature cues were used to solve the correspondence problem. Feature identity seems to be an especially important cue, although overall configuration might also play a role. More generally our findings strengthen evidence of the importance of surface feature correspondence cues and their role in the establishment and maintenance of persisting object representations.

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23.317

The effect of speed on the typical and atypical development of motion-defined form perception

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Our previous work on motion-defined form perception showed: 1) slow maturation to adult levels by 7 years of age, and 2) large fellow-eye deficits in children with amblyopia. These developmental changes could reflect the functioning of the M/dorsal or the P/ventral pathway. The current study used motion speed to bias the relative contribution of the M/dorsal (fast motion) and P/ventral (slow motion) pathways to the processing of motion-defined form.

Motion-defined rectangles (vertical or horizontal) were created by moving a proportion of dots coherently (up or down) while the remaining dots moved in random directions at the same speed within the rectangle. Outside the rectangle, dots moved in the opposite direction with the same speed and coherence. Monocular motion coherence thresholds, for discriminating rectangle orientation, were determined at slow (0.85 deg/s) and at fast speeds (5.1 deg/s) using a staircase procedure.

First we examined normal development in children (4-6 years), adolescents (11-12 years) and young adults. Consistent with our previous results, coherence thresholds were higher in children than in adolescents and adults, with no difference between the two older groups. In addition, coherence thresholds were lower at the slow than at the fast speed for all three groups.

Next we examined patients aged 11 years and older with anisometropic and/or strabismic amblyopia. A few individuals showed a deficit in either eye at both speeds, and thresholds were lower in those with compromised binocularity. As a group, however, performance was similar to that of the controls. This is contrary to our previous results, possibly due to the older age of the observers or to the use of coherence rather than minimum-speed thresholds.

Our results provide no evidence for a developmental difference in M/dorsal versus P/ventral pathways. The speed effect may reflect the stronger contribution of the slow-motion system to motion-defined form perception.

23.318

Aging, retinal eccentricity, and global motion perception

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This study compared the sensitivity of 8 older (mean age - 70.5) and 8 younger (mean age – 20.2) observers to the direction of global motion presented in the retinal periphery. The task was to discriminate between two sequentially presented random-dot cinematograms (RDCs) of different average angular direction. Within the RDCs individual dots moved in a "random-walk" based on a distribution of directions. To manipulate noise the standard deviation of this distribution was set at 0, 4.5, 18, or 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. The results indicate main effects age, eccentricity, and noise level. There were significant interactions between age and eccentricity, age and noise level, as well as eccentricity and noise level. Post-hoc analyses indicated that older observers had increased thresholds at eccentricities of 22 and 40 degrees while younger observer did not differ significantly across eccentricity. This result indicates that there is a loss in sensitivity to global motion direction in the retinal periphery for older observers. 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 eccentricities matching those used in this study. The results indicate a loss in acuity for both age groups as eccentricity was increased. Older and younger observers did not differ significantly in acuity. An ANCOVA was performed to examine if the effect of eccentricity was based on declines in acuity. The results indicate losses in the discrimination of global motion direction for older observers occur independently of losses in acuity.

Acknowledgement: This work supported by NIH AG13419-06 and NEI EY18334-01.

Perceptual Learning: Models and Mechanisms

Saturday, May 9, 8:30 am – 12:30 pm
Poster Session, Royal Palm Ballroom 6-8

23.319

Perceptual learning can increase feed-forward neural response in early visual cortex

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Training on a visual task can, in some cases, produce changes in neural response in early visual cortex. But it remains unknown whether these effects reflect receptive field changes of early visual neurons or instead reflect feedback from later visual areas. We addressed this issue by testing whether learning can affect the earliest visual evoked potential (VEP) component, termed C1. Five subjects were trained to detect a low contrast sinusoidal grating of fixed diagonal orientation in a 2AFC task for over 28 days. Training took place at a single location in a selected quadrant of the visual field, and locations at the same eccentricity in the three other quadrants were used as controls to test the specificity of learning. Horizontal gratings in all four quadrants were also used as controls. Before and after the training, subjects' detection thresholds for all eight stimuli (4 locations x 2 orientations) were measured. In separate sessions, VEPs in response to briefly presented high contrast versions of the gratings were also measured. To control attention, subjects performed a demanding RSVP letter task at fixation while EEG data were acquired. Behavioral thresholds reliably decreased for the trained pattern. For stimuli at the trained location, amplitudes of the C1 component of the VEP (80-100 msec post-stimulus) were 22% greater for horizontal patterns than diagonals prior to training. Following training on diagonals, amplitudes were 19% greater for diagonals. Training produced only a small change in the difference between horizontal and diagonal amplitudes for patterns presented at the untrained locations (<6%). Because the C1 is likely associated with the initial activity in primary visual cortex, these results suggest that visual perceptual learning can increase neural response through local receptive field changes rather than through feedback from higher areas.

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23.320

An fMRI study of motion perceptual learning with suppressed and un-suppressed MT

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Motion perceptual learning is possible even when MT is putatively suppressed using a motion-opponent psychophysical stimulus. Here, using fMRI, we investigated whether this learning took place at MT. Observers performed a motion-axis orientation discrimination task on a stimulus designed to suppress MT via motion opponency. The stimulus consisted of counter-phase paired dots oscillating along a common motion axis (Qian and Andersen, 1994). Care was taken to ensure that no static frame of the stimulus movie provided task-relevant information, ensuring only motion information could be used for discrimination. We first verified that the stimulus indeed suppressed hMT+, as compared to a control stimulus within which the dot phase was changed from 180° to 0° to relieve motion opponency. Observers then trained extensively on one of the two stimuli, and were scanned pre- and post-training. Motion perceptual learning occurred for all trainees and transferred partially to the orientation perpendicular to the trained orientation. No reliable BOLD change was found at hMT+ or V1 in the control group trained without MT suppression. Learning in the experimental group, however, led to enhanced suppression of hMT+ by counter-phase paired dots and to a BOLD reduction at V1. By combining all trainees' data we also identified clusters of activity that were correlated with the amount of behavioral transfer. Reliable negative correlations were found bilaterally in the middle/superior occipital regions and unilaterally in a ventral region of the right occipital lobe that included a portion of the collateral sulcus. Our results indicate that motion perceptual learning with counter-phase paired dots enhanced MT opponency, possibly to suppress noisy responses. This learning also led to a reduced BOLD response in V1, indicating that motion opponency at MT possibly originated at V1. In comparison, when MT functioned normally, motion perceptual learning took place downstream from MT.

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23.321

Reward facilitates hemodynamic responses in higher visual areas

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The availability of financial reward can influence performance on tasks requiring visual discrimination, but the neural mechanisms giving rise to such changes in behavior remain unclear. In particular, whether reward has a direct or modulatory influence on visual processing remains uncertain.

Here, using functional magnetic resonance imaging, we investigated such possible effects of reward on visual judgements and activity in human visual cortex. Participants discriminated the orientation of two achromatic gratings presented successively in one visual field, while ignoring gratings presented to the other visual field. They received financial reward for each correct judgement at trial end. Critically, our event-related fMRI design allowed us to distinguish BOLD signals associated with visual stimulation by the gratings from those attributable to reward feedback, which was given audibly after a variable delay at trial end, when no visual stimuli were being presented.

We found a dissociation in responses in visual cortices between direct and modulatory effects of reward. While higher visual areas showed bilateral activation on trials when reward was given, compared to when no reward was given, no effect of reward was observed on earlier retinotopic levels of visual representation. In contrast, correct performance that was financially rewarded led to lateralised modulation of activity on the subsequent trial in retinotopic representations of the visual stimulus in primary visual cortex. Thus our findings demonstrate not only that visual cortex is modulated by reward, but that the effects of reward differ in early retinotopic and higher visual areas.

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23.322

Where in the motion pathway does task-irrelevant perceptual learning occur?

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During task-irrelevant perceptual learning (TIPL), sensitivity to stimulus features improves through exposure despite a lack of directed attention to them (Seitz and Watanabe, 2005). The properties of TIPL have been actively studied. For motion direction stimuli, Watanabe et al. (2002) suggested that TIPL occurs at a lower level in motion processing because learning was found for the local but not global motion direction of a dynamic dot display. However, the type of motion processing cells that provide a substrate to this kind of directional learning is still unknown. Here, we investigated if this learning is specific to the contrast polarity of the motion signals of the task-irrelevant stimulus. The procedure was similar to that employed in Seitz and Watanabe (2003). We developed a random dot motion stimulus, based on Wehrhahn and Rapf (1992), to target motion cells selective to contrast polarity by ensuring motion information arises only from signal dot onsets, and not their offsets. We measured the change in discrimination performance of human subjects in 4 non-cardinal directions for both positive and negative contrast polarities, after being exposed repetitively to a motion stimulus of a single contrast polarity while performing an attentionally-demanding RSVP task. Results show that learning does not transfer to the unexposed contrast polarity, suggesting that TIPL for motion stimuli can occur at or before the stage of directional V1 simple cells. These data support the prediction of the 3D FORMOTION model that a short-range directional filter generates directional V1 cells sensitive to contrast polarity, before projecting to MT via a long-range directional filter that pools across opposite contrast polarities (e.g., Chey, Grossberg, and Mingolla, 1997; Grossberg, Mingolla, and Viswanathan, 2001).

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23.323

Perceptual learning for speed discrimination in optical flow

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Problem. Perceptual learning can improve observer performance in visual decision making tasks (Dosher et al., Psychological Review, 112, 2005). Here we investigate perceptual learning for motion speed discrimination of a coherent motion pattern subsequently displayed at different speeds in one quadrant (random motion at all other quadrants). The goal is to evaluate whether performance is still improved when the coherent motion is presented in a different quadrant.

Methods. We propose a neural model of motion perception consisting of a hierarchy of areas to represent the main processing stages along the dorsal pathway in visual cortex, namely V1, MT, and MSTd (Bayerl & Neumann, Neural Computation, 16, 2004; Ringbauer et al., LNCS 4669, 2007). Optical flow is detected in area V1 and integrated in area MT by speed and direction sensitive neurons. Global motion patterns are spatially integrated subsequently in model area MSTd cells which are sensitive to rotational, radial, and laminar motion patterns (Graziano et al., J. of Neuroscience, 14, 1994). Model MSTd cells project to dorso-lateral area LIP where cells temporally accumulate responses to judge and discriminate different motion configurations (Hanks et al., Nature Neuroscience, 9, 2006). Here, perceptual learning is incorporated through synaptic reweighting in LIP controlling the input stimulus and the strength of mutual inhibition between recurrent competitive field neurons (Grossberg & Pilly, Vision Research, 48, 2008).

Results and Conclusion. The model shows decreased reaction time after several trials in a training setup. Additionally small speed differences can be discriminated more accurately even if the target pattern is presented in a quadrant that has previously not been probed during training. Thus the model predicts that improved speed discrimination performance after perceptual learning using a selected quadrant can be transferred to other locations as well.

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Saturday Sessions

23.324

Relating changes in processing capacity to changes in electrophysiological variables in visual perceptual learning

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Studies of visual perceptual learning have documented the extent to which basic perceptual abilities, such as contrast detection, can improve given systematic practice. The majority of these studies have focused on reductions in detection and identification threshold. Recently, Blaha and Townsend demonstrated perceptual practice can produce large improvements in perceptual capacity, measured as the total work per unit time, quantified at the level of the integrated hazard function of the response time (RT) distribution. In addition, their results strongly suggested the increase in capacity was indicative of a strong perceptual organization. The present effort had three goals: (a) replicate the large improvements in capacity documented by Blaha and Townsend using measures based on RTs, (b) relate those improvements to improvements in measures based on response frequencies (specifically, detection thresholds), and (c) relate both types of improvements to changes in measures based on scalp-level EEG. Six observers began by performing a detection task with a contrast-defined pattern. Contrast levels were supra-threshold and the stimulus was split vertically into two halves. Each half of the stimulus could be present or absent. Half of the observers were instructed to give a positive response if they detected one or both halves present. Remaining observers were instructed to give a positive response only if they detected both halves present. EEG, RT and response choice were recorded. Following the initial session, observers completed 10 days of perceptual practice with the stimulus pattern and threshold changes were recorded. Finally, observers completed an additional set of detection blocks in which EEG, RT, and response choices were again recorded. Critical results were (a) large and reliable reductions in detection thresholds, (b) large and reliable increases in capacity, and (c) large shifts in ERP amplitudes and latencies. Results are interpreted with respect to implications for cortical efficiency in perceptual learning.

23.325

Perceptual learning of texture segmentation is specific for retinal location but not first-order orientation channel

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A modulation of orientation in an orientationally narrow-band visual texture results in contrast modulations within two narrow orientation channels in the absence of a modulation in overall contrast. These contrast modulations typically do not occur in the channel which contains the bulk of the contrast in the texture but rather occur in 'off-orientation' channels. In other words, the relevant (contrast-modulated) information is contained within orientation channels distinct from channels containing irrelevant (unmodulated) information. As such, a perceptual mechanism which detects such texture modulations could potentially improve its performance by improving its ability to restrict second-order analysis to the relevant channels while ignoring the irrelevant channels. This might occur through a process of template retuning at the level of orientation-selective first-order perceptual filters. Whereas texture segmentation of orientation-modulated textures has indeed been shown to be subject to perceptual learning, it is not known whether this learning occurs through template retuning of orientation-selective first-order perceptual filters. We created textures containing contrast modulations in two distinct orientation channels. The contrast modulations in the two channels were either in-phase or counter-phase. The former results in textures which contain a modulation of overall contrast. These can be detected by mechanisms which integrate information across all first-order orientations and would hence not benefit by template retuning of their first-order filters. All textures also contained contrast in two separate orientation channels which were not modulated. The task of observers required detection of the contrast modulations in the relevant channels. Observers trained in at least ten sessions of 500 trials each. Performance showed a steady improvement across training sessions. This improvement was specific to retinal location but not to the first-order orientation channels which contained the relevant information. This suggests that perceptual learning of texture segmentation does not involve template retuning at the level of first-order perceptual filters.

23.326

Aging and Perceptual Learning

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Perceptual Learning (PL) and the underlying neural plasticity have been mostly studied with younger adults. For example, with younger adults,BOLD activity changes were observed only in the trained region of V1 due to PL (Yotsumoto, Watanabe and Sasaki, 2008). Recent research has found evidence of PL for older subjects (Ni, Watanabe and Andersen, 2007) Here, we examined PL examined the underlying neural mechanisms of PL in older subjects by measuring BOLD responses.

Older adults, aged 65-75 years, underwent three behavioral training sessions of a texture discrimination task (TDT) (Karni and Sagi, 1992). Each session lasted about 45 minutes and was conducted on three separate days. They also participated in two fMRI sessions before and after the series of training sessions. PL training occurred in one quadrant of the visual field. In the fMRI sessions the trained and a non-trained quadrant were tested and BOLD activities in respective regions of cortical areas were compared.

Results showed (1) that TDT performance with older subjects improved after training and (2) that BOLD activity only in the trained region/side of each V1, V2, V3 and the dorsolateral prefrontal cortex was significantly larger than in an untrained region/side.

These results indicate that in contrast to PL with younger adults in which only V1 was activated, multiple areas are involved in PL with older individuals. These results suggest that as aging occurs recruitment of multiple new areas may be needed to compensate for less plasticity in V1. In addition, neural recruitment occurs only in the trained region of the areas critical to perform the task.

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23.327

Concrete and Abstract Perceptual Learning without Conscious Awareness

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Purpose: When perceptual learning (PL) occurs in simple tasks, the learner is commonly unaware of the specific stimulus variables determining a classification. In contrast, the discovery of abstract relations in PL is sometimes thought to necessarily involve conscious awareness. We sought evidence for unconscious PL in tasks requiring the learner to discover either concrete attributes or an abstract relational basis for a classification. Method: Subjects viewed grid displays each consisting of 144 small squares in a 12 x 12 array. Each square in a grid had one of 4 gray levels. Participants judged whether each grid contained an embedded pattern, which was not described; learning could occur based on accuracy feedback. "Concrete" patterns were defined by 10 pixel locations having specific grayscale values. "Abstract" patterns were defined by pixel relations, not specific values. Experiment 1 tested concrete pattern discovery in three presentation and response conditions (presence/absence judgments for single instances, left/right judgments for paired comparisons, or "odd-one-out" triplets, in which one grid contained a target and two others did not). Experiment 2 tested discovery of abstract relations based on spatial or color relations. For patterns defined by spatial relations, pixel color was uniform and constant, but the pattern could appear anywhere in a grid. For patterns defined by color relations, position was constant and target color was uniform for each display, but color varied across displays. Speed of acquisition and conscious report of patterns were assessed. Results: Paired comparisons resulted in fastest learning. Learning occurred for both concrete and abstract embedded patterns even when participants could not describe the pattern. A pattern-drawing task designed to measure explicit knowledge found that most successful learners typically had little or no knowledge of target shape. Conclusion: Neither concrete nor abstract perceptual learning appear to require conscious awareness.

23.328

Playing Action Video Games Leads to Better Perceptual Templates

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Action video game playing substantially improves visual performance; however, the source of this improvement remains unclear. Here we use the equivalent external noise technique to characterize the mechanism(s) by which action video games may facilitate performance (Lu & Dosher, 1998).

In a first study, Action Video Game Players (VGPs) and Non-Action Video Game Players (NVGPs) performed a foveal orientation identification task at different external noise levels. Threshold versus external noise contrast (TvC) functions were measured at two performance criterion levels. VGPs showed lower thresholds than NVGPs with a marked difference at high noise levels. Fitting the data with the Perceptual Template Model indicated that two independent factors contribute to the superior performance of VGPs: an 11% additive noise reduction and a 25% external noise exclusion.

The causal effect of action video game playing was confirmed in a 50 hour training study, whereby NVGPs were randomly divided into an experimental group that played action video games and a control group that played control games. TvC functions were measured before and after training. The same change as in VGPs was observed in action game trainees, whereas no change in external noise reduction was observed in the control group. This work establishes that playing action video games leads to robust external noise exclusion, consistent with the use of better matched perceptual templates.

To confirm that action video game playing leads to the development of better templates for the task at hand, we also used a probabilistic neural model of orientation selectivity. We found that changes in TvC curves induced by action video game playing can be captured by changing one parameter - the strength of the feedforward connections in the model. Together, this work demonstrates that action video game playing improves performance by allowing gamers to develop better task-relevant templates than non gamers.

23.329

Orientation thresholds and perceptual learning: An elaborated perceptual template model

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The discrimination of two stimuli can be measured as a contrast threshold at a constant stimulus difference (i.e., +/- 45 deg orientation) or as an orientation threshold at a given contrast. Both can be understood together within an elaborated perceptual template model (ePTM) that incorporates the effects of judgment precision, or non-orthogonal stimuli for discrimination (Jeon, Lu, & Dosher, 2008). Perceptual learning improvements in contrast thresholds have been studied in different external noise conditions (Dosher & Lu, 1998, 1999), while stimulus difference thresholds have not. Here we investigate orientation psychometric functions and thresholds and perceptual learning. (1) Orientation thresholds in zero noise and in high noise improve with practice in a peripheral orientation discrimination experiment in which the angles of discrimination are altered by an adaptive staircase; threshold angle difference narrowed gradually with practice. (2) Orientation psychometric functions were measured at three contrast levels and eight external noise levels to measure orientation threshold TvC functions at fovea; consistent with prior reports (Lu & Dosher, 2004) foveal performance showed little or no effect of learning comparing the first to the last half of sessions. (3) A similar experiment measured orientation discrimination at 5 deg in the periphery; peripheral discrimination performance showed perceptual learning between the first and last half of sessions, with larger learning effects in high external noise. In both (2) and (3) the ePTM provided a very good account of the orientation psychometric functions in different levels of external noise. These results widely validate the elaborated perceptual template model in accounting for accuracy as a joint function of orientation difference, contrast, and external noise, with perceptual learning resulting in reduced impact of external and additive internal noises.

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23.330

Modeling perceptual learning in external noise with Hebbian reweighting

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Using the external noise plus training paradigm, we find evidence that two independent mechanisms, stimulus enhancement and external noise exclusion, support perceptual learning in a range of tasks. Here, we show that re-weighting of stable early sensory representations through Hebbian learning (Petrov, Dosher & Lu, 2005) provides an excellent account of a large range of data: (1) perceptual learning reduced contrast thresholds at all levels of external noise in peripheral orientation identification (Dosher & Lu, 1998, 1999), (2) significant learning only occurred in the high external noise conditions but not in zero or low external noise conditions in foveal orientation identification (Lu & Dosher, 2004), (3) in second-order letter identification and auditory modulation detection, the performance improvements predominantly occurred in low external noise conditions (Dosher & Lu, 2007, Kong, Lu, Dosher & Zeng, 2004), (4) training with low noise exemplars transferred to high noise performance, while training with exemplars embedded in high external noise did not transfer to low noise performance (Dosher & Lu, 2005), and (5) pre-training in high external noise only reduced subsequent learning in high external noise, whereas pre-training in zero external noise practically eliminated or left very little additional learning in all the external noise conditions (Lu, Chu & Dosher, 2006). In the re-weighting model, perceptual learning strengthens or maintains the connections between the most closely tuned visual channels and a learned categorization structure, while it prunes or reduces inputs from task-irrelevant channels. Reducing the weights on irrelevant channels reduces the contributions of external noise and additive internal noise. Manifestation of stimulus enhancement or external noise exclusion depends on the initial state of internal noise and connection weights in the beginning of a learning task. Both mechanisms reflect re-weighting of stable early sensory representations.

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23.331

Coarse-to-fine learning in scene perception: Bayes trumps Hebb

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Recent studies suggest that the coherent structures learned from multi-element visual scenes and represented in human memory can be best captured by Bayesian model comparison rather than by traditional iterative pair-wise associative learning. These two learning mechanisms are polar opposites in

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how their internal representation emerges. The Bayesian method favors the simplest model until additional evidence is gathered, which often means a global, approximate, low-pass description of the scene. In contrast, pair-wise associative learning, by necessity, first focuses on details defined by conjunctions of elementary features, and only later learns more extended global features. We conducted a visual statistical learning study to test explicitly the process by which humans develop their internal representation. Subjects were exposed to a family of scenes composed of unfamiliar shapes that formed pairs and triplets of elements according to a fixed underlying spatial structure. The scenes were composed hierarchically so that the true underlying pairs and triplets appeared in various arrangements that probabilistically, and falsely, gave rise to more global quadruple structures. Subjects were tested for both true vs. random pairs and false vs. random quadruples at two different points during learning -- after 32 practice trials (short) and after 64 trials (long). After short training, subjects were at chance with pairs (51%, p>0.47) but incorrectly recognized the false quadruples (60%, p<0.05). Showing a classic double dissociation after long training, subjects recognized the true pairs (59%, p<0.05) and were at chance with the quadruples (53%, p>0.6). These results are predicted well by a Bayesian model and impossible to capture with an associative learning scheme. Our findings support the idea that humans learn new visual representations by probabilistic inference instead of pair-wise associations, and provide a principled explanation of coarse-to-fine learning.

Neural Mechanisms: Receptive Fields

Saturday, May 9, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

23.402

The representation of transparent motion in the non-Fourier responses of LGN Y-cells

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Recently, we showed that non-Fourier (second-order) image features are represented subcortically in the responses of LGN Y-cells. To further investigate this representation, we characterized tuning for the envelope and carrier parameters of interference patterns. We found that Y-cell responses depended strongly on carrier temporal frequency (TF), and had lowpass, bandpass, or highpass tuning. Envelope TF tuning, on the other hand, was bandpass and peaked at relatively low temporal frequencies. In addition, many neurons were moderately selective for the orientation of the carrier but were not selective for drift direction. Responses oscillated at the envelope TF, regardless of the carrier TF, indicating that Y-cells encode the position of the envelope relative to the receptive field, but only when that envelope modulates a carrier within a defined range of spatiotemporal frequencies.

Perceptually, the envelope of an interference pattern is perceived as drifting across the carrier. Since Y-cell responses modulate at the TF of the envelope but not the carrier, they may signal this occlusion of a background object (the high spatial frequency carrier) by an object in the foreground (the low spatial frequency envelope). Thus, Y-cells carry a monocular cue for the dynamic occlusions that signal depth ordering and that underlie the perception of multiple object velocities within a local retinotopic space (motion transparency). While representations of depth structure and motion transparency are traditionally thought to arise from intra-cortical processing, our results suggest that they may first be represented subcortically by the nonlinear responses of Y-cells.

23.403

Variability in the responses of primary visual cortical neurons to natural movies

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We investigated the response properties of primary visual cortical neurons of the anesthetized cat when presented with natural movies. First, we computed the inter-spike interval (ISI) histograms of the 60 cells in our database. We found the majority of the cells to exhibit a predominance of short ISIs. The maximum value in the histograms was below 2 ms in 39 cells, and below 4 ms for 52 cells. Next, we compared the firing rate distributions of each neuron to exponential (y=a*exp(b*x)) and power (y=a*x^b) functions. We found 43 of the cells were significantly better characterized by power functions (p<0.05 and R-square>0.75), while 13 of the cells were best fit by exponential functions. Finally, we investigated the spike-count and spike-time variability across repetitions within 40 ms windows, equivalent to the duration of a single movie frame. We compared the variability of each cell to 1000 surrogates generated using a time-varying Poisson process with a relative refractory period computed from the ISI histograms. With the rate changing every 40 ms, we found that only 1.2% of the windows with an average of at least 1 spike per window exhibited Fano Factors that were lower than 95% of the surrogates. This percentage remained invariant with faster rate changes in the surrogates. Using an entropy measure to quantify spike-time variability, we found 49.3% of the aforementioned windows exhibited lower variability than 95% of the surrogates with rates changing every 40 ms. This percentage decreased to 37.28%, when the rates changed every 5 ms instead. Our results indicated that when stimulated with natural movies, striate cortical neurons exhibited responses: 1) with short intervals, 2) that were better described using power-law distributions instead of exponential distributions, and 3) with spike-time variability that was substantially lower than that predicted from time-varying Poisson processes with relative refractory periods.

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23.404

Differences in spatial signal processing between neurons in the input and output layers of the macaque primary visual cortex, V1

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The primary visual cortex (V1) is the gateway for visual information to reach other cortical areas. Here we report differences in V1 spatial processing by using different mapping techniques to measure neuronal receptive fields in different V1 layers of sufentanil-anesthetized monkeys. Layer-2/3 neurons, unlike their layer-4C counterparts, showed significantly different spatial properties when mapped with sparse noise (SN, Jones and Palmer, 1987) and dense noise [Hartley subspace (Ringach et al, 1997) and m-sequence white noise (Reid et al 1997)] by reverse correlation. Many layer-2/3 neurons had spatial maps with multiple elongated on/off subregions when mapped with dense noise, but had unimodal and less elongated spatial maps when mapped with sparse noise. The similarity between the sparse-noise map and the dense-noise map, quantified as the spatial correlation between the two maps, was significantly lower for layer-2/3 neurons than for layer-4C neurons. For layer-2/3 neurons, the preferred orientation from dense-noise maps tended to be closer to the preferred orientation measured with drifting gratings than was the orientation preference of sparse-noise maps. Moreover, the majority of layer-2/3 neurons (93%) responded more strongly to light decrements (DEC) than to light increments (INC) when mapped with sparse noise [log (INC/DEC) = -0.37+0.32], but this was not the case for layer-4C neurons [log (INC/DEC) = -0.08+0.38]. The dark-dominated responses in V1 superficial layer might provide the substrate for stronger light-decrement responses presented in several psychophysical

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studies (e.g. Zemon et al 1988; Chubb et al 2004; Olman et al 2008). Overall, these results suggest that, compared to neurons in layer 4C, layer 2/3 cells are affected by additional nonlinear stages of signal processing. Therefore, frequently used models of V1 neurons, such as the L-N-P [dynamic Linear filter – static Nonlinearity – Poisson spike encoder] model, may not be sufficient for most neurons in V1.

Acknowledgement: This study is supported by EY-001472 (R.M.S.) and the Robert Leet and Clara Guthrie Patterson Trust Postdoctoral Fellowship (C.I.Y.). We thank Patrick Williams and Marianne Maertens for participating in some of the experiments.

23.405

Image discontinuity changes LFP gamma-band activity in primary visual cortex V1

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In V1 cortex, large continuous visual stimuli suppress neurons' firing rates and power in the local field potential (LFP) spectrum > 70 Hz. However, the spectral peak of LFP power in the gamma-band (around 50 Hz) often increases with stimulus size (Bauer et al. 1995; Henrie et al 2006). This differential effect of stimulus size on the gamma-band peak could be explained if 1) gamma-band activity represents local neuronal activity, which is more synchronized by large stimuli (Gail et al 2000) or 2) gamma-band activity represents neuronal activity in a large area of the cortex and grows stronger when more V1 neurons are activated by large stimuli. To decide between 1 and 2, we studied LFP responses to visual stimuli with or without spatial discontinuities.

LFPs were recorded in response to a large-area (8 deg radius) sinusoidal grating centered on receptive fields of neurons at the recording site. We also measured gamma-band coherence between different recording sites. Spatial continuity of the grating pattern was broken by an annulus of mean gray. Annulus inner diameter was around 1 deg. The gap between the outer and inner annulus radii ranged from 0.05 to 0.2 deg. To measure how much gamma-band power was evoked from the receptive field periphery, LFPs were recorded when the central disk region was blank.

A small visual gap of width 0.1deg greatly reduced LFP power at 50Hz for half of the recording sites (20/50) and gamma-band coherence also could be affected by image discontinuity. Furthermore, the amount of gamma-band activity evoked by annuli with inner diameters > 1 deg was always small. Our results indicate that gamma-band activity in the LFP is a signal mainly from the local cortex and that image discontinuity can change the pattern of gamma-band activity.

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23.406

Orientation detection and discrimination domains in the primary visual cortex

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Orderly maps of orientation preference are a hallmark of the primary visual cortex in many species. This systematic arrangement is thought to facilitate averaging within groups of similarly tuned neurons, minimize connection length, and ensure uninterrupted functionality over visual space. The preferred orientation of a neuron, i.e., the location of the peak of its orientation tuning curve, is the orientation best detected by the neuron. But the location of the steepest gradient of the tuning curve determines the orientations best discriminated by the neuron. Since primates excel at both discrimination and detection, we asked whether the organization of sensory information for both tasks follows the same principles. We combined electrophysiology with optical imaging of intrinsic cortical signals to study the primary visual cortex of anesthetized, paralyzed bush babies for fine orientation discrimination. Sinusoidal gratings at behaviourally optimal spatial and temporal frequencies were presented at different orientations. Using receiver operating characteristic (ROC) analysis, we computed neurometric curves and best discriminable orientations for single neurons as well as discrimination probability maps over large patches of V1 from the intrinsic signals. For single neurons, preferred orientation alone was not a consistent predictor of the best discriminable orientations since the latter depended on the peak as well as the width of the orientation tuning curve. But discrimination probabilities were organized in orderly maps for different axes of discrimination across the cortical surface, indicating that orientation tuned neurons in V1 are grouped together by the location of the steepest gradient of their tuning curves in addition to the location of the peaks. Pinwheels in detection and discrimination maps were coincident and edges of ocular dominance domains intersected both detection and discrimination domains at steep angles. We suggest that sensory information is similarly and equitably organized across V1 for both detection and discrimination of orientation.

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23.407

Neurons in primary visual cortex show dramatic changes in filtering properties when high-order correlations are present

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V1 is widely considered to act primarily as a feedforward bank of filters followed by simple nonlinearities ("LN" systems). However, when LN models are built from simple analytically-convenient stimuli, their predictions of neural responses to natural scenes are only modestly accurate. One possibility is that this inaccuracy is merely quantitative, and can be remedied by adding gain controls, modulatory feedback, and multiple subunits to the basic LN structure. Alternatively, there might be fundamental qualitative differences between the computations performed by real cortical neurons and those performed by these models.

Since natural scenes have characteristics that traditional analytic stimuli lack, differences between responses of real and model V1 neurons likely reflect sensitivity to the distinguishing characteristics of natural scenes, namely, high-order correlations (HOCs). To isolate the effects of HOCs, we created sets of binary checkerboard stimuli in which second-order correlations were absent, but selected HOCs were present. Moreover, because our stimuli had identical contrast and spatial frequency content, they would equally engage cortical gain controls. For each of these statistical "contexts", we determined the receptive field map – i.e., the L stage of the LN model that best accounts for the neuron's responses. Because stimuli were constructed so that second-order correlations were absent, these maps could be obtained by reverse correlation.

Recordings were made via tetrodes in four locations in macaque V1. In most (13/16) neurons, there were dramatic effects of high-order "context" on receptive field structure, including heightened sensitivity, development of spatial antagonism, or changes in response time course. In a few neurons, RF maps could only be obtained in the presence of high-order structure. These behaviors are not present for model LN neurons. This suggests that alternative model structures, such as strongly recurrent networks, are required to account for V1 responses even at a qualitative level.

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23.408

Orientation change detection and orientation pooling in space and time performed by two subpopulations of neurons in V2

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Neurons in V1 mainly extract oriented luminance boundaries, while neurons in V2 detect more complex boundaries, including texture boundaries. Here we investigate the processing of orientation signals in V1 and V2, and find two distinct subpopulations of neurons in V2 based on their dynamics.

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We recorded responses from single neurons in V1 and V2 of anesthetized monkeys. Stimuli consisted of a 4x5 or 6x6 grid of adjacent rectangular regions, covering the non-classical receptive field. Each region contained sinusoidal gratings with either the preferred orientation or the non-preferred orthogonal orientation controlled by m-sequences (frame rate 20 ms or 40 ms).

V1 neurons have monophasic responses to the orientation signal in individual regions, and their timing is consistent across the population. In contrast, V2 neurons have two distinct patterns of responses: some are biphasic, with an initial peak width narrower than the V1 responses ('transient V2 neurons'); others are monophasic, with a broader peak than the V1 responses ('sustained V2 neurons'). The biphasic response pattern indicates dynamic orientation tuning and predicts that the optimal stimulus within a patch is the non-preferred orientation followed by the preferred orientation.

Responses to combinations of orientations reveal additional distinctions between V1 and the two V2 subpopulations. Neurons in V1 have nonlinear interactions consistent with cross-orientation suppression. Transient V2 neurons exhibit the opposite: larger responses to orientation discontinuities than to continuous orientation. Sustained V2 neurons show no measurable nonlinear spatial interaction.

This study shows, firstly, how non-linear as well as linear responses of V2 neurons differ from V1 responses. Secondly, we identified two different classes of orientation selective V2 neurons. The transient V2 neurons differentiate the V1 input in space and time and therefore respond well to changes in orientation. Sustained V2 neurons pool the V1 input and respond better to constant orientation signals.

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23.409

Visual response properties of striate cortical neurons projecting to V2 in macaque

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The second visual area in the macaque (V2) is the major recipient of feedforward 'driver' projections from striate cortex (V1). As a gateway to the ventral stream, V2 may underlie important aspects of visual form processing. The convergence of multiple V1 inputs onto larger V2 receptive fields suggests that V2 neurons may combine simple cues across space, giving rise to selectivity for complex image features. V2 neurons have been reported to be selective for angles, complex shapes, illusory contours, object boundaries, and relative binocular disparity.

It is unclear how these selective responses are generated from V1 inputs. We therefore identified V1 neurons projecting to V2 by antidromic electrical stimulation, and measured their visual response properties. We placed stimulating electrodes in middle V2 layers, and recording electrodes in the retinotopically-matched V1 location. V1 cells that passed the collision test were taken to be V2-projecting. Antidromically-activated spikes had minimal latency jitter and short conduction velocities (1-5 ms).

We measured the responses of V2-projecting neurons with sinusoidal gratings that varied in contrast, direction, spatial frequency, drift rate, size, chromatic modulation, and interocular spatial phase. To quantify neuronal selectivity, we fitted appropriate model functions and computed tuning indices. We compared our results with those from larger V1 datasets recorded without knowledge of neuronal connectivity to V2. Most projection neurons in our sample were complex (F1/DC <1), moderately selective for grating orientation but unselective for direction. Interestingly, most showed significant binocular phase interactions, and were better driven by luminance-modulated than chromatically-modulated stimuli. The response properties of the V2-projecting neurons suggest that they mostly carry information about visual form. These results place informative constraints on computational models of V2.

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23.410

Cortical origin of contrast response function contextual modulation in V1 population activity measured with voltage-sensitive dye imaging

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In psychophysics and physiology, it is well established that the contrast gain control is context-dependent. In both human and monkey ocular following studies, it has been shown that modulations of the contrast response functions (CRF) induced by a peripheral stimulus are delayed. We investigated the role of cortico-cortical interactions on this delayed contextual modulations using recording of population activity with voltage sensitive dye imaging (VSDI) in area V1 of behaving monkeys.

Dynamics of contrast response functions to a local stimulus were found to be very similar in V1 cortical activity and ocular following responses (OFR). At both levels, contrast gains increase over time in response to a single grating motion. However, adding a dynamical surround both clamps the contrast gains to their initial value and maintains larger dynamical ranges. Using an ideal observer model, we show that these results can match the behavioral observation (see Perrinet et al. VSS 2009).

To investigate the cortical origin of this modulation, the visual input was manipulated while measuring V1 activity using VSDI. In order to test whether the peripheral modulation originated from V1 horizontal intracortical connectivity (slow connectivity between small receptive fields, sensitive to slow motion and static stimuli, with precise retinotopic organization) and/or feedback from MT (fast connectivity from large receptive fields, sensitive to fast motion, with gross retinotopic organization), bipartite stimuli with different properties were used: (i) different spatio-temporal scales, (ii) surround containing or not motion signal and (iii) varying center-surround distance.

Our experiments show that non-linear interactions between and within cortical areas lead to the modulation of the CRF. Depending on stimulus characteristics, we observed a dynamical balance between fast facilitation and slower suppression that results from a strong interplay between horizontal and feedback connectivity.

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23.411

Inferring monkey ocular following responses from V1 population dynamics using a probabilistic model of motion integration

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Short presentation of a large moving pattern elicits an ocular following response that exhibits many of the properties attributed to low-level motion processing such as spatial and temporal integration, contrast gain control and divisive interaction between competing motions. Similar mechanisms have been demonstrated in V1 cortical activity in response to center-surround gratings patterns measured with real-time optical imaging in awake monkeys (see poster of Reynaud et al., VSS09). Based on a previously developed Bayesian framework, we have developed an optimal statistical decoder of such an observed cortical population activity as recorded by optical imaging. This model aims at characterizing the statistical dependance between early neuronal activity and ocular responses and its performance was analyzed by comparing this neuronal read-out and the actual motor responses on a trial-by-trial basis. First, we show that relative performance of the behavioral contrast response function is similar to the best estimate obtained from the neural activity. In particular, we show that the latency of ocular response increases with low contrast conditions as well as with noisier instances of the behavioral task as decoded by the model. Then, we investigate the temporal dynamics of both neuronal and motor responses and show how motion information as represented by the model is integrated in space to improve population decoding over time. Lastly, we explore how a surrounding velocity non congruous with the central excitation information shunts the ocular response and how it is topographically represented in the cortical activity.

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URL: http://incm.cnrs-mrs.fr/LaurentPerrinet/Publications/Perrinet08vss

23.412

Neuronal activity in area MT during perceptual stabilization of ambiguous structure-from-motion

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During continuous viewing of an ambiguous display, perception spontaneously alternates between two alternative interpretations of the stimulus. Such perceptual alternation can be greatly slowed down all the way to a standstill if the stimulus is periodically removed from view, a phenomenon called ‘perceptual stabilization’ (Leopold et al NatNeuro 2002). While brain activity during perceptual switches has been studied extensively, neuronal activity during perceptual stabilization remains unexplored. Here, we report neuronal responses in area MT in two behaving macaque monkeys under two conditions that differ in the strength of perceptual stabilization. In the first condition, we presented ambiguous structure-from-motion (SFM) stimuli periodically, a standard paradigm for stabilization in humans. The monkeys’ behavioral reports confirmed minute-long stabilization and their ocular responses mirrored the perceptual reports. In the second condition, we intermixed ambiguous SFM with disparity-defined unambiguous SFM across trials. In this latter condition, the monkeys did not show any evidence for perceptual stabilization. We analyzed neuronal activity that was simultaneously recorded with ~10 electrodes in the form of multi-unit spiking activity and local field potentials using multivariate decoding techniques (Tsuchiya et al PLoSONE 2008). Using linear decoders, we were able to predict the percept during stimulus presentation (~70% correct), but not during the pre-stimulus blank periods in the stabilization condition. A significant difference between the stabilization and the non-stabilized conditions was the latency of decoding accuracy; while the decoding accuracy reached its peak within 0.2-0.3 sec from the stimulus onset in the stabilization condition, it reached the peak at ~0.7 sec in the non-stabilization condition. We conclude that while MT does not represent explicit information during pre-stimulus blank periods, it is highly primed in the stabilization condition such that upon stimulus onset its activity converges towards one perceptual state much faster than in the non-stabilized condition.

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23.413

An information theory approach to linking neuronal and behavioral temporal precision reveals sparse encoding and decoding underlying a rapid perceptual judgment

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A major challenge in understanding the neuronal mechanisms of cognition and perception is the possibility that a pattern or locus of neuronal activity may be correlated with a particular task, but not directly responsible for its execution. One approach is to simultaneously measure physiology and behavior in reaction time tasks. However, because neurons even in higher areas such as inferotemporal cortex have response latencies shorter than the fastest reaction times seen in perceptual tasks (~150-200 ms), mean reaction time measures do not strongly constrain underlying physiological mechanisms. Moreover, reaction time distributions can be strongly affected by task or subject biases. Here we focus on measurements of behavioral performance that can place stronger constraints on physiological mechanisms: temporal precision and reliability. We quantify these measures by applying information theory to contingency tables between behavior and stimulus constructed at a variety of temporal resolutions and delays. The method integrates aspects of behavior that are traditionally considered separately: performance (% correct) and response timing. By applying this methodology to behavioral models based on the dynamics of a decision variable, including both diffusion and temporal probability summation, we find that the method’s measures of dynamics are less susceptible to noise than traditional reaction time metrics. Finally, we demonstrate that the same methodology can also measure the precision of neuronal discharge. In particular, we analyzed the relationship of brief epochs of activity in area MT to both sensory events (encoding information rate) and behavioral choices (decoding information rate) during a rapid motion detection task. For this task, we find that the reliability of individual neurons over tens of milliseconds is nearly sufficient to explain behavioral performance. Thus, a consideration of temporal precision suggests cognitive tasks do not require extensive pooling of neuronal activity over either space or time.

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23.414

Pharmacological enhancement of cortical inhibition affects lateral interactions in human vision

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Perceptual facilitation, a decrease in detection threshold for low-contrast Gabor patches (GPs), occurs when a low-contrast GP is flanked by collinearly oriented high-contrast GPs. It was suggested earlier that a spatial architecture of excitation and inhibition is the basis of these lateral interactions. The GABAAR agonist, lorazepam, enhances the cortical inhibition and thus disrupts the balance between inhibition relative to excitation (I/E) that has been implicated in plasticity regulation and has recently been shown to affect visual perception. Here we recorded Event-Related Potentials (ERPs) in healthy volunteers to study the effects of pharmacological interference with the I/E balance on lateral interactions. Our previous studies provided evidence for N1 peak amplitude modulation by collinear context (Sterkin et al., 2008). Moreover, we also found a robust correlation between N1 peak amplitude and the backward masking effect (Sterkin et al., 2007). We measured the latency and amplitude of N1 elicited by a foveal GP and collinear flankers separated by 1.5 or 3 wavelengths before and after the uptake of lorazepam. As expected, lateral interactions induced behavioral suppression for the separation of 1.5 wavelengths and facilitation for 3 wavelengths. However, facilitation was significantly abolished after lorazepam uptake and the N1 amplitude was robustly decreased for the separation of 3 wavelengths, reminiscent of the backward masking effects reported earlier. Surprisingly, reaction time was shortened after the uptake of lorazepam. These results imply that both behavioral manifestation and the neuronal correlates of lateral interactions are modulated by the pharmacologically induced increase of cortical inhibition. Specifically, this may suggest a mechanism of noise reduction that promotes faster and unambiguous processing. Thus, our findings support a critical role for the I/E balance in maintaining context effects in the visual cortex.

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Perceptual Organization: Contours

Saturday, May 9, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

23.416

Recovering metric object properties through spatiotemporal interpolation: What is the size of an object that is never present in the stimulus?

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Purpose. Spatiotemporal interpolation (STI) refers to perception of complete objects from fragmentary information across gaps in both space and time. Palmer, Kellman & Shipley (2006) found that STI for both illusory and occluded objects produced performance advantages in a discrimination paradigm. Here we tested accuracy of metric properties in representa-

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tions obtained through STI. Method: The PSE for the length of the base of a moving triangle was obtained using a staircase method for 15 subjects. A white triangle oscillated horizontally for 4 seconds on white background. The triangle was specified in the control condition as three dots located at the vertices and in the STI condition as a white illusory triangle specified by sequential partial occlusions of black background elements in its path. Spatiotemporal (vs. spatial) interpolation was ensured by allowing no more than one vertex of the triangle to be visible at any moment. Two edge lengths (6 and 4.5 degrees), three triangle shapes, and two conditions were tested using interleaved staircases in a within subjects design. Although the dots provided the same spatial and timing information as in the STI condition, they did not induce perception of interpolated contours or a coherent object. If STI does not produce metric representations, we expected similar performance for control and STI conditions. Results. Neither shape nor edge extent affected accuracy of perceived edge length ($p > .05$). STI produced more accurate perception of extent ($p < .001$). STI can produce object representations with accurate metric properties. An object constructed through STI does not exist at any moment in the stimulus, yet its size appears to be accurately encoded. Cognitive inferences about length based on position and timing (control condition) were much less accurate, suggesting a special role of perceptual object formation from STI in producing representations of functionally important object properties.

URL: http://kellmanlab.psych.ucla.edu/Lab_Website/Projects.html

23.417

The Plot Thickens: Exploring Illusory Contours

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In exploring different illusory contours, we have come across several cases that seem to resist a simple unifying explanation and do not easily fit current explanations. For example, one arrangement yields strong illusory contours when circles are the stimuli, but no effect when comparable squares are used. Similarly, brightness assimilation-like illusory contours result in conditions in with some inducing stimuli but not others that would seem comparable.

In addition we have been exploring illusory contours with inducing stimuli that are very different from those traditionally used. The work is a mix of exploration and the systematic assessment of some factors involved.

The work offers new possibilities, but also raises questions about illusory contours.

URL: http://perceptualstuff.org/

23.418

Developmental onset of illusory form perception in pigtailed macaque monkeys

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Previous studies have shown that the development of global form perception in humans is gradual when compared to other basic visual functions (e.g. visual acuity). The development of basic visual functions is mirrored in human and non-human primates. Few investigations of the development of object recognition and global form perception have been conducted in primate infants. A few studies of human infants suggest that global form perception is present near birth, while data from children suggest that it develops around age 5 years or later. Most studies of children confound development of language and perception, or specifically instruct the participants. To avoid these confounds, we used an animal model and Kanizsa illusory contours as an assay of global form perception. We recently showed that 1.5 year-old macaque monkeys demonstrate the ability to perceive Kanizsa illusory forms (Feltner & Kiorpes, VSS, 2008). We have now studied the time period during which this ability develops.

Using a modified 2-alternative forced-choice preferential looking paradigm, one infant pigtailed macaque monkey was tested at 6 months and 12 months of age. At 6 months, the monkey was able to differentiate novel from familiar real forms. The monkey was then tested with five Kanizsa illusory forms that were paired into four test conditions. Following a 2-sec habituation period, he was asked to correctly identify a novel illusory contour. The monkey showed chance performance averaged across the four test conditions (66%). However, at 12 months of age, he successfully demonstrated the ability to discriminate Kanizsa illusory contours (83%). These results indicate that the ability to discriminate differences between Kanizsa illusory forms develops between 6 and 12 months of age. Further, this evidence supports the idea that global form perception develops post-natally, at a more gradual rate than more basic visual functions.

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23.419

Filling in the Gaps: The Development of Contour Interpolation

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Adults can see bounded figures even when local image information fails to provide cues to specify their edges (e.g., Ginsburg, 1975). Such contour interpolation leads to the perception of subjective contours -- edges perceived in the absence of any physically present discontinuities (e.g., Kanizsa, 1955). We examined the development of sensitivity to shape formed by subjective contours and the effect thereon of support ratio (the ratio of the physically specified contours to the total edge length).

Children aged 6, 9, and 12 years and adults (n = 20 per group) performed a shape discrimination task. Sensitivity to shape formed by luminance-defined contours was compared to shape formed by subjective contours with high support ratio (interpolation of contours between the inducers was over a small distance relative to the size of the inducers) or low support ratio (interpolation of contours was over a larger distance).

Results reveal a longer developmental trajectory for sensitivity to shape formed by subjective contours compared to shape formed by luminance-defined contours: only by 12 years of age were children as sensitive as adults to subjective contours ($p<.05$), whereas sensitivity for luminance-defined contours was adult-like by 9 years of age ($p>.1$). The protracted development of sensitivity to subjective contours is consistent with evidence for delayed development of feedback connections from V2 to V1 (Burkhalter, 1993) known to be important for the perception of subjective contours (e.g., Ffytche & Zeki, 1996). As in adults, sensitivity to subjective contours was better with higher support ratio by 9 years of age ($ps<.01$). Remarkably, 6-year-olds' sensitivity was independent of support ratio ($p>.1$). The results suggest that, over development, support ratio becomes a reliable predictor for interpolation, so that contours that are more likely to reflect real objects' contours (i.e., highly supported contours) are more easily interpolated.

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23.420

An fMRI Examination of Contour Integration in Schizophrenia

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Background: Behavioral and electrophysiological studies of schizophrenia have consistently demonstrated impairments in the integration of visual features into unified perceptual representations. Specific brain regions involved in this dysfunction, however, remain to be clarified. This study used functional Magnetic Resonance Imaging (fMRI) to examine the relative involvement of visual cortex areas involved in form perception, and parietal and frontal regions involved in attention, in the visual integration impairment in schizophrenia. Methods: Fourteen patients with schizophrenia and 14 healthy controls were compared on behavioral performance and data acquired via fMRI while completing a contour integration task that had previously been used to identify a visual integration deficit in schizophrenia. Results: Schizophrenia patients demonstrated poorer con-

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tour integration than controls. Analyses of peak signal change indicated that while the groups were equivalent in area V1, the schizophrenia group demonstrated reduced signal in areas V2-V4, which are the earliest regions sensitive to global configurations of stimuli. Moreover, whereas the control group demonstrated greater recruitment of prefrontal and parietal areas during perception of integrated forms compared to random stimuli, the schizophrenia group demonstrated greater recruitment of frontal regions during perception of random stimuli. The groups differed on brain regions involved in form perception even when they were matched on accuracy levels. Conclusions: The contour integration disturbance in schizophrenia involves both deficient basic visual processes (beginning at least as early as occipital region V2), as well as reduced feedback from visual attention regions that normally serves to amplify relevant visual representations relative to irrelevant information.

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23.421

Perturbations of Element Orientations Reveal Grouping Processes in Contour Integration

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Surfaces in the world can produce extended contours on the retina. How are these extended contours perceptually constructed by visual processes that initially extract only small pieces of the contour (e.g., neurons with small receptive fields in V1)? We used response classification to determine how the orientations of small (12 arcmin) edge elements along an extended semi-circular contour influenced the perception of that contour. Four observers were familiarized with two canonical patterns formed by placing 13 elements either A) tangent to a semi-circular contour (3.2 deg diameter), or B) orthogonal to this contour. Observers perceived A as a smooth, semi-circular contour. Pattern B resembled a “necklace” with the elements pointing radially to the center of the semicircle. We then independently and randomly perturbed the orientations of the 13 elements using a uniform “orientation noise” distribution (+90 degrees in 5 degree bins) to create 2560 stimuli (each presented twice). Observers made a forced-choice classification on each trial; did the stimulus (presented for 167 ms) look more like the semi-circular or the radial canonical pattern? Using logistic regression we derived the relative weights for each observer for all 13 elements; the weights estimate the independent contribution of each element to the overall pattern classification. All observers gave more weight to elements near the middle of the stimulus (e.g., near clock positions from 5 to 7 for a 3 to 9 o’clock semi-circle). Using a model of contour integration based on natural image statistics (Geisler et al., 2001), we found that local elements were not treated completely independently in these judgments. Rather, adjacent elements were grouped into more extended pieces of the contour possibly using a transitive rule as proposed by Geisler et al. Even in a task that did not explicitly require contour integration, we find evidence for these elemental grouping processes.

23.422

Prediction by the human visual system: extrapolation of complex curves

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Successful prediction may be the main objective of any cognitive system. We investigate how humans solve the underconstrained problem of spatial extrapolation of complex 2D curves.

Contour continuation problems are usually modeled based on local variational principles such as minimizing total curvature or variation of curvature and have only been applied to a very limited set of curves classes. Singh&Fulvio (2006) showed that only a probabilistic model of these constraints can explain the continuation of arcs of Euler spirals.

We investigate whether the same model generalizes to more complex curves such as polynomials or regular curves, how much higher-order information is used and how the extrapolation is influenced by the experimental design. Subjects report either the position of a single curve dot behind a semi-circular occluder or draw the distribution of possible extrapolants.

Our results show that subjects report multiple curves for more complex curves if they are given the chance (e.g., by drawing distributions or by probability matching).

We approach the extrapolation problem from a more global Bayesian perspective and show that the results are more consistent with Bayesian model averaging rather than purely local models.

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23.423

Strength of Contour Interpolation Behind a Moving Occluder Revealed by a Dot Localization Task

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Contour interpolation mechanisms can allow perception of whole objects behind occluders despite fragmental inputs. Spatial and temporal integration of visual inputs has been examined using dynamically occluded displays, and Palmer, Kellman, and Shipley (2006) suggested that a visual representation, the dynamic visual icon, maintains fragmented inputs and integrates them across spatially and temporally sparse regions. Two aspects of dynamic visual icon remain to be explored. One involves the limits on visual persistence in the dynamic visual icon, and the other is the precision or strength of interpolation. Here, we examined the temporal limits of dynamic visual icon and the strength of interpolation behind moving occluder.

A dot localization task (Guttman & Kellman, 2004) was used to reveal the strength of interpolation and temporal span of visual persistence. An illusory-contour square 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. A small dot was presented near one of the illusory contours, and the observer made a forced-choice judgment of whether the dot appeared inside or outside the perceived illusory square. Dot position varied according to two interleaved staircase procedures. We estimated the location at which the observer perceived the interpolated contour and the precision or strength of its representation as a function of presentation cycle of inducing figures.

Results showed that error of location decreased with increasing presentation cycle, and that precision varied with the cycle. These results suggest that the temporal limits of dynamic visual icon are up to 200 ms, and that the strength of contour interpolation persists in a limited temporal span of visual processing. Further, our study indicates that the dot localization paradigm reveals the spatiotemporal and qualitative characteristics of visual representation of interpolated contour.

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URL: http://www.kgwu.ac.jp/faculty/bungakubu/shinri/unuma/index.htm

23.424

Implementing curve detectors for contour integration

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We recently presented a model of contour integration in which grouping occurs due to the overlap of filter responses to the different elements [May, K.A. & Hess, R.F. (2008). Journal of Vision, 8(13):4, 1–23]. The image receives two stages of oriented filtering, separated by a nonlinearity. Then the filter output is thresholded to create a set of zero-bounded regions (ZBRs) within each orientation channel. Finally, spatially overlapping ZBRs in neighbouring orientation channels are linked to form 3D ZBRs within the space formed by the two dimensions of the image along with a third dimension representing orientation. If the 1st and 2nd stage filters have the same orientation, the model detects snakes, in which the elements are

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parallel to the contour path; if the 1st and 2nd stage filters are orthogonal, the model detects ladders, in which the elements are perpendicular to the path. The model detects both straight and curved contours, and correctly predicts that detection of ladders is largely unaffected by contour smoothness, but fails to explain the finding that jagged snakes are harder to detect than smooth snakes that follow an arc of a circle. The advantage for smooth snakes, and several other findings, suggest that the primitive features detected by snake-integration mechanisms are fragments of contour with constant sign of curvature. A detector for any shape of contour can be created by summing spatially shifted outputs from different orientation channels: this is equivalent to filtering with a receptive field that matches the desired shape, and would be simple to implement physiologically. We extended our earlier model by combining filter outputs in this way to create detectors for smooth contour fragments with a range of different curvatures. This approach makes the model more robust to noise, and explains the advantage for smoothly curved snakes.

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Spatial Vision: Crowding and Peripheral Vision

Saturday, May 9, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

23.425

Response-Triggered Covariance Analysis of Letter Features

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Abnormal feature integration has been suggested as a cause of letter crowding. Nandy and Tjan (2007) reported that the number of letter features utilized by human observers is similar for identifying crowded and non-crowded letters, but there are fewer valid features and more invalid features for crowded letters. Using a set of 26 lowercase letters constructed of Gaussian patches that could be individually turned on or off, last year we reported that the patch locations within a given letter that correlated with an observer's response are largely invariant between the crowded and non-crowded conditions. To ascertain that the result was not an artefact of the assumption that each patch location was independent, and to identify higher-order features used by human observers, this year we adapted a covariance-based reverse correlation technique to examine if the amount of first- and second-order features (formed by a conjunction of patches) utilized for identifying crowded and non-crowded letters remains similar. We considered only the false-alarm trials and only at the target-letter location. We used the principal component analysis to partially prewhiten the distribution of the stimuli that were presented, before computing the mean stimulus (first-order classification image) and the covariance matrix, for each of the 26 letter responses. From the covariance matrix, we computed the second-order classification image for each letter response in the form of a correlogram. The RMS of the pixel values in each classification image was used to quantify the amount of features present. The amount of first- and second-order letter features at the target location was significantly lower ($p < 0.05$) for crowded than for non-crowded letters. Considering that the way we perturbed the stimulus did not include any spurious letter features, our finding is consistent with previous report that crowding leads to a decrease in the number of valid features.

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23.426

Positional averaging within and without contours explains crowding between letter-like stimuli

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Crowding - the breakdown in object recognition that occurs when objects are presented amongst clutter in the peripheral visual field - is known to depend on the similarity between simple targets and distractors (e.g. orientation). Here we consider how these findings generalise to more complex letter-like stimuli. We employed targets that were 'T's in one of four orientations (north, east, south or west) abutted by a single cross-like distractor falling in one of four locations (N,S,E,W relative to the target). Distractors were composed of horizontal and vertical lines identical to the target, but with a randomised intersection that fell anywhere within a square-region equal to the target dimensions. Stimuli were presented 10 deg. in the upper visual field at a size that supported 75% correct target-identification. In addition to the standard retinotopic anisotropy (e.g. more crowding from more eccentric distractors) we report several novel target-centered anisotropies (i.e. results that hold under global rotation of the entire target-distractor combination). First, for an upright T, distractors are more intrusive when they lie to the left or right than when they are above or below the target. Second, when subjects make errors their reports correlate strongly with the distractor identity. Although at first glance this is consistent with subjects confusing the identity of the distractor and target elements, a simple "distractor-substitution" model would predict equal confusions with all distractor types. By contrast, errors with an upright T target and a □ distractor (for example) were rarely due to subjects reporting the distractor-identity, compared to the case when distractors were 'left' and 'right' pointing 'T's. We show that a model based on the weighted positional average of the features comprising the target and distractor (with tighter positional tuning for near-aligned contour structure compared to non-aligned contour structure) produces behavior consistent with these results.

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23.427

A new technique for measuring the critical spacing of crowding

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Crowding is under intense study due to its relation to object recognition, but little is known about its development during childhood. The commonly used technique for measuring critical spacing requires the report of a target's identity while it is surrounded by distracters. While this method has proven effective in adults, infants and other difficult-to-test populations are unable to report a target. Here we introduce change detection as a tool to overcome this obstacle in measuring critical spacing. We simultaneously present two targets, one on each side of fixation. Each target is flanked by two distracters. All the stimuli are flashed at 2 Hz for 3 s. During one of the many flashes, one of the two targets is changed to a different target. When distracters are placed at or beyond critical spacing, the change attracts the observer's attention and induces a measurable saccade. We vary the spacing between the target and the distracters to determine critical spacing with unconstrained viewing and eye tracking. In a separate test, observers fixate and press a key to report on which side of the screen the change occurred. To confirm that our method produces results comparable to the traditional method, the same observers participate in a standard crowding test. Our results with normal adults show that the eye tracking method accurately measures critical spacing (slightly less than one half eccentricity) without explicitly asking the observer to report.

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23.428

Crowding by invisible flankers

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In this study the effect of masked flankers on crowding was explored using a moving array of letters and masks. A target letter moved briefly in a circular path around fixation. The target was flanked radially by two other letters, one on the inside and one on the outside that moved along with and crowded the target. Each flanker was preceded and followed (spatially and temporally) along its circular path by noise squares, which functioned as pre- and post-masks rendering the flankers invisible. Subjects were instructed to report the identity of the target. Observers failed to accurately report the identity of the target when it was crowded by flankers despite the fact that these flankers were masked and not visible themselves. A second test where the flankers were removed and only the masks were presented along with the target, confirmed that subjects were much more accurate in reporting the target when it was not crowded by the invisible flankers.

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23.429

Crowding without visual awareness

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Purpose. Visual crowding refers to the impaired identification of a peripheral stimulus when it is surrounded by flankers with similar patterns. According to an attention explanation, crowding happens because attention fails to individualize the target among the flankers due to limited spatial resolution of attention. As voluntary attentional selection requires visual awareness, here we ask whether visual awareness is necessary for crowding to happen.

Method. Two normally sighted observers adapted to a dicoptic stimulus located at 25° in the lower visual field for 5 s. The non-dominant eye was shown a low-contrast (x16 of the detection contrast threshold) Gabor target (oriented at 45°) with or without 4 Gabor flankers (oriented at 45° or -45°). The observers were unaware of the target and flankers because the percept was always dominated by a series of chromatic dynamic noise presented to the dominant eye. Contrast threshold at the retinal location of the target was measured by a 2IFC detection task. Threshold elevation was calculated by comparing thresholds with and without adaptation, and was measured in both crowded and isolated conditions.

Results. Threshold elevation was found only when the target and test had the same orientation. Threshold elevation in the crowded condition was 31 ± 6% lower than the control condition.

Conclusions. The magnitude of orientation-specific adaptation was reduced in the presence of flankers, even though the observers were unaware of neither the target nor the flankers. Thus, crowding happens without visual awareness. Our findings challenge the role of voluntary attention in crowding.

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23.430

The fine spatial structure of crowding zones

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Crowding, the marked inability to identify shapes in peripheral vision when targets are flanked by other objects, has been widely studied. The following gross characteristics of the zone of crowding have been consistently replicated and there is growing consensus that these represent the hallmarks of crowding: (a) the spatial extent of crowding scales with eccentricity (b) the zone is elliptic with its major axis pointing towards the fovea and (c) an outward flanker is more effective at crowding than an inward flanker. In the current study, we extended these findings by undertaking detailed measurements of the crowding zone by using a single letter ('E') to flank a letter target (one of 10 Sloan letters) positioned at 10° in the inferior field. The flanker was placed along 12 radial directions centered on the target and at 5 flanker-target separations (1.25° to 6.25°), thus obtaining identification accuracy measures at 60 locations around the target. We found that the crowding zone is not elliptical, even though an elliptic fit can be used to provide summary statistics that are in agreement with classical findings. More interestingly, our maps (obtained from three subjects) reveal that the zone of crowding is not convex, with islands of ineffective flanking locations intruding into an otherwise crowding-inducing region. These occur mostly along the tangential direction and can sometimes lie very close to the target. There is also significant variability of the zone among subjects. Our results augment existing data sets on the crowding zone, which tested only a few cardinal directions (typically 4) or used a pair of symmetrically placed flankers (e.g. Toet & Levi, 1992) that could bias the shape toward the fovea. Most importantly our findings will help the development of computational models that can account for the shape of the zone (Nandy & Tjan, SfN 2008).

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23.431

Crowding acts beyond the locus of binocular suppression

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Purpose: Crowding refers to the detrimental effect on object recognition caused by the presence of nearby objects. Crowding becomes stronger as the target-flanker similarity increases (Kooi, Toet, Tripathy, & Levi, 1994). Prior adaption to an image suppresses its percept in binocular rivalry. We use binocular suppression to dissociate what is presented to the eye ("eye level") and what is perceived ("percept level'). Here we ask if the similarity effect on crowding happens at the eye or the percept level.

Method: Three normal-sighted observers performed an orientation-discrimination task with Gabor patches (sigma of Gaussian envelope = 1/3 deg). A red target was presented to one eye at 5 deg in the lower visual field for 100 ms. Four flankers were presented to both eyes with different colours between the two eyes (red vs. green). The perceived flanker colour was manipulated by the colour of adapting patches (1s in duration prior to the presentation of the target). The flankers could have the same or different colour as the target at the eye and percept levels independently. The orientation threshold for 75% correct was estimated through the 2AFC method of constant stimuli with eight target orientations (0.01 to 30 deg tilt from the vertical line). The strength of crowding was measured by threshold elevation – the ratio of threshold in crowded conditions to threshold in isolated condition.

Results: At the "percept level", threshold elevation was significantly higher in the same-colour condition than in the different-colour condition (mean difference = 2.33 ± 1.71). At the "eye level", no significant difference was found between the same-colour and different-colour conditions (mean difference = 0.31 ± 0.35).

Conclusions: Crowding was made stronger by the increased colour similarity between the target and flankers at the percept level, but not at the eye level. Our data suggests that crowding happens after binocular suppression.

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23.432

The effects of transient attention and target contrast on crowding at different eccentricities

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This study examined the effects of target contrast and transient attention – the stimulus-driven component of spatial attention– on crowding at various eccentricities. Previous studies have found that precueing attention can improve identification accuracy and reduce the elevation of contrast and orientation threshold in crowding, but were inconclusive regarding the ability of attention to reduce the spatial extent of crowding (i.e., the critical distance). Reducing target-flankers similarity has also been shown to improve performance and reduce the extent of flankers' interference, but target contrast behaves differently –only when the target has a higher contrast than the flankers crowding is reduced.

To test how accuracy and the critical distance are affected by precueing, manipulation of contrast, and manipulation of eccentricity we performed 4 experiments in which the observers had to indicate the orientation of a target presented with 2 flankers. In two experiments we tested the effects of precueing transient attention. On the cued trials, a small dot appeared adjacent to the target location prior to its onset, and on the neutral trials a small circle appeared in the center. In the other two experiments we examined the effects of target contrast. We employed three contrast conditions: a) both target and flankers had high contrast; b) both target and flankers

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had low contrast; and c) the target had a higher contrast than the flankers. Additionally, in all four experiments we systematically manipulated target eccentricity and target-flankers distance.

The results show that both precueing target location and increasing target contrast improved accuracy and reduced the critical distance. Interestingly, when both the target and flankers had high contrast, accuracy was higher than when both had low contrast, though, the critical distance was not affected. Similar effects were found at all eccentricities. These findings are discussed with regard to the current views on crowding.

23.433

Texture processing model visualizes perception of Pinna-Gregory illusion

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We propose a model explaining the spiraling and intertwining circles illusions of Pinna & Gregory (2002). The spiral illusion is produced by a series of concentric circles, each composed of alternating black and white outlines of squares whose sides are aligned with the tangent of the circle. Rotating every square by 45 degrees in every other circle leads to a different illusion of intertwining circles. While the physical difference between the two illusions is a subtle change in orientation, the perceptual difference is great. Pinna & Gregory (2002) suggested that these illusions may result from interactions between long and short range integration. However, the illusion is absent at fixation, suggesting the effect is due to mechanisms of peripheral vision.

We have previously modeled visual crowding, a key aspect of peripheral vision, with a texture processing model (Balas, Nakano, & Rosenholtz, in submission). This model represents visual stimuli by joint statistics of cells sensitive to different position, phase, orientation, and scale. We suggest that the Pinna & Gregory illusions might be a natural by-product of this sort of statistical representation in peripheral vision.

Using (Portilla & Simoncelli, 2000) we can synthesize images which are constrained to share the same joint statistics as those computed. We call these images "mongrels". Our hypothesis is that these mongrels are, approximately, "samples" of peripheral percepts of the stimuli. Do mongrels of these illusory stimuli predict the illusory percepts?

Subjects marked contours on mongrels from the spiral and intertwining illusions, or from a control image of concentric circles made of only white squares. Their markings corresponded to the perception of spirals, many intersecting contours, or concentric circles, respectively. This suggests that the model makes accurate perceptual predictions for these illusions, and provides a method to peek into a possible representation of visual information in the periphery.

Acknowledgement: Edward Adelson

URL: http://people.csail.mit.edu/alvin/pinnaweb/pinna.html

23.434

Radial line bisection biases in the periphery

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The perceived midpoint of a horizontal line is typically to the left of center. Line bisection biases also occur for centrally presented vertical lines. A number of studies have found that vertical and horizontal lines biases are uncorrelated, suggesting that bisection biases are based on independent mechanisms for vertical and horizontal lines. We measured line bisection biases in the near periphery to look for independent line bisection mechanisms beyond the central visual field. Lines with 0, 45, 90 or 135 degrees orientation were displayed at eight peripheral locations. Each trial displayed a pre-transected line for 200 msec and the observers (n=4) pressed a button to indicate which end the transector appeared nearest. The position of the transector was adjusted using a staircase procedure with the point of subjective equality calculated as the average of the last six staircase reversals. The line bisection bias at a given orientation and visual field location was based on the average point of subjective equality from eight to ten staircases. The results showed a consistent pattern of line bisection biases that appeared to be radial for three observers. Two observers showed a centripetal bias but one observer showed a centrifugal bias. The radial pattern of line bisection biases may indicate that vertical and horizontal biases are mediated by a single mechanism in the periphery. Furthermore, the individual differences in direction of bias may indicate that line bisection depends on a plastic representation of space across the visual field. The data can be explained by a metric of space that relies on the allocation of attention. Some observers may attend to the inner part of line segments, resulting in a centripetal line bisection bias, while others attend to the outer segment, resulting in a centrifugal line bisection bias.

23.435

Does semantic information survive crowding?

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Visual crowding degrades feature discrimination and object recognition in the periphery, yet several studies have demonstrated continued processing specific to the crowded target (e.g. He et al., Nature, 1996; Parkes et al. Nature Neuro, 2001; but see Hancock et al, JOV, 2008). Findings of residual processing can be utilized to test mechanism(s) of crowding (for a review, see Levi, Vis. Res, 2008). We examined associative priming in flanked and unflanked conditions using a lexical decision task (LDT). In a dual-task threshold experiment, subjects viewed a flanked or unflanked word (or non-word) in the periphery and made a 2AFC word/ non-word discrimination. Second, they reported any individual letters seen in the letter string. Across the seven eccentricities tested, we found the classic pattern of crowding for both tasks. In the main experiment, a flanked or unflanked prime word preceded a semantically related or unrelated target word that appeared at fixation (e.g. target 'WEST' paired with prime 'EAST', or 'TAKE'). The prime word appeared near Bouma's boundary, or at one of two peripheral eccentricities that had been determined to be well crowded in the threshold experiment. Following each LDT, subjects also made a word/non-word discrimination of the prime word to verify crowding on each trial. Across all trials, a comparison of reaction times between the related and unrelated conditions (Unrelated – Related) revealed an associative priming benefit in the unflanked condition and to a lesser degree in the flanked condition. However, when only incorrect trials were analyzed (a strict measure of crowding) priming was reduced in the flanked condition. Four of five subjects followed this pattern of results. These findings suggest that crowding reduces the semantic priming effect.

23.436

The limit of spatial resolution varies at isoeccentric locations in the visual field

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Goal: Human visual performance varies across the visual field. Performance decreases with eccentricity in a variety of tasks. Performance can also differ at isoeccentric locations. Both contrast sensitivity and spatial frequency discrimination are better along the horizontal meridian than the vertical meridian resulting in a horizontal-vertical anisotropy (HVA) and at the lower than the upper region of the vertical meridian, resulting in a vertical meridian asymmetry (VMA). Furthermore, the limit of spatial resolution – the spatial frequency at which discrimination performance is at chance (cutoff point) – is lower in the periphery than in the fovea. Here, we investigated whether the HVA and the VMA extend to spatial resolution: Do the cutoff points in resolution vary at isoeccentric locations in the visual field?

Method: Observers performed an orientation discrimination task on Gabors of varying spatial frequency at four isoeccentric locations of the visual field (North, South, East and West). In each trial, a tilted Gabor patch was presented in one of the above-mentioned locations at either a parafoveal or

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peripheral eccentricity (4 vs. 8 degrees). We obtained psychometric functions for orientation discrimination with respect to spatial frequency for each location and then estimated the spatial frequency cutoff point.

Results and conclusions: Cutoff spatial frequencies were significantly lower, indicating poorer performance, along the vertical meridian (North and South) than the horizontal meridian (East and West) at both parafoveal and peripheral eccentricities. In addition, they were lower for the North compared to the South location. These results show that the limit of spatial resolution, assessed by spatial frequency cutoff, differs at isoeccentric locations in the visual field. We propose that the observed differences originate from underlying anatomical inhomogeneities (e.g., cone density and cortical extent of the field representation) along the meridians.

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23.437

Increasing time compression with eccentricity: A magnocellular property?

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It has been demonstrated that a decrease in stimulus visibility causes apparent time underestimation mediated by transient signals(1). Therefore, time compression should increase in peripheral vision as consequence of a decrease in stimulus visibility. We used parvocellular (P) and magnocellular (M)-biased flashes to test time perception in the range of milliseconds of a variable flash interval (VFI) at different eccentricities (0-48º). We found for both (M and P-biased flashes) an increase in time compression with eccentricity. Nevertheless, when stimulus visibility was "equalized" across the visual field, an increase in time compression was only found for M-biased stimuli. A second task was performed using the same P and M-biased flashes and VFI. Subjects reported if they perceived one or two successive stimuli. Results showed that the minimum VFI to avoid that the second flash was masked by the first one increased with eccentricity for the M-biased but not for the P-biased flashes in both -"standard" and "equalized"- conditions. Then we hypothesize that M pathway accounts for time underestimation and that its increasing with eccentricity could be an inherent property of the M system more than a result of a decrease in stimulus visibility. These results allow a better understanding of the temporal dynamics of conscious perception across the visual field and gives new clues about the role of M pathway in awareness. (1) Terao M et al, Reduction of stimulus visibility compresses apparent time intervals. Nat Neurosci. 2008 May;11(5):541-2

23.438

The Letter in the Crowd: Developmental Trajectory of Single Letter Acuity and Foveal Crowding

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Crowding (Stuart & Burian, 1962) refers to impaired target recognition caused by surrounding contours. Studies on developmental changes in crowding (Atkinson et al., 1988; Bondarko and Semenov, 2005; Semenov et al., 2000) fail to provide a clear picture. To investigate the developmental trajectory of foveal crowding, groups (N = 20/age group) of adults (mean age = 19.4 yrs, range 18 - 23 yrs) and children aged 5.5, 8.5 and 11.5 years (± 3 months) were asked to discriminate the orientation of a Sloan letter E. We first measured the single-letter threshold, defined as the stroke width discriminable at 79% correct performance. We then multiplied the single-letter threshold by 1.2 and surrounded it with flankers consisting of four sets of three bars randomly oriented horizontally or vertically. The crowding threshold was measured as the distance between the nearest edges of the flankers and the central letter yielding 79% correct performance.

Mean single-letter thresholds were 1.0, 0.8, 0.8 and 0.8 arcmin for 5-, 8-, 11-year-olds and adults, respectively. Single-letter thresholds for 5-year-olds were significantly worse than those for all older age groups, which did not differ significantly from each other. The crowding threshold did not differ significantly among children, (9.9, 9.7, and 7.8 times stroke width for 5-, 8-, and 11-year-olds, respectively) but decreased significantly to 3.5 times the threshold stroke width in adults. Thus, single letter acuity is mature by age 8 but even 11-year-olds need more space between adjacent contours than do adults to avoid the deleterious effects of crowding. According to current theories (Levi, 2007; Motter, 2002; Pelli et al., 2007), crowding occurs when features of stimuli are inappropriately combined. Therefore, the stronger influence of crowding on younger children might be caused by immaturities in the brain areas where early visual inputs are combined, such as V4.

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

23.439

Towards an easier way to measure the visual span

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While reading, people advance their eyes by a distance equal to the "visual span," four times per second. Thus, the tenfold increase in reading speed during childhood implies a proportional increase in the visual span, and there is some data to support this (reviewed in Pelli & Tillman, 2008, Nature Neuroscience). The visual span is defined as the number of letters, in a line of text, that one can identify without moving one's eyes. That is hard to apply with children. In normal adults, the visual span is limited by crowding. It is not clear what determines the visual span of children. We are developing a paper test to measure visual span. Large visual gaps are introduced, isolating words below a certain length, and this impairs reading speed if the words are shorter than the visual span. We will describe several different designs and their merits. All require only a stopwatch and an observer who can read.

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URL: http://psych.nyu.edu/pelli/posters.html

Multisensory Processing: Visual and Auditory Perception

Saturday, May 9, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

23.440

Cross-modal transfer of motion processing from audition to vision

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In order to best navigate our world, we must combine information gathered by our various sensory systems. What role does feature-based attention play in the integration of multi-modal stimuli? In vision, feature-based attention has been shown to enhance the processing of an attended feature, such as a specific direction of motion, throughout the visual field. Do these attentional effects transfer across modalities?

Previous research has suggested that the transfer of visual motion to auditory motion processing originates at the neural level. However, evidence for the symmetric transfer of auditory motion to visual motion processing has proved more elusive. We investigated whether controlled attention to auditory motion in depth accentuates the processing of visual motion in depth, as measured psychophysically. Auditory motion in depth was simulated by a ramp in volume over time that either increased for motion toward the observer or decreased for motion away. The adapting stimulus was visual motion in depth that was simulated by either an expanding or contracting ring centered at fixation. Subjects attended to either auditory motion in the same direction as the adapting visual stimulus, or to auditory motion in the opposite direction as the adapting visual stimulus. After adaptation, we measured the strength of the visual MAE using a motion nulling paradigm. The visual MAE was larger when the visual motion was in the same direction as the attended auditory motion, suggesting

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that auditory motion in depth enhances the processing of a corresponding visual stimulus. This transfer of motion processing across modalities could facilitate the binding of corresponding sensory information into a unified percept of a single moving object, enhancing the ability of the visual system to interpret motion in depth.

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Synesthetic colors for phonetic Japanese characters depend on frequency and sound qualities

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The determinants of synesthetic color choice for Japanese characters which symbolically represent vowels or syllables were studied in two Japanese synesthetes, who report seeing color for characters. The study used Hiragana and Katakana characters that represent the same set of syllables although their visual forms are dissimilar. The synesthetes selected a color corresponding to 71 Hiragana and 71 Katakana characters from a palette of 138 colors. Both synesthetes showed a similar and stable tendency. First, the results for Hiragana and Katakana characters were remarkably consistent. For both synesthetes, the mean geometric distance in the RGB color space between the colors selected for a Hiragana character and its Katakana counterpart were less than half of the average distance between the 138 colors used in this experiment. The selection depended on the sounds of the characters, not on the physical form of the visual input. Second, saturated colors were chosen for single vowels, while muted colors were chosen for voiced consonants. The results suggested that the color saturation depended on the frequency of the characters. Third, the color choice was more influenced by the consonant than by the vowel. Characters that share the same consonant were colored with similar hues, while no hue consistency was found for characters with the same vowel. The synesthetes were retested three weeks later, and their color selections were identical or very similar. Overall, these results indicate that the synesthetic colors for phonetic Japanese characters (Hiragana and Katakana) depend on the characters' frequency and sound qualities, especially of the consonants.

23.442

Synesthetic colors for logographic Japanese characters depend on the meaning

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The determinants of synesthetic color choice for Kanji characters (Japanese logographs, which symbolically represent a word or phrase) were studied in two Japanese synesthetes, who report seeing color for characters, numerals and letters. The genuineness of their synesthesia was tested by an embedded pattern detection task out of a monochrome array of scattered Arabic numerals (Ramachandran & Hubbard, 2001), where both of them showed outstanding performance. Eight sets of 12 Kanji characters were used as stimuli that represent numerals, color names, names of colored objects, and are homophones (two sets of /kou/ and /shi/), characters sharing the same components (left and right radical sets), and characters that are composed of component(s) that are visually similar to Katakana characters (Japanese phonetic symbols). The synesthetes selected a color corresponding to each Kanji character from a palette of 138 colors. Both synesthetes showed a similar and stable tendency. First, their color selections for Kanji numerals were remarkably consistent with those for Arabic numerals, which had been tested separately. For both synesthetes, the mean geometric distance in the RGB color space between the colors selected for a Kanji numeral and its Arabic counterpart were less than half of the average distance between the 138 colors used in this experiment. Second, the corresponding color selection was consistent with almost all the Kanji characters for color names and colored objects. Third, their color selection did not depend on homophony or radical commonality. Fourth, the colors selected for compound Kanji characters were not determined by the components, but were determined by the overall meaning. Taken together, these findings suggest that for logographic Kanji characters, the synesthetic color selected by both Japanese synesthetes depends on the meaning.

23.443

Perception-based responses in a sub-region of multisensory superior temporal sulcus: Distinct BOLD responses with perceived-synchronous and perceived-asynchronous audiovisual speech

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Research on audiovisual integration has shown the superior temporal sulcus (mSTS) to respond differentially to temporally-synchronous and asynchronous stimuli. Specifically, a sub-region of mSTS responds only to stimuli that are temporally aligned in a binary fashion, with no response to stimuli out-of-sync even 100ms. A second sub-region of mSTS has been shown to produce a graded response: the more asynchronous a stimulus, the higher the BOLD response. Here, we investigate the latter sub-region by testing a hypothesis that this sub-region of mSTS responds differentially to the perception of asynchrony, as opposed to the level of asynchrony of the stimulus.

To test this hypothesis, we identified the asynchrony level at which each participant perceived audiovisual spoken-word stimuli to be synchronous 50% of the time and asynchronous 50% of the time (mean = 167ms). Two types of fMRI runs were presented. First, block-design localizer runs in which audio-only, visual-only, or audiovisual spoken words were presented while participants performed a one-back task. Second, event-related runs in which audiovisual spoken words were presented with either no offset (synchronous), a 400ms offset (asynchronous), or at the individuals 50%-level offset while participants performed a synchrony-judgment task.

A sub-region of mSTS was identified using localizer runs, defined as the conjunctions of areas that responded to audio-only and visual-only presentations. BOLD responses were then extracted from event-related runs. As previously shown, asynchronous stimuli elicited greater BOLD responses than synchronous stimuli. Trials at the 50%-level of asynchrony were divided by perception into perceived-synchronous and perceived-asynchronous trials. Importantly, BOLD responses with perceived-synchronous trials matched those of physically-synchronous trials (offset = 0ms), and BOLD responses with perceived-asynchronous trials matched those of asynchronous trials (offset = 400ms). Thus, activation in this region of mSTS is influenced primarily by the perceived synchrony of the audiovisual stimulus, rather than the actual physical synchrony.

23.444

Perceived Temporal Synchrony: Interactions Between a Continuous Audiovisual Stream and a Discrete Audiovisual Event

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Temporal synchrony is the perception of simultaneity from sensory inputs that may not necessarily be simultaneous. We sought to determine whether there were differences in perceived temporal synchrony between a continuous audiovisual stream and a discrete audiovisual event. We also determined whether the audiovisual stream and the audiovisual event interacted with each other when presented simultaneously. Five participants viewed either a 3-second 1 Hz sinusoidally oscillated audio visual stream, a 167 msec audio visual event, or a combination of both. The audiovisual stream consisted of white noise and a grating; the intensity of the white noise and the contrast of the grating oscillated between 10% and 40%. The audiovisual event consisted of white noise and a grating at 100% intensity and contrast. The audio and visual components of both the stream and the event were temporally offset by ±300, ±233, ±150, ±83, or 0 msec. Participants judged the synchrony of the audiovisual stream, the audiovisual event, or both depending on what was present in that particular trial. The data showed that when presented alone, participants were more sensitive to temporal offsets in an audiovisual event than in an audiovisual stream. When presented with an audiovisual stream, participants were less sensitive to the temporal offsets in the audiovisual event and the synchrony of the audiovisual stream itself did not influence the perception of the

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audiovisual event's temporal synchrony. However, when presented with an audiovisual event, participants were not less sensitive to the temporal offsets in the audiovisual stream. Also, there was a trend that the perception of temporal synchrony in the audiovisual stream was biased towards the temporal synchrony of the audiovisual event. These data support the importance of distinct features as critical determinants of temporal synchrony and show that temporal synchrony information present in two events can influence one another.

23.445

Timing the sound-induced flash illusion

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In the sound-induced flash illusion, when two beeps are presented simultaneously with a flash, a second illusory flash is perceived (Shams, Kamitani & Shimojo, 2000). Even though this phenomenon has been examined by a number of authors (e.g., Andersen, Tiippana & Sams, 2004; Berger, Martelli & Pelli, 2003; McCormick & Mamassian, 2008; Shams, Kamitani & Shimojo, 2002), little is known about the exact parameters driving the illusion. A recent study found that the effect is not as robust as it was previously thought, and there is a large disparity in the occurrence of the illusion from a subject to another (Mishra, Martinez, Sejnowski & Hillyard, 2007). A number of reasons might explain this variable occurrence of the illusion but one of them is that the parameters used to generate the illusion are suboptimal. It has been shown that timing is an important aspect of multisensory illusory effects, such as in the McGurk (Munhall, Gribble, Sacco & Ward, 1996) and the ventriloquist effects (Slutsky & Recanzone, 2001). Here, we investigated the temporal constraints of the sound-induced flash illusion. More specifically, we studied the effect of the variance in the timing of the flashes and the beeps using a classification image technique. Results will be given a Bayesian interpretation.

23.446

Sensory and decisional factors in the resolution of stream/bounce displays

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The stream bounce effect (Sekuler, Sekuler & Lau, 1997) typically depicts two identical targets that move toward one another from opposite sides of a 2-D display, coincide, and continue past one another along linear trajectories. The targets can be perceived to either stream past or bounce off of one another with equal likelihood. However, streaming is the dominant perception in motion displays free of additional transients while a transient (e.g. auditory or visual) presented at the point of coincidence shifts this bias towards bouncing. From a psychophysicist's point of view, this transient induced shift in perceptual bias could be caused by at least three factors: 1) integration at the sensory level where the transient signal and the visual motion sequence are integrated at an early stage of processing and that combination becomes available to conscious awareness determining the response; 2) a decisional level of processing where the two inputs are available independently and the observer's response is based upon decisional biases or strategies; 3) a combination of 1 and 2. We quantified the relative contributions of sensory and decisional factors in resolving stream/bounce displays using novel motion sequences in which the motion targets were visually distinguishable. We measured sensitivity (d') and criterion (c) using a signal detection paradigm in which targets objectively streamed on 50% of the trials and bounced in the remaining trials. We presented an auditory click at coincidence on 50% of the streaming and 50% of the bouncing sequences. Observers were required to indicate whether the targets streamed or bounced. Mean d' values for detecting bounces were little different between the sound and no sound conditions while c was significantly more liberal in reporting bounces in the sound condition compared to the no sound condition. These results suggest decisional factors dominate the resolution of stream bounce displays.

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23.447

Auditory-visual integration in texture perception mediated by tactile exploration

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People often examine textured surfaces by rubbing them, producing sounds characteristic of each texture. Because people move their fingers at a relatively constant speed, we predicted that modulation frequencies in vision and audition may be representationally associated. For example, if a texture is coarse, it will be low in spatial frequency and rubbing it will generate a sound with low-frequency amplitude modulation; if a texture is fine, it will be high in spatial frequency and rubbing it will generate a sound with high-frequency amplitude modulation. If these associations result in auditory-visual integration, one would predict that (1) observers should be able to consistently match each spatial frequency with an appropriate frequency of amplitude modulation, and (2) the ratio of the matched amplitude-modulation frequency to spatial frequency should be relatively constant, and it should agree with the typical speed of tactile exploration. Note that the matching should be based on physical rather than retinal spatial frequency because the sounds generated during tactile explorations depend on the former. As predicted, the matched visual and auditory modulation frequencies were strongly correlated, and the matching did not depend on viewing distance (55 or 110 cm) indicating its dependence on physical spatial frequency. Speeds of tactile exploration inferred from these matches were 2.8, 5.1, and 8.7 cm/s for gratings with physical spatial frequencies of 3.33, 1.25, and 0.33 cm–1, respectively. First, these inferred speeds are reasonable for tactile explorations. Second, the fact that the inferred speed increased for lower spatial frequencies is consistent with the fact that the speed of tactile exploration needs to be increased for slowly undulating textures to generate a reasonably high vibratory frequency for tactile receptors. Overall our results demonstrate an auditory-visual integration in texture perception that is likely to be mediated by the multisensory experience of examining surfaces.

23.448

Veridical auditory information enhances visual sensitivity to biological motion

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People exhibit remarkable visual sensitivity to point-light displays of human movement. A neural region that has been strongly implicated in the perception of human actions generally, and the processing of point-light displays specifically, is the posterior region of the Superior Temporal Sulcus. The STSp has also been implicated in the integration of signals across modalities in the formation of multimodal representations of observed actions.

Because perception of human action is mediated by the STS, and because the STS has been implicated as a region where sensory inputs are integrated, we hypothesized that the addition of auditory cues corresponding to human actions depicted in point-light displays should improve visual sensitivity to those actions. Previous research has shown that audiovisual temporal frequency matching improves when auditory cues are phase-locked to upright point-light walkers but not to scrambled or inverted versions of these displays (Saygin, Driver, & De Sa, 2008). Here we further asked whether semantically appropriate auditory cues improve sensitivity more than cues that are coincident with the action but semantically unrelated.

To test this hypothesis, a psychophysical study was conducted wherein participants detected the presence of coherent point-light walkers in a mask under unimodal (visual) or audiovisual conditions. Participants in the

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audiovisual conditions heard either pure tones or veridical footfalls coincident with the walkers' footsteps. Results revealed a significant improvement in detection sensitivity when visual displays were paired with veridical auditory cues (footfalls). The addition of coincident yet non-veridical auditory cues (tones) tended to, but did not significantly, enhance detection of coherent point-light walkers. The fact that merely coincident auditory cues did not increase detection sensitivity suggests that the effect cannot be due to temporal coincidence alone. Rather, these psychophysical results converge with neurophysiological evidence suggesting that the analysis of human action reflects the integration of high-level auditory and visual processes.

23.449

Multisensory Cue Integration in Audiovisual Spatial Localization

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Introduction: In line bisection (LB) tasks healthy observers perceive the midpoint (pse) of visual stimuli, such as lines, leftward of veridical - a phenomenon known as pseudoneglect (PN) (Jewell & McCourt, 2000). A rightward bias has been reported for spatial intervals defined by auditory stimuli. Lateral visual cues further bias pse (McCourt et al., 2005). We ask whether auditory cues can similarly bias pse in a visual LB task, and characterize the interaction of visual and auditory spatial cues. Bayesian rules characterize cue combination for many tasks; however, multisensory interactions are frequently superadditive (non-Bayesian). We test various cue combination rules concerning their ability to predict visual line bisection behavior. Methods: Forty-six observers completed a tachistoscopic LB task (McCourt & Jewell, 1999). Pse was determined in an uncued condition, as well as when unilateral visual and auditory cues were delivered, alone or in synergistic or antagonistic combination. Results: A 3 x 3 repeated measures ANOVA demonstrated a significant leftward bias (PN) in line-bisection judgments. Pse was influenced by cues such that left cues induced greater leftward bias than those elicited by right cues. This bias was strongest when the visual cue was presented to the line's left and weakest when visual cue was presented to the line's right. Similarly, leftward bias was significantly smaller when an auditory cue was presented to the line's right than when there was no auditory cue present. Discussion: A Bayesian cue combination model and a Quick-summation model (capable of accommodating both super- and sub-additive summation) were compared in their ability to predict the subject data. Model results and Akaike Information Criteria values for each model are presented.

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23.450

See an object, hear an object file: Object correspondence transcends sensory modality

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An important task of perceptual processing is to parse incoming information from the external world into distinct units and to subsequently keep track of those units over time as the same, persisting internal representations. Within the realm of visual perception, this concept of maintaining persisting object representations has been theorized as being mediated by 'object files' – episodic representations that store (and update) information about objects' properties and track objects over time and motion via spatiotemporal information (e.g., Kahneman et al., 1992). Although object files are typically conceptualized as visual representations, here, we demonstrate that object-file correspondence can be computed across sensory modalities. We employed a novel version of the object-reviewing paradigm: Line-drawn pictures (e.g., a phone and a dog) were briefly presented within two distinct objects in a preview display. Once the pictures disappeared, the objects moved (to decouple objecthood from location) and then a sound (e.g., a dog bark) occurred. The sound was localized to the left or right of the display, corresponding to the end locations of the two objects. Participants were instructed to indicate whether the sound matched either preview picture or whether it was novel (e.g., a dog bark would 'match' if either preview picture was a dog). Participants were significantly faster to respond when the sound occurred with the object originally containing the associated picture compared to when the sound occurred with the other object. This significant response time benefit provides the first evidence for visual and auditory information working in tandem to underlie object-file correspondence. An object file can be initially formed with visual input and later accessed with corresponding auditory information. Object files may thus operate at a highly abstract level of perceptual processing that is not tied to specific modalities.

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23.451

Visual, auditory and bimodal recognition of people and cars

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We have an impressive ability to quickly recognize people from seeing their face and can also recognize identity, but not as well, from a person's voice. When both a voice and face are paired together we show an intermediate level of performance. Here we asked whether this dominance of visual information over auditory information was specific to face-voice pairs or whether this was also the case for recognition of other auditory visual associations. We specifically asked whether visual and auditory information interact differently between face-voice pairs compared to car-car horn pairs. In two separate experiments, participants learned a set of 10 visual/auditory identities— face-voice pairs and car-car horn pairs. Subsequently, participants were tested for recognition of the learned identities in three different stimulus conditions: (1) unimodal visual, (2) unimodal auditory and (3) bimodal. We then repeated the bimodal condition but instructed participants to attend to either the auditory or visual modality. Identity recognition was best for unimodal visual, followed by bimodal, which was followed by unimodal auditory conditions, for both face-voice and car-car horn pairs. Surprisingly, voice identity recognition was far worse than car horn identity recognition. In the bimodal condition where attention was directed to the visual modality there was no effect of the presence of the auditory information. When attention was directed, however, to the auditory modality the presence of visual images slowed participant responses and even more so than in the unimodal auditory condition. This effect was greater for face-voice than car-car horn pairs. Despite our vast experience with voices this yields no benefit for voice recognition over car horn recognition. These results suggest that, although visual and auditory modalities interact similarly across different classes of stimuli, the bimodal association is stronger for face-voice pairs where the bias is toward visual information.

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23.452

Characteristic sounds make you look at the targets faster in visual search

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We previously demonstrated that characteristic sounds (without location information) facilitate target localization in visual search (PBR 2008). 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. However, because response time was indicated by key presses, it is possible that characteristic sounds might have facilitated the process of target confirmation, rather than the process of searching for the target. The present study investigates this using eye movements as the mode of response. The target (e.g., a cat) was verbally indicated at the beginning of each trial. Each search display contained a target (e.g., a cat) and seven distractors (e.g., a car, a mosquito, a dog, a lighter, a bicycle, a stapler, and a wineglass). The display was presented simultaneously with a sound that was either associated with the target (e.g., "meow") or a distractor (e.g., "clink"), or with no sounds. The task was to fixate the target as quickly as possible. As soon as the participant fixated the target (as determined with an eye tracker) the search display disappeared and response time was recorded. This saccadic response time reflects the time it takes to find the target and is unlikely to be contaminated by post-search processes such as target confirmation. The targets' characteristic sounds significantly speeded saccadic response times compared to both distractor sounds and no sounds. Furthermore, characteristic sounds produced a significantly higher proportion of fast response times (<250 ms) as compared to both distractor sounds and no sounds. These new results confirm that characteristic sounds speed the process of locating visual targets via object-specific cross-modal enhancements. Indeed, when you look for your lost keys, you should jiggle someone else's.

23.453

Multisensory Benefits of Playing Video Games

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A fundamental aspect of perception is the rapid and reliable combination of sensory information from multiple modalities. Accurate perception of a given multisensory object is therefore highly reliant on the ability to analyze and compare the temporal and spatial information of the input from each modality such that their correspondence is correctly computed. Previous studies have shown that playing video games enhances visual attention as well as visual perception (e.g., Green & Bavelier, 2003; 2007). However, considering that video games are typically multisensory in nature, containing both auditory and visual components, their influence seems likely to reach beyond unimodal visual effects and to alter the processing of multisensory information more generally, a realm that has been little investigated. To address this, we presented subjects with auditory and visual stimuli occurring at varying stimulus onset asynchronies (SOAs) in 50ms increments, from the auditory stimulus (a tone) coming 300ms before the visual (a checkerboard) to 300ms after. Subjects participated in a simultaneity judgment task (did the stimuli appear at the same time or at different times?) and a temporal-order judgment task (which stimulus came first?). For the simultaneity judgment task, non-video-game players showed a broader and more asymmetric window of integration, as they were more likely than video-game players to report the stimuli as simultaneous when the auditory followed the visual. In the temporal-order judgment task, video-game players were more accurate than non-video-game players at the most difficult SOAs (those close to simultaneous). No between-group differences in response times were observed; however, all subjects responded more slowly at the most difficult SOAs. Together, these results suggest that the benefits of playing video games occur not only in the visual modality, but they can also impact the processing of multisensory information, including by altering one's temporal window and accuracy of multisensory integration.

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Attention: Capture

Saturday, May 9, 8:30 am – 12:30 pm
Poster Session, Vista Ballroom

23.501

Informative cues attenuate attentional capture by irrelevant distractors

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Irrelevant color distractors capture a participant's attention during search for a unique shape. However, this capture may not be a purely bottom-up process. Recent research in our lab (Moher, Egeth, Yantis, and Stuphorn, in preparation) has demonstrated that foreknowledge of the probability that an irrelevant color distractor will appear has an impact on the attentional capture achieved by that specific distractor; expected distractors caused less interference in visual search compared to unexpected distractors in both eye tracking and manual response time data. Recently, we have begun exploring whether giving participants information about the upcoming distractor, such as its location or color, will attenuate the effects of capture. In a series of experiments, participants searched for a unique shape among 8 otherwise homogenous shapes, and there was a color distractor present on half of all trials. Prior to each trial, subjects received one of three different cue types. One cue type was neutral, which contained no information about a distractor on the upcoming trial. A second cue type told participants that there would be a distractor on the upcoming trial. A third cue type told participants either the color of the upcoming distractor (Experiment. 1) or the location of the upcoming distractor (Experiment 2). All cues were 100% predictive. Cues that were informative about the color, location, or even mere presence of an upcoming singleton distractor lead to less interference by that distractor. Previous research has shown that participants can use information about an upcoming target to speed visual search. These results suggest that participants are able to incorporate information about an upcoming irrelevant distractor in order to attenuate the effects of that distractor and thus speed visual search as well.

Saturday Sessions

23.502

Top-Down Control of Attention Capture Takes Time: Evidence From Trial By Trial Analyses of Capture by Abrupt Onsets

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A number of studies have shown that observers can employ top-down control over attentional capture by abrupt onsets. For example, abrupt onsets that do not match an observer's attentional set (Folk et al, 1992) or those that occur outside the focus of attention (Theewes, 1991), do not capture attention. Likewise, when observers perform a search task high in perceptual load, the ability of abrupt onsets to capture attention is attenuated (Cosman & Vecera, 2008). However, in the real world our attention is regularly captured by items that are completely irrelevant to the task we are performing at a given time. Studies showing evidence of top-down control of capture by abrupt onsets have employed blocked designs in which reported reaction times are averaged across multiple blocks of trials. As a result, it is possible that onset capture in early trials is obscured by aggregating RTs across blocks of trials. The current set of experiments attempted to examine whether or not infrequent or strategically presented abrupt onsets that are completely irrelevant to task performance capture attention in the face of top-down manipulations known to attenuate such capture. Participants performed a contingent-capture task, a focused attention task, and a perceptual load task in which the abrupt onset was never relevant to performance of the task. Across all experiments, it was shown that during early trials abrupt onsets captured attention regardless of top-down attentional control settings. This effect eventually decreased and disappeared in later trials, indicating that top down control took time to "tune up" to the displays used in a given task before affecting attention capture. These results suggest that the configuration of top-down control takes time and that abrupt onsets can initially capture attention despite top-down control settings.

23.503

Attentional capture by a salient non-target improves target selection

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Salient non-targets usually interfere with target selection and produce increased reaction times (RTs) and lower accuracy (e.g. Posner, 1980). Here we demonstrate that a perceptually salient (i.e. high contrast) non-target can facilitate target selection in a visual search task, when it is predictable. Eye-tracking data indicate that this facilitation is due to better inhibition and faster non-target rejection when attention is captured. Inhibition was

indexed by more first fixations away from the salient non-target as well fewer subsequent fixations on the non-target. Faster rejections due to attentional capture were indicated by shorter first saccade initiation times to the salient non-target followed by shorter dwell times once the non-target had been fixated. This effect of salient non-target facilitation was modulated by working memory such that higher visual short term memory loads produced less inhibition (more attentional capture) and less effective non-target rejection of the salient non-target. This suggests that working memory is essential for maintaining a representation of the salient non-target's task-relevance and initiating commands to move attention and the eyes away from it. We argue that while attentional capture by perceptually salient stimuli may be automatic, information regarding the current statistical relevance of that stimulus may be held in working memory and used to guide voluntary attention and maximize behavioral efficiency.

23.504

Bridging attentional capture and control: Evidence from a partial report paradigm with color singletons

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Despite a vast body of research, it remains unclear whether a singleton captures attention even if the singleton is of no relevance to the task. The present study addressed the question of how the presence of a color singleton influences the efficiency of target selection in a partial report experiment with poststimulus masks. Subjects reported the letters from a circular array of 6 letters and 0, 2, or 4 digits. All characters were white and encircled by a white outline. One twelfth of the presented letters and one twelfth of the presented digits were color singletons. A singleton differed from other characters only with respect to the color of the encircled local background. For both singleton and nonsingleton elements, the probability that an element showed a letter rather than a digit was 5/7. At most one singleton was presented in any given display.

The probability distribution of the number of correctly reported letters was analyzed as a function of number of digits, singleton presence, and singleton type (target vs. distractor) at 7 exposure durations ranging from 10 to 200 ms. Also, the probability of reporting a presented letter was analyzed as a function of letter type (singleton letter, or letter presented in a display without any singleton, with a singleton digit, or with a singleton letter). The (preliminary) results showed virtually no effect of occurrence of singletons on subjects' mean scores. However, a singleton letter had a higher probability of being reported than a nonsingleton letter. This was also reflected by singleton weights when fitting the data by a mathematical model based on Bundesen's (1990) "theory of visual attention" (TVA).

23.505

Catch me if you can: The need to switch between attentional sets enhances contingent attentional capture effects

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Irrelevant distracters capture attention to a greater degree when they share a feature (e.g., the color red) with an attentional set that defines targets (e.g., "red letters") than when they do not possess such a target-defining feature, a phenomenon known as contingent attentional capture. However, it is unclear whether the magnitude of such capture varies with whether distracters and targets possess features that match the same or different attentional sets. Given prior studies indicating that set switching is a time-consuming process, we hypothesized that increasing attention to a distracter whose color matches one attentional set (e.g., the color red) would make it harder to detect a subsequent target whose color matches a different (versus the same) attentional set (e.g., the color green). In Experiment 1, we asked participants to search for target letters presented in either of two colors (e.g. "red" or "green") within a central rapid serial visual presentation (RSVP) stream, while ignoring distracters in two peripheral streams. Because the central RSVP stream also contained letters whose colors were task-irrelevant (e.g., purple, blue, orange, etc.), participants needed to actively maintain distinct attentional sets for the two task-relevant colors (e.g., "red" and "green") in working memory. As predicted, target detection performance in the central RSVP stream was worse when the target's color (e.g., red) matched a different (versus the same) attentional set than the distracter's color (e.g., green). In Experiment 2, this color switching effect was eliminated when all colors were grouped into the same attentional set (i.e., when subjects were instructed to identify letters of any color among grey items). These findings demonstrate that the need to switch between distinct attentional sets enhances contingent attentional capture effects, and extend prior findings from the attentional blink, task switching, and working memory literatures indicating that set switching incurs behavioral costs.

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23.506

Attentional Capture is Modulated by Object-based Representations

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The contribution of object-based representations to attentional guidance has almost exclusively been investigated within the framework of top-down attentional guidance. It has been demonstrated that object-based representations guide top-down attentional selection as measured by object-based effects. Little is known, however, regarding the contribution of object-based representations to bottom-up, or stimulus driven, attentional control. In the present set of three experiments we investigated whether the extent of attentional capture is in fact modulated by object-based representations. Participants viewed a central rapid serial visual presentation (RSVP) stream in which a target letter was defined by a specific color (e.g., red). The RSVP stream was superimposed onto a set of three objects (a cross like configuration). On critical trials, irrelevant color singleton and three neutral distractors appeared in the periphery. On half of the trials the irrelevant colored singleton appeared on the same object as the central target, while on the other half of the trials the irrelevant colored singleton appeared on a different object. We replicated the canonical contingent attentional capture finding such that peripheral singleton produced a decrement in central target identification that was contingent on the match between the singleton color and the target color. We also observed that the magnitude of attentional capture was modulated by whether the irrelevant color singleton appeared on the same or different object (i.e., object-based effect). Additionally, it was observed that the extent to which object-based representations modulated attentional capture depended upon the search mode of the observer (i.e., singleton search mode or feature search mode). These results suggest that object-based representation guide bottom-up as well as top-down attentional control, as well as provide further constraints on the mechanisms of object-based selection.

23.507

What Causes IOR and Contingent Capture?

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The involuntary attention effect is the finding of faster RT to identify targets presented in a cued than uncued location even when the cue location is random with respect to the target location. We proposed that there are at least two separate mechanisms responsible for involuntary attention: (1) a serial search mechanism that accounts for performance when the target is difficult to locate, and (2) a decision mechanism that accounts for performance when the target is easy to locate. The serial model predicts that as the number of possible target locations increases, the cueing effect increases. The decision model makes the opposite prediction.

We previously demonstrated that when the target is easy to locate, in the absence of distractors in the display, the decision model accounts for the involuntary attention effect. However, when the target is made difficult to locate by presenting distractors with the target, the serial model accounts for the involuntary attention effect (Prinzmetal & Ha, 2008).

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Here, we investigated two findings associated with involuntary attention: (1) IOR (inhibition of return) is the finding that when the cue-target interval is relatively long, observers are slower to identify targets in the cued than in the uncued location. (2) Contingent capture is the finding that the involuntary attention effect is larger when the cue and target are similar than when they are not similar.

We obtained IOR only when there were no distractors in the display. IOR was larger with 2 than 6 possible target locations. Thus IOR is better described by the decision mechanisms. We obtained contingent capture only when there were distractors, and the effect was larger with 6 than 2 locations. Contingent capture is due to a serial mechanism. Hence there are at least two separate mechanisms responsible for involuntary attention.

23.508

On the ability to overcome attention capture in visual search

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A sudden change in color is typically less salient in capturing attention than the onset of a new object. However, a meta-analysis of four visual search experiments (N=46) revealed that color changes initially (i.e., in the first 90 trials) do capture attention, but thereafter the effect disappears. This decline can be explained with an account, where the initial bottom-up capture is later “overridden” by a top-down inhibition process. This inhibitory tagging takes some time to build up, probably because the viewer must first experience that the color change as such is not relevant for the current task. The equivalent meta-analysis for onsets also revealed that new objects continue to capture attention. On the basis of the inhibitory account it is argued that onsets are special because they do not differ from the other elements in the display. Two experiments showed that onsets cease to capture attention when they become different from the other search elements in color (Experiment 1) or in luminance (Experiment 2). Experiment 3 on the other hand showed that color changes continue to capture attention when the color change is reversed, such that the changed element no longer differs from the other elements in the search display. The findings of these three experiments provide further evidence for the inhibitory account.

23.509

Previewing inoculates against attentional capture

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The objective of this study is to discover what endows an object, appearing as an abrupt onset, with the capacity to capture attention. We examined the situation in which attention had already been prioritized to a target location when the abrupt onset, which always materialized in a distractor location, appeared. Neo and Chua (2006) showed that so long as the onset object was presented infrequently, attention that had been prioritized could still be captured by the onset. In this study, the following experimental logic was used: we preview the object that would later appear as an onset. The question was whether the preview would modulate the capacity of an abrupt onset in capturing attention. To discover just which aspects of the onset was critical, we previewed different aspects of the critical stimulus in separate experiments. To the extent that a feature is critical in attentional capture, previewing that feature should impair attentional capture. In Experiment 1, the critical stimulus (both its form [four spots] and mode of appearance [an abrupt onset]) was previewed. Capture was eliminated, which implied that the preview logic worked. In Experiment 2, we previewed only the form of the critical stimulus but not its mode of appearance. In Experiment 3, the critical stimulus’s mode of appearance was previewed (essentially, the local luminance transients that accompany the onset). The critical stimulus in both experiments failed to capture attention, suggesting that both the form and the mode of appearance of the critical stimulus had to be previewed before its attention-capturing capacity would be undercut.

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23.510

Fear Factor: Attention capture by fearfully expressive faces in an RSVP task

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When participants search rapid serial visual presentation (RSVP) streams for a single target, accuracy is high, given that distractors in RSVP do not usually deplete the attentional resources required to perform the target search. Attentional blink (AB) occurs when RSVP streams include two targets. Accuracy for identification of the first target (T1) is typically high, but accuracy for the second target (T2) is impaired if it is presented less than 500 ms after the first target (Raymond, Shapiro, & Arnell, 1992). However, researchers have demonstrated that a task-irrelevant RSVP distractor can act as an involuntary T1 and result in an AB provided that it adequately matches the target search template or is visually novel. Task-irrelevant T1 arousing words capture attention and enter awareness at the expense of T2 targets (Arnell, Killman, Fijavs, 2007). In the present experiment, participants performed single target T2 search for recognition of an intact scene imbedded among 16 scrambled scenes and faces. The task-irrelevant T1 distractor image of an intact face varied in emotional expression (happy, fear or neutral) and appeared 270ms (within the AB window) or 630ms (outside the AB window) before the T2 target scene onset. We also included a control condition with no T1 distractor. RSVP stream images were presented for 90 ms each. Participants performed a 4-AFC scene matching task following the RSVP stream. Preliminary results indicate significantly poorer accuracy for identification of scenes preceded by a task-irrelevant T1 face image presented at 270 ms compared to 630 ms but only for fearful emotional expressions. The emotional expression, happy, did not cause AB. This suggests that fearful emotional expressions capture attention and enter awareness at the expense of goal-driven targets, signifying preferential attentional processing perhaps as an evolutionary self preservation mechanism.

23.511

Attentional Capture by Emotional Faces in Adolescence

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Relatively little is known about how emotional stimuli affect attentional processing during adolescence. Neuroimaging data suggest that the anterior cingulate cortex (ACC) is central to the integration of these processes and the ACC is still maturing in teenagers. A face flanker task that required identification of the emotional expression of a central face when flanked by either congruent or incongruent facial expressions was administered to both adolescents and adults. Performance was also measured on a more traditional letter identification flanker task, where the identification of a central target letter is more difficult when flanked by congruent rather than incongruent letters. Previous research also suggests that for adults, negative faces capture attention more effectively than positive faces. This leads to greater interference for a positive face flanked by negative faces than for a negative face flanked by positive facial expressions. Adolescent performance on face flanker tasks has not been previously described in comparison to adults. However, it has been suggested that adolescents may find emotional information more distracting than adults. Preliminary results show that adolescents in their mid-teens have comparable performances in terms of error rates and reaction times to adults on the letter flanker task. However, they show worse performance on the face flanker task, with more errors and slower reaction times than adults. This suggests that when an emotional demand is added to an attentional task, teenagers perform more poorly than adults. This is likely due to cortical immaturities in frontal lobe circuitry, that fail to adequately over-ride the bottom-up mechanisms associated with identifying negative facial expressions.

23.512

Individual difference in “release time” from attentional capture

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Visual short-term memory (VSTM) capacity for simple objects is known to be severely limited, yet highly variable across individuals. These individual differences have often been ascribed to variability in storage space. However, it is also possible that it stems from the efficiency of attentional control that restricts access to VSTM. In the present study, we examined the relationship between VSTM capacity and vulnerability to two types of attentional capture: stimulus-driven (Bottom-up) and contingent (Top-down) attentional capture. We found that low and high capacity individuals show equivalent levels of stimulus-driven attentional capture. By contrast, high and low capacity individuals show dramatically different levels of contingent attentional capture. More precisely, even though low and high capacity individuals initially show an equivalent contingent capture effect, low capacity individuals show much slower recovery from capture than high capacity individuals. These results suggest that individual differences in VSTM may stem from variability in how quickly attention is released after being captured by distractors that partially overlap with the current target goals.

23.513

Video game playing improves recovery from attentional capture

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Recent studies indicate that playing video games improves performance on attention tasks by enhancing top-down control over visual attention. However, whether this increase in top-down control can modulate the effects of bottom-up attentional processes is unknown. To examine this issue, video game players and non-video game players performed an attention capture task. Participants made a speeded response to the orientation of a line segment within a unique target shape, and on half the trials a distracting task-irrelevant color singleton was presented. Results show that video game players' performance was equal to non-video game players when a target appeared in isolation, indicating that both groups are equally vulnerable to capture by the target. However, video game players responded more quickly than non-video game players when a distractor was present, indicating that video game players are better able to recover from the interfering effects of task-irrelevant distraction. That this benefit is due to video game playing was reinforced by a significant negative correlation between time playing video games and the magnitude of the capture effect. When these data are coupled with the findings of previous studies, the collective evidence indicates that video game playing enhances top-down attentional control which in turn can modulate the negative effects of bottom-up attentional capture.

Attention: Temporal Selection and Modulation

Saturday, May 9, 8:30 am – 12:30 pm
Poster Session, Vista Ballroom

23.514

Spatiotemporal dynamics of attentional updating across saccades

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The world appears stable despite frequent eye movements that change the location of visual input relative to eye position. Questions remain as to how the visual system integrates visual input while maintaining spatial attention across saccades. Recent work has examined whether visual attention is maintained across saccades in spatiotopic (world-centered) or retinotopic (eye-centered) coordinates. When subjects attend to a spatiotopic location, visual attention is initially maintained in retinotopic coordinates. However, retinotopic facilitation declines by 250 ms post-saccade, leaving only the task-relevant spatiotopic facilitation at later delays (Golomb, Chun, & Mazer, 2008, J. Neurosci.). The current study examined the spatiotemporal dynamics of this shift by probing an intermediate location to determine whether attentional facilitation transitions discretely from retinotopic to spatiotopic locations or expands to encompass spatiotopic, retinotopic, and intermediate locations. Subjects executed a guided saccade while holding a cued spatiotopic location in memory. After the saccade, subjects made a speeded orientation discrimination response to a probe that appeared at 50, 250, or 400 ms post-saccade. The oriented probe appeared at the attended spatiotopic location, the retinotopic location, an intermediate location between the spatiotopic and retinotopic locations, or eccentricity-matched control locations. Subjects were explicitly and implicitly biased towards maintaining attention in spatiotopic coordinates. Consistent with previous findings, the response time to a probe at the retinotopic location was facilitated over the control location immediately after the saccade. This retinotopic facilitation declined by later delays, while the task-relevant spatiotopic location remained facilitated at all tested delays. Facilitation at the intermediate location was less than at retinotopic and spatiotopic locations and did not vary in a time-dependent manner. These findings suggest that top-down attention can result in enhancement of discrete retinotopic and spatiotopic locations without spreading across intermediate locations.

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23.515

The time-course of covert cuing using spatial frequency targets

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Purpose: Covert cuing tasks are used to study the deployment of visual attention over space and time. Previously, we reported target spatial frequency (SF) and 3-D object context effects on inhibition of return (IOR) at a long cue-to-target SOA (VSS, 2007). The present study tested for similar SF and object effects with a placeholder paradigm more commonly used in covert cuing tasks. We examined the influences of target SF and context on shifting attention over time by using a range of SOAs with both 2-D and 3-D placeholders. Based on our previous findings, greater IOR was expected for high SF compared to low SF targets at our long SOA. Facilitation was expected at short SOAs for all SFs and both contexts. Method: Placeholders were 2-D outline squares (Exp. 1) and the same outline squares on the front faces of 3-D cubes (Exp. 2). The cue was a brief (50 ms) thickening of the outline square. A Gabor patch target (1, 4, & 12 cpd) followed at one of three SOAs (50, 100 ms, 500 ms) on 80% of the trials. Results: Contrary to our previous results, IOR magnitude was similar for all SFs and contexts at the 500 ms SOA. No inhibition or facilitation occurred for any target or context at 100 ms SOA. Interestingly, significant inhibition was found for 12 cpd targets for both contexts at the 50 ms SOA. Conclusion: Other than the inhibition found for 12 cpd at 50 ms, covert shifts of attention were unaffected by target SF over SOA. The lack of target SF or 3-D object influences with a placeholder paradigm indicates their presence in our previous study was because of the SF specific cues used.

23.516

The size of the cued area does not affect scaling of attentional focus on temporal order judgment task

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Purpose: Brief peripheral cues can attract the attentional focus allowing the advantageous processing of stimuli presented inside. It has been stated that the focus of attention is variable in width according to task requirements. The cue size can modulate the scaling of attention, i.e. the attentional focus can be concentrated in small regions or enlarged to include larger areas. In two experiments we manipulated the size and the cue lead time to investigate the scaling of attention using a temporal order judgment task (TOJ). Methods: The peripheral cue was an outlined square and the test stimuli were two letters ("F" and "J"). The letters were separated by a variable interval of 20 to 200 ms. In each trial one of the two letters was presented inside and the other outside of the frame. Cue lead time was 100 ms (Experiment 1) and 100 ms and 400 ms (Experiment 2). The participant's task was to judge what letter appeared first. Results: The stimulus presented inside the cue has an advantage in relation to the stimulus presented outside, and the short cue lead time produced more advantage than the long one, but without any influence of the cue size on the temporal perception. Conclusion: The manipulation of cue size did not affect the perception of temporal order, even when more time was given for the adjustment of the focus to the size of the cue. We discuss different mechanisms involved in processing of information for JOT and RT tasks.

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23.517

Early and late modulation of attentional selection by multiple attentional control sets: ERP evidence

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We have previously demonstrated that two attentional control sets (ACSs), each defined by a separate color, can be maintained over distinct locations in space, as observed in reaction times (RTs) to target stimuli. The current study used event-related potentials (ERP) to examine the neural responses to both cues and targets in order to determine the timing and specificity of attentional capture in this paradigm. Participants were instructed to maintain central fixation while responding to targets of only one color per location (e.g., blue target at left placeholder, green target at right placeholder). Prior to target onset, each placeholder was highlighted with a cue that matched the ACS for that side ("good" cue), a cue that matched the ACS for the opposite side ("bad" cue), or an achromatic cue ("neutral" cue). Behavioural results confirmed that target RTs are fastest for trials with good cues, relative both to trials with bad cues and to trials with neutral cues. This behavioural effect was reflected in the ERPs time-locked to target onset; specifically, the P3 component, a neural marker of attentional selection and consolidation, peaked at earlier latencies for targets following good cues. We also examined the ERPs time-locked to cue onset, specifically the N2pc component that reflects the current locus of attention. In our paradigm, a greater N2pc amplitude would indicate that attention has shifted in response to the cue. We found the greatest N2pc amplitudes for good cues relative to neutral cues, with a smaller although still discernible degree of capture for bad cues. Together these results suggest that late attentional selection is responsible for speeded target processing, and that ACSs do not operate as an early, all-or-nothing filter of bottom-up capture.

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23.518

How is the spatial attention focused on object?

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It has been supposed that the attentional "spotlight" shrinks toward attended object. How does this spatial modulation of focal attention occur? Using a dual-task procedure, we investigated the time course of transformation of attentional extent. Observers were asked to detect the occasional dimming of object image presented at the center of the display. This task was to make their attention focused onto the object. Simultaneously they detected a probe, a brief flash of small dot stimulus presented at the periphery. Probe SOA, delay of the probe onset relative to the central object onset, was varied among 40~640 msec. We predicted that the performance of probe detection would be gradually impaired as the probe SOA increased because the extent of attention would gradually shrink to the object. However, results showed that the probe detection rate was reduced when the probe appeared immediately after (~160 msec) or late after (520~ msec) the onset of central object, compared to the intermediate SOAs (280~400 msec). This finding suggests that there are two stages of attentional shrinkage to object. At the earlier stage, attention may improve the visual processing irrespective of spatial position (general enhancement). After that, attentional resource might be concentrated to the attended position (central object) at the expense of the periphery, then the reduced probe detection was observed with longer SOAs. Further experiments to test the hypothesis will be reported.

23.519

Cooccurrence binding errors: Are people bound to the chairs they are sitting on?

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People watching rapid serial visual presentation (RSVP) of scenes may experience binding errors so that objects from different scenes presented in succession are seen as cooccurring within the same scene (with line drawings, Intraub, 1989; pairs of letters, Bowman & Wyble, 2007; and letters in words, Holcombe & Judson, 2007). One might assume that since natural scenes, unlike artificial stimuli, may be processed holistically (e.g., Oliva & Torralba, 2006), they would be less affected by cooccurrence misbinding. To test this assumption we compared two types of stimuli: colored photographs of distinctive people sitting in chairs, and digit-letter pairs.

On each trial two target images were embedded in an RSVP sequence of distractors (photographs of indoor scenes or pairs of keyboard symbols) presented at the rate of 93 ms/image. The second target (T2) followed the first one (T1) at lag 1, 2 or 6. Subjects were asked for an ordered report of both T1 and T2. As expected, there was a substantial attentional blink for both kinds of materials, with lower report of the second pair at lag 2 compared with lag 6. Lag 1 performance was good (lag 1 sparing).

For both natural scenes and alphanumeric pairs, binding and order errors were maximal at lag 1. This loss of temporal information at lag 1 can be considered the cost for successful processing of two scenes presented in close succession (Bowman & Wyble, 2007). Surprisingly, the proportion of binding errors for integrated natural scenes (a person in a chair) was the same as for alphanumeric pairs. For both types of stimuli there were more binding errors than order errors (reversals) for correctly bound pairs. This pattern of results suggests that natural scenes in RSVP are rapidly decomposed into their constituent objects before the processing of temporal order.

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23.520

Non-Retinotopic Feature Integration is Pre-Attentive

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How features are integrated into a unique percept is one of the most puzzling questions in visual neuroscience. According to Feature Integration Theory, features are bound together by attention. In recent years, a variety of studies has shown that features of moving objects are integrated along their motion trajectories and, hence, across different retinotopic locations. For example, we presented a central Vernier that was slightly offset either to the left or right. On either side of this central Vernier, a sequence of non-offset flanking lines followed eliciting a percept of two diverging motion streams. Although the Vernier itself was largely invisible in this sequential metacontrast paradigm, surprisingly, its offset was perceived within the motion streams. If one of the flanking lines was offset itself, this offset was integrated with the offset of the Vernier. To investigate the role of attention in this non-retinotopic feature integration, an auditory cue was presented indicating to which of the two motion streams observers had to attend. The timing of the cue-onset was systematically varied from 500 ms before stimulus onset to 300 ms after its offset. Interestingly, non-retinotopic feature integration occurred even in conditions when the cue was presented 300 ms after the offset of the motion streams. This finding suggests that non-retinotopic feature integration is mediated by pre-attentive motion grouping and not by attention.

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Saturday Sessions

23.521

Attention processes in action video game players

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Action video games present players with complex visual environments and numerous visual and cognitive tasks to perform. Recent evidence has shown that action video game players (gamers) have improved attentional abilities compared to non-gamers. In a series of experiments we evaluated three aspects of attention and control in action video game players and non-gamers: a manual task switching paradigm investigated participants' ability to rapidly switch between a prepotent task and a novel one; an anti-cuing task assessed levels of control over voluntary and involuntary attention; and an illusory conjunction task provided an assessment of the speed and accuracy of conjoining shape and color to a location in space. When gamers were compared with non-gamers, they showed distinct advantages. Gamers had smaller task switching costs than non-gamers, indicating that they were able to disengage from irrelevant task processes more rapidly. The anti-cuing task revealed that gamers were faster at summoning voluntary attention and were better able to resist involuntary attention capture. Gamers also showed fewer illusory conjunctions than non-gamers, suggesting faster feature binding. Taken together, in the tasks reported here gamers seem to be more resistant to distraction, supporting an improvement in their ability to select the relevant information in their environment. In addition, the reduction in illusory conjunctions suggests that there is a general improvement in their speed of deployment of visual spatial attention.

Acknowledgement: Supported by NIH Grant DA14110 to APS.

Spatial Vision: Natural Scenes

Saturday, May 9, 8:30 am – 12:30 pm
Poster Session, Vista Ballroom

23.522

The Effect of Color Saturation and Luminance Contrast on Color Naturalness

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In the natural world, physical laws constrain object reflectance. These constraints are learned by the visual system and affect our naturalness perception of images. The goal of this study on natural images is to discover which image statistics are used to determine color naturalness. In a series of experiments, we investigated the role of color in our perception of naturalness by asking subjects to rate the naturalness of the color saturation for different images. We found that observers could easily differentiate unnaturally over or under-saturated images from their original natural counterparts with certain accuracy. Moreover, this ability is not based on the observers' memory of specific pictures nor is it based on high-level knowledge about object color (memory color) since observers could correctly judge natural color saturation for images they had never seen before and for objects with native colors (e.g. oranges) and non-native colors (e.g. cars). Furthermore, natural color saturation judgments differed from global saturation judgments for random-pixel images made from the original natural images indicating that image structure is important for judging natural color because color distributions vary from image to image (e.g. pictures of snow and pictures of fruit). Additionally, both luminance contrast and saturation of an image affect our judgment of color naturalness. If the luminance contrast is reduced without changing chromaticity, the image appears increasingly over-saturated unless color saturation is also reduced. Our findings suggest that critical information lies in the luminance-color relationship. Further investigation shows that as color saturation increases or luminance contrast decreases, color appearance changes from surface color mode to aperture (self-luminous) color mode, and objects unlikely to be self-luminous appear unnatural. We suspect that this mechanism also aids our natural saturation judgment.

23.523

Effect of Retinal Ganglion Cell Sampling on the Local Power Spectra of Natural Images

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The retina encodes images with decreasing resolution as a function of eccentricity from the central fovea: ganglion cell density decreases rapidly with eccentricity and the receptive field size of ganglion cells increases rapidly with eccentricity. This architecture imposes substantial computational constraints on the downstream components of the visual system that are involved in estimating scene properties and in selecting eye movements. To understand these constraints it is important to characterize how spatial information extracted by the retina varies with eccentricity. To address this question we collected natural images with a 36 bit camera calibrated to the spectral responses of human photoreceptors and converted them 12 bit gray-scale images. We then estimated the responses of retinal ganglion P cells to the natural images using a model based directly on existing measurements of the optics of the human eye, the sampling density of human ganglion cells, and the receptive field parameters of macaque ganglion cells. Finally, we characterized the relative spatial information in the ganglion cell responses by measuring the local power spectra of the responses at various retinal eccentricities and comparing them to the local power spectra of the responses in the fovea. We find that (i) the local power spectra at all eccentricities are modeled well by a simple two-parameter formula: one parameter controlling the slope of the power spectrum as a function of spatial frequency, the other controlling the intercept (closely related to the overall power), (ii) the slope and intercept observed at any given eccentricity is quite predictive of the "true" (foveal) slope and intercept, and (iii) the uncertainty about the "true" (foveal) power spectrum grows with eccentricity. These natural scene statistics suggest hypotheses for how downstream mechanisms might compensate for the effects of retinal eccentricity and how they might select eye movements in natural tasks.

23.524

Contrast Perception and Contrast Variance in Natural Scenes

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The distribution of contrast in natural scenes is highly non-uniform. We examined how this variability affects apparent contrast and contrast discrimination thresholds. Natural images were randomly selected from the Van Hateren image database and viewed through one hundred non-overlapping pseudo-randomly positioned Gaussian apertures. The local rms contrast of each aperture was systematically manipulated, thus allowing control of contrast variation and mean contrast across the image. Observers performed two main tasks, first a matching task in which they adjusted the contrast of an image in which all apertures had the same rms contrast to match that of an image whose contrast was varied across the image but otherwise was identical. In the second experiment, a 2AFC task, the observers indicated which of two images with the same contrast variation but differing means had higher contrast. As the variation in contrast across the image increased, the apparent contrast of the image increased for both real scenes and phase-randomized versions of the same image. Additionally, sensitivity to change in the mean contrast of the image decreased when the variation in contrast across the image increased. The thresholds were higher for real scenes compared to phase randomized scenes even when their luminance distributions were equated. Equivalent noise analysis showed that the difference between sensitivity to real and random phase images was caused mostly by an elevation in local noise, with little systematic change in sampling efficiency across the four observers. These results suggest that

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local contrast responses are modulated by the presence of spatial structure and phase alignment across spatial scales in natural scenes which acts as an additional source of contrast variation.

23.525

Crowding effects in central and peripheral vision when viewing natural scenes

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How do effects of crowding manifest themselves when viewing elements of natural scenes? We studied the effects of crowding in central and peripheral vision using suprathreshold discrimination experiments. Observers rated the differences between two 5.2-deg patches of natural images that were presented alone or amongst four flankers. In the central condition the targets were located at fixation, and in the peripheral condition the targets were displayed at 16 degs eccentricity in the lower right visual field. In Experiment 1, the flankers were identical to one another - either the same as one of the target images (SAME) or completely different (DIFF) - and were located at 5.2, 6.6 or 8.2 degs (center-to-center) away from the target. In central vision, small crowding effects were found only at very small spacing distances in the SAME condition. In the periphery, crowding effects were evident in both SAME and DIFF conditions, although they were significantly higher in the SAME condition. Spacing distance between target and flankers did not (or barely) had an effect. In Experiment 2, the DIFF distractors were different to the targets and to each other, and were located at 5.2, 8.2 and 11.2 degs away from the targets. In central vision, there were a very small crowding effect for the DIFF condition at the nearest spacing but none for the SAME condition. In the periphery, crowding remains significant for both SAME and DIFF conditions, but the effects for SAME were only marginally larger than those for DIFF at the smallest spacing distance. These results are consistent with previous crowding research demonstrating: (1) weaker crowding in central vision and (2) stronger crowding when target and flankers are similar. We postulate that the increased crowding in the periphery with similar flankers and small distances is primarily caused by an increased likelihood for mismatched feature comparisons.

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23.526

Boundary segmentation of naturalistic textures: roles of sparseness and local phase structure

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Some texture boundaries are easier to segment than others, and characterizing these discrepancies is an important step in understanding the neural mechanisms of texture segmentation. Previously (Baker et al., VSS 2008), we demonstrated that removing the higher-order statistics from natural textures decreases contrast boundary segmentation thresholds. We also observed that the amount of "stuff" in a texture (sparseness) appears to predict the degree to which this is the case.

To examine this issue in greater detail, we created synthetic textures that mimic the properties of natural textures. Our micropatterns were Gaussian-windowed broadband edges, created as sums of phase-aligned sine waves, which provided local edge structure and a local spectral slope of 1/f. According to the method in Kingdom et al. (Vision Research 2001), we synthesized a global spectral slope of 1/f by varying the size distributions of these micropatterns. This allowed us to (1) remove all higher-order statistics by phase-scrambling the texture, or (2) remove local phase alignments by phase-scrambling the micropatterns, while (3) varying texture sparseness by changing the number of micropatterns.

We contrast-modulated the texture to create a boundary. Participants made forced-choice judgments of boundary orientation (left- vs. right-oblique). We obtained modulation-depth thresholds using constant stimuli for intact, globally scrambled, and locally scrambled textures at a series of micropattern densities.

For sparse textures global phase-scrambling considerably reduces modulation-depth thresholds, consistent with our previous findings in natural textures. As the micropattern density is increased, the effect of global phase scrambling is progressively reduced. We observe no effect of local phase scrambling at any density level.

These results suggest that natural boundary segmentation is impeded by the sparseness of textures but not by the local edge structure of the elements that comprise them.

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23.528

Image Features Predict Edge Causation in Natural Images

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Purpose: Object recognition requires that one reconstruct aspects of a 3-Dimensional scene from its 2-Dimensional image. More specifically, the observer must explain image contrast patterns in terms of their causes in the environment. What features in the image facilitate this estimation? We hypothesized that edge boundaries, texture, repetition of elements, and edge profile would be predictive of human cause estimations.

Methods: In study one, subjects were asked to view regions of interest (ROIs) containing an edge and choose one of four possible edge causes (i.e. albedo, depth, shadow, specularity). In the second part of the study, a group of trained "experts" were asked to look at the same ROIs and determine whether or not each contained particular features (i.e. closure, texture, or repetition). Finally, a clustering algorithm was used to classify the ROI's edge profile.

Results: Analysis for expert feature classification was done using a 3x3x2 MANOVA with image features as factors and cause estimation as the dependent variables. The analysis determined that edge image features have an effect on edge cause estimation. There were main effects of all three factors. Closure had an effect on albedoness, depthness, and specularness ($p<.001$) and an effect on shadowness ($p<.05$). Texture had an effect on depthness ($p<.05$); and repetition had an effect on albedoness and shadowness ($p<.05$). Linear regression was used to evaluate the effect of edge profiles. Distance from four cluster centers was used as the predictor, with cause estimation as the criterion. Results indicate that distance from a cluster's center is predictive of edge causation. Cluster1 predicted albedoness, $p<.001$; cluster2 and cluster3 predicted depthness, $p<.05$, $p<.001$ respectively; cluster1 and cluster4 predicted shadowness, $p<.01$, $p<.001$; cluster1, cluster2 and cluster 4 predicted specularness, $p<.01$, $p<.001$, $p<.001$.

Conclusion: Closure, texture, repetition of elements, and edge profile are predictive of human edge causation estimation.

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23.529

Optimal "multiplicative" interactions between local and long-range contour cues: where natural image statistics meets single neuron computation

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Detecting object contours is a key function of the visual system, though the underlying neural operations remain poorly understood. It is generally accepted that: (1) long-range contour extraction begins in V1; (2) contour cues are propagated about the cortex by the massive network of horizontal connections between pyramidal neurons; and (3) long-range contextual inputs arriving from outside their classical receptive fields (CRF) do not

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drive V1 neurons by themselves, but can "multiplicatively" boost their responses to stimuli within the CRF (Kapadia et al. 1995). Two key questions remain unanswered, however: (1) What should be the form of the interaction between local and long-range contour cues to optimize contour detection, and (2) what neural mechanism(s) might mediate this interaction? To address the first question, we defined a "classical" Gabor-like oriented edge filter CRF(x), and two "contextual" filters sensitive to different aspects of long-range contour structure: M1(x) responded to aligned edge "flankers" just outside the CRF, and M2(x) consisted of an oriented filter superimposed with the CRF but at a coarser scale. Using human-labelled van Hateren images, we computed the contour probability CP = Prob(contour | CRF(x), Mi(x)) separately for both contextual modulators. We found that both M1 and M2 did in fact boost the gain of the CP function in response to increasing CRF input, providing direct support from natural contour statistics for a multiplicative CRF-extraclassical interaction. To address the second question, we compared the measured CP functions to the nonlinear interactions we observed between synaptic inputs delivered to proximal vs. distal basal dendrites in a detailed compartmental model of a neocortical pyramidal neuron using the NEURON simulation environment. We found good matches between the two sets of functions, suggesting that nonlinear synaptic integration within basal dendrites of pyramidal neurons could help mediate long-range contextual interactions in neocortex.

23.530

Human Estimation of Local Contrast Orientation In Natural Images

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Background and Objective: Estimation of local contrast orientation is an important step in perceiving object shape. Orientation estimations may be computed via a bank of oriented filters, as in V1 hypercolumns, or by using steerable filters. Two problems become apparent when using filters to estimate orientation. First, the region of interest may contain some clutter, perturbing the filter's output. Second, filter kernels of various sizes may be used. Which scale is best? In this study, we show how human observers use one problem to solve the other.

Methods: Five subjects viewed 500 local image patches, each bisected by an object contour. Method of adjustment was used to estimate orientation. Patches were then filtered using steerable filters; the filters returning orientations and contrast magnitudes. Patches were also filtered using a weighted covariance filter, to determine the extent to which the target pattern of the steerable filter (e.g. a step edge) accounted for the luminance variance within the image patch.

Patches with high subject agreement (n=104) were analyzed further. Two algorithms predicted human estimation. In one, the steerable filter scale with maximum magnitude was chosen and the angle estimate made at that scale. In the second, the weighted covariance filter was used to select scale. If humans use variance-accounted-for in estimating orientation, we expect the second algorithm to be the better predictor of human estimation.

Results: A matched pair t-test showed that the predictions of the variance-accounted-for algorithm were more accurate than the steerable filter algorithm, $t(102) = 1.679$, $p=.048$, in predicting human estimations.

Discussion & Conclusion: Results of this study show that the dual problems of orientation estimation can be solved by considering both at once. Observers estimate orientation by first choosing the scale that provides the greatest signal relative to the overall variance in the image patch, thus avoiding clutter.

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23.531

A walk through the woods explains the space variant oblique effect

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Psychophysical studies have demonstrated the reduced discrimination ability for obliquely oriented patterns as compared to horizontal and vertical ones in the central area of the visual field. This so called oblique effect is reversed at larger eccentricities, where oblique patterns are discriminated and detected better. What is the origin of this space variant oblique effect? It has been proposed to understand it through the second order statistics of natural images, as quantified by the power spectrum.

To investigate the role of higher order statistics and task behavior we obtain image sequences by simulating an agent navigating through simulated wooded environments. Unsupervised learning algorithms are used to learn a sparse code of the images but contrary to previous approaches, the learning is separately carried out for different regions of the visual field and different gaze allocations during walking. The learned receptive fields show a preference for horizontal and vertical orientations at the center and oblique directions in the periphery, larger area with increasing eccentricity, and steeper radial tuning curves. Furthermore, it is shown that the distributions are significantly dependent on where gaze is directed within the visual field during walking. Finally, by simulating walking through environments with severely reduced higher order statistics it is shown that the second order dependencies are not sufficient for observing the receptive fields anisotropies. The analysis was repeated on a dataset obtained from human subjects walking through a wooded environment also demonstrating comparable results.

We conclude that the properties of model receptive fields not only depend on the statistics of visual scenes in the environment, but also on the statistics imposed on the stimulus by the imaging geometry and the statistics of the interaction with the environment during natural task execution. Taking all these determinants together, receptive fields can be learned that explain the oblique effect.

23.532

Comparing image structure with local motion structure in real life optic flow

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It is known that static the structure of the natural environment, as characterized by the distribution of spatial frequencies found from databases of natural images, displays a characteristic distribution of spatial frequencies. Here, we analyse video sequences generated by physically moving a camera through various visual scenes to examine the static structure present in sequences of frames as well as the dynamic structure present in the motion produced. We show that the motion signal maps generated by a two-dimensional array of correlation-based motion detectors (2DMD) vary systematically across space with changes in the motion field containing important cues to self motion as well as scene structure. For each movie sequence we filtered the motion signals with first-order differential of Gaussian filters to extract a measure of the continuity of the flow-field. We also extracted the power spectra of both the static image sequence and the dynamic motion outputs and examined to what extent the motion structure was dependent on the image structure. Despite the substantial levels of noise affecting the motion signal distributions - attributed to the sparse nature of optic flow and the presence of irregular camera jitter - we are able to observe characteristic patterns as well as differences between environments, such as indoor and outdoor scenes. Considering the information present in the spatial layout and variation of the motion signal distributions arising from real-life image sequences helps us to understand optic flow processing in the context of the constraints on possible motion patterns introduced by the structure of natural images.

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23.533

Prior expectations in line orientation perception

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The visual world is full of contours, with a preponderance of cardinal (vertical and horizontal) orientations (Switkes et al., 1978). Do observers behave in a Bayesian fashion, with visual orientation estimates based on a prior distribution reflecting these statistics? For such a Bayesian estimator, estimated orientation of ambiguous stimuli will be biased toward cardinal orientations. Methods: On each trial, two stimuli were shown, one on the left and one on the right side of the display, for 750 ms. Each consisted of 64 Gabor patches in a circular window. The Gabor orientations in a stimulus were either all identical (L: low noise) or were normally distributed with standard deviation approximately 20 deg (H: high noise; SD chosen per observer based on a pilot discrimination experiment). One stimulus (the standard) had a fixed mean orientation (varied across blocks); the other (the comparison) varied in mean orientation. Observers indicated which stimulus had greater (more "clockwise") mean orientation. Conditions (across blocks) included 12 standard orientations (spanning 180 deg) and three comparison types (LvL, HvH, LvH). The LvL and HvH conditions allow one to estimate the just-noticeable difference as a function of orientation at each noise level. The LvH condition allows one to estimate the prior distribution used by observers (Stocker & Simoncelli, 2006). Results: Observers showed a classic oblique effect—better discrimination at the cardinals—in the LvL conditions, but not in the HvH conditions due to stimulus noise. In the LvH conditions, observers behaved as if the perceived orientation of the high-noise stimulus was systematically biased toward the nearest cardinal orientation. The data are consistent with a Bayesian observer that uses a non-uniform prior distribution over orientation, with peaks at the cardinal orientations.

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23.534

Visual gist of natural scenes derived from image statistics parameters

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Natural images are highly structured in their spatial configuration. In the past it has been shown that the contrast distribution of natural images is almost always adequately described by a Weibull type distribution (Geuseboek & Smeulders, 2003) in which 2 free parameters are fitted. We have recently shown that these parameters explain up to 50% of the variance in the early ERP and these parameters correlate 0.84 and 0.93 with the modeled output of X and Y cells of the LGN (Scholte et al., submitted). Here we will present BOLD-MRI data that show that beta and gamma also explain single trial activity in the occipital and temporal cortex and the parietal cortex respectively. Also, the beta and gamma parameters seem to order the natural images along the dimensions of the number of objects that are present in the scene and depth organization of the scene. We will test this hypothesis by estimating beta and gamma for artificial stimuli with a predetermined number of objects and depth organization, and by evaluating brain responses to such stimuli. Our results indicate that the summary statistics of the Weibull distribution (beta and gamma) may be used by the brain to efficiently and very rapidly extract information about the visual gist of natural scenes.

23.535

Visual discomfort and natural image statistics

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Images with excessive energy at medium spatial frequencies (Fernandez & Wilkins Perception 2007) or that have high color contrast or no luminance contrast (Wilkins et al ECVP 2008), appear uncomfortable or aversive and can induce headaches in hypersensitive observers. Such stimuli are uncharacteristic of natural images, and we therefore examined whether ratings of visual discomfort generally increase with deviations from the spatial and chromatic properties of natural scenes. Full-color 14° images were generated from noise or random overlapping rectangles (Mondrians). Slopes of the amplitude spectra for luminance or chromatic contrast were varied independently to create image sets ranging from strongly blurred to sharpened in luminance or color relative to a "natural" 1/f spectrum. Subjects viewed the images on a monitor for 10 sec each and rated both discomfort and artistic merit on a 7-point scale. Perceived blur was dominated by the luminance slopes, with discomfort rated lowest for the 1/f spectra for both the filtered noise and Mondrians, which were ranked similarly. In comparison, spatial variations in color had only weak effects. In a second set of Mondrians, focus and luminance contrast were fixed while color was varied along axes at 45° intervals in the LM vs. S chromatic plane (for images with the same mean gray but different hue angles), or was confined to one pole of each axis (for images that varied in a single average hue). Discomfort ratings were lowest for a blue-yellow axis (-45°), a direction that is again typical of natural outdoor scenes. Notably these ratings of discomfort were not related to judgments of artistic merit. Thus for both spatial and chromatic content the least aversive images corresponded to characteristic properties of the natural visual environment, and may reflect a normalization of visual coding to the natural world.

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23.536

ImageNet: Constructing a Large-Scale Image Database

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Image dataset is a pivotal resource for vision research. We introduce here the preview of a new dataset called "ImageNet", a large-scale ontology of images built upon the backbone of the WordNet structure. ImageNet aims to populate each of the majority of the 80,000 synsets (concrete and countable nouns and their synonym sets) of WordNet with an average of 500-1000 clean images. This will result in tens of millions of annotated images organized by the semantic hierarchy of WordNet. To construct ImageNet, we first collect a large set of candidate images (about 10 thousands) from the Internet image search engines for each synset, which typically contains approximately 10% suitable images. We then deploy an image annotation task on the online workers market Amazon Mechanical Turk. To obtain a reliable rating, each image is evaluated by a dynamically determined number of online workers. At the time this abstract is written, we have six completed sub-ImageNets with more than 2500 synsets and roughly 2 million images in total (Mammal-Net, Vehicle-Net, MusicalInstrument-Net, Tool-Net, Furniture-Net, and GeologicalFormation-Net). Our analyses show that ImageNet is much larger in scale and diversity and much more accurate than the current existing image datasets. A particularly interesting question arises in the construction of ImageNet – the degree to which a concept (within concrete and countable nouns) can be visually represented. We call this the "imageability" of a synset. While a German shepherd is an easy visual category, it is not clear how one could represent a "two-year old horse" with reliable images. We show that "imageability" can be quantified as a function of human subject consensus. Given the large scale of our dataset, ImageNet can offer, for the first time, an "imageability" measurement to a large number of concrete and countable nouns in the English language.

Acknowledgement: A Microsoft Research New Faculty Fellowship Award a Princeton Frank Moss gift

Special Populations: Disorders and Disease

Saturday, May 9, 8:30 am – 12:30 pm
Poster Session, Vista Ballroom

23.537

Brightness as a function of current amplitude in human retinal electrical stimulation

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Six human subjects with late stage retinitis pigmentosa were implanted with a prototype epiretinal prosthesis consisting of a 4x4 array of sixteen stimulating electrodes with the goal of eventually restoring functional vision. As described previously, this device reliably elicits visual percepts by electrically stimulating intact cells of the neural retina. An important problem for restoring function is to calibrate each electrode to account for differences in the brightness of percepts as a function of stimulation amplitude.

We measured apparent brightness as a function of electrical current amplitude, using both subjective magnitude rating and brightness matching procedures in two chronically implanted subjects. We found that both magnitude rating and brightness matching data can be described using a simple model where apparent brightness increases as a power function of stimulation intensity (B=aCg). For both experiments, good fits for both subjects could be obtained using a fixed value of the exponent g, and only allowing the scaling factor, a, to vary across electrodes.

These results suggest that it should be possible calibrate brightness across an entire array of electrodes by measuring a single parameter for each electrode. For example, single brightness matching measurements made at a relatively high amplitude on each electrode would be sufficient to describe relative perceived brightness across electrodes, and thereby provide a simple method of creating the appearance of equally bright phosphenes across an entire array and across a wide range of brightness levels.

23.538

Visual attributes following an acute optic neuritis episode – a longitudinal study

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Optic neuritis (ON) is an acute inflammatory optic neuropathy that usually causes transient loss of vision. Whether its clinical aspects derive from damage to the parvocelluar or magnocelluar fibers is an ongoing debate in the literature. Our aim was to study whether differential involvement of this two fibers' types governs the clinical aspects of ON along the disease course. Ten ON patients were examined during the acute phase; 1 month; and 4 months following the ON episode. Visual acuity, contrast sensitivity, color perception, visual fields, motion detection, object from luminance and object from motion (OFM) extractions were estimated in both the affected and unaffected eyes, as well as in 10 eyes of healthy age-matched controls. One month following the acute phase, the visual fields had returned to normal or near normal levels in all but one of the patients. This co-occurred with a return of visual acuity, contrast sensitivity and color perception. However, motion perception kept impaired. Lower motion detection rates and extended reaction times were found in the affected eyes compared to the unaffected and the healthy eyes controls but these differences did not reach statistical significance. When testing the affected eyes' ability to recognize OFM, a significant deficit ($p<0.05$) was evident (although object recognition was intact). These deficits still exist 4 months after the acute phase. Our findings may support a specific magnocelluar deficit in ON and may give an explanation for the patients' persisting visual complaints while standard visual testing is normal. Although damaged motion detection may explain some of the OFM deficit, it could not be its entire cause. Simple motion detection can principally be completed by a single local motion detector, however extracting OFM demands spatial integrative processing. These different motion related capabilities may remain damaged after an ON episode.

Acknowledgement: Study supported by: The Caesarea Edmond de Rothschild foundation

23.539

Visual Development in Preterm Infants: Assessing the Impact of Transient Thyroid Hormone Deficiencies

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Preterm birth is associated with an increased risk of visual impairment. However, not all visual deficits can be fully explained by the typical prematurity morbidity factors. In addition, children born preterm often exhibit transient hypothroxinemia of prematurity (THOP) due to premature severing of the maternal supply of thyroid hormones. Because thyroid hormone (TH) is critically needed for multiple facets of early brain development, including the structures needed for visual processing, and because the maternal thyroid supply is essential throughout pregnancy, it is possible that THOP contributes to the visual impairments seen in preterm children. To test this hypothesis, we used both clinical tests and visual evoked potential (VEP) techniques to assess visual abilities in two cohorts of preterm infants whose TH levels were measured in the perinatal period. In the first cohort born 30 to 35 weeks gestation, we found associations between low TH levels and reduced visual attention at 3 months corrected age (Study 1) and poor visuomotor abilities at 12 and 18 months corrected age (Study 2). In the second cohort born 23 to 35 weeks gestation, THOP severity was negatively correlated with visual attention at 3 months corrected age (Study 3) and contrast sensitivity and color vision at 6 months corrected age (Study 4). These findings therefore suggest that TH is necessary for the development of early visual abilities and that THOP may partially explain the visual deficits of preterm infants.

Acknowledgement: We would like to thanks March of Dimes and the Vision Science Research Program for fundings this research.

23.540

Efficacy of NeuroVision's NVC™ Technology Treatment on Unaided Visual Acuity in Moderate Myopes

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NeuroVision's NVC™ vision correction is a non-invasive treatment based on visual stimulation and facilitation of neural connections responsible for vision. This treatment involves an internet-based computer generated visual training exercise regime using sets of patient-specific stimuli (Gabor patches) to sharpen contrast sensitivity function (CSF) and visual acuity (VA). The reported treatment successes were mainly in low myopes (-0.50DS to -1.50DS). This study is a pioneering effort to evaluate the efficacy of NeuroVision's treatment for unaided VA (UCVA) improvement in moderate myopes (-1.75DS to -3.00DS). 102 moderate myopes were given NeuroVision treatment, while another 35 subjects in a control group were given placebo treatment resembling the NeuroVision treatment in a superficial way. Each subject completed 40 sessions of treatment within 3 months. The end-of-treatment examination indicated a mean UCVA improvement of 0.17(+/-0.01) LogMAR for the treatment group and 0.10(+/-0.03) LogMAR for the placebo group. In addition, 58% of the treatment group and 42% of the control group have 0.2 LogMAR or more UCVA improvement in at least one eye. Nevertheless, the difference between the two percentages was not significant ($P>0.05$, Fisher's Exact Test). However, after one year without further treatments, post-treatment examinations revealed strong retention of UCVA improvements in the treatment group but not in the control group; the treatment group still retained a mean UCVA improvement of 0.14(+/-0.01) LogMAR, while the mean control group improvements dipped to 0.05(+/-0.02) LogMAR. Moreover, 50% of the treatment group retained 0.2 LogMAR or more UCVA improvement in at least one eye after one year, significantly greater than the 24% observed in the control ($P=0.01$, Fisher's Exact Test). The retention results indicated that NeuroVision's NVC vision correction produced a stable one year post-treatment improvement in UCVA for moderate myopes.

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23.541

The mapping of spatial frequency across amblyopic visual cortex

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Aims: Human amblyopes exhibit spatial frequency-specific behavioural deficits and we sought to understand how spatial frequency is represented in the amblyopic cortex and what aspects of processing might be disrupted.

Methods: MR images were acquired on a 1.5T Siemens scanner using a TR of 3sec. We used a phase-encoded design with a sinusoidal checkerboard stimulus (8Hz; 80% contrast; 20° field) that cycled from high to low spatial frequency (0.5-6c/d) and vice versa. Here we compare the phase responses as a function of stimulus spatial frequency.

Results: Following on from the approach of Sasaki et al, (2001 Nat. Acad Sci USA, 98, 2077) in normals, we found a similar mapping of spatial frequency across the amblyopic cortex, going from higher spatial frequencies more centrally, to lower spatial frequencies more peripherally. However, while there is a similar relationship between preferred spatial frequency for the amblyopic and normal eye, the spatial frequency map is less regular for the amblyopic input, reflecting the fact that fewer voxels exhibit a clear spatial frequency preference.

Conclusions: Spatial frequency is mapped in a qualitatively similar way for the normal and fellow amblyopic eye, although voxels exhibit less spatial frequency preference for the amblyopic eye input. This can be modeled as a broader spatial frequency tuning of individual cortical cells receiving input from the amblyopic eye.

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23.542

The roles of contrast and luminance in amblyopic suppression

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Purpose: It is known that amblyopes perceive little mismatch in suprathreshold contrast between the amblyopic eye (AME) and the fellow fixing eye (FFE) under monocular viewing [Hess, R. F. & Bradley, A. (1980). Nature, 287, 463-464]. However, under binocular viewing the information from the amblyopic eye is suppressed. Here we examined whether this suppression involves predominantly luminance- or contrast-based information.

Methods: Two squares appeared within the top-left and bottom-right quadrants of one eye, while the other two appeared within the top-right and bottom-left quadrants of the other eye. In the luminance matching task, observers adjusted the luminance of the squares presented to one eye. In the contrast matching task, gratings were presented within all four squares. Observers adjusted the contrast of the gratings presented to one eye. Contrast detection thresholds were also measured for these stimuli under monocular and dichoptic viewing conditions.

Results and Discussion: Amblyopic observers showed interocular mismatches for the luminance matching task. Mean matching luminance was 35.8 cd/m2 for the AME and 24.7 for the FFE. That is, squares seen by the AME looked darker than squares seen by the FFE. On the other hand, in the contrast matching task, there was little mismatch between the two eyes for a wide range of luminance contrasts. This is consistent with previous findings under purely monocular viewing. Contrast detection thresholds for these stimuli were higher for the dichoptic presentations than for the monocular presentations, suggesting a stronger suppression of the AME under dichoptic viewing. Amblyopes reported that mean luminance was perceived to be darker by the AME compared with the FFE. This observation is in line with our results showing there is substantial mismatch in the luminance matching task, but not in the contrast matching task. We are currently studying the role of luminance-based processing in amblyopia.

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23.543

Motion direction discrimination in strabismic amblyopia: effects of stimulus contrast and size

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It is established that amblyopic eyes are impaired at motion tasks requiring segregation of signal from noise; yet the fidelity of amblyopic motion processing in the absence of external noise is unclear. We investigated the effects of stimulus size and contrast on the ability of strabismic amblyopes to detect the motion direction of briefly (70ms) presented Gabor patches. The stimuli had a spatial frequency of 0.5cpd, and the size was varied from 5.3° to 18.5°. Two contrasts were tested for all stimulus sizes: a high contrast of 98% was used for all participants, and a low contrast of 1.5% was used for the control participants. The low contrast varied for the amblyopic observers as the stimulus had to be visible to the amblyopic eye. The stimulus was a two-frame motion pulse, constructed by shifting the phase of a Gabor patch on consecutive frames. Measurements were made under both monocular and binocular viewing conditions for 5 amblyopic and 5 control participants. Amblyopic eyes were impaired relative to control eyes for the monocular high contrast condition but did not differ from fellow eyes. The effect of size was consistent across all eyes for the high contrast stimulus. For the monocular low contrast condition, amblyopic eyes showed a pronounced curtailment in the beneficial effects of spatial summation on motion discrimination, relative to control eyes and the fellow eyes. For controls, binocular viewing greatly increased the beneficial effects of spatial summation relative to monocular viewing. No such effects were observed for amblyopic observers, suggesting that the amblyopic eye did not contribute to task performance under binocular viewing conditions. Interestingly, monocular performance for the amblyopic fellow eye was superior to monocular performance for either eye of controls. Our results suggest a specific deficit in spatial summation of low contrast motion information in strabismic amblyopia.

23.544

Compensatory changes in activity in effector circuitries during visually guided behavior following V1 damage in humans

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The human visual system is intimately interconnected with effector circuitries that mediate visually-driven behavior. fMRI studies have shown that damage early in the visual stream, e.g. in V1, decreases responsiveness throughout higher-level visual circuitry. However, we know little about how such damage affects activity in effector circuitries. Interestingly, most patients with long-standing V1 damage are "high-functioning" in terms of visually-guided behavior, suggesting that the system must compensate somehow for the perceptual deficit. To identify whether intact brain areas exhibit changes in BOLD signal during performance of a visually-driven behavior, 3 stroke patients with right V1 damage causing left homonymous hemianopia and 4 age-matched controls underwent whole brain fMRI. Subjects performed a global, left-right direction discrimination task using random dot stimuli presented at 100% and near-threshold coherence at two locations in each of their visual hemifields. Global direction discrimination performance in the intact hemifield of hemianopes was similar to that of control subjects. In the blind field however, performance was at chance levels. The BOLD response was modeled at the individual subject level

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and statistical parametric maps were analyzed at the group level using a 2 (Group) X 2 (Hemifield) mixed factorial design. There was no main effect of hemifield and no interaction between group and hemifield. However, there was a main effect of group. As expected, control subjects exhibited greater activity than hemianopes in the right areas 17/18, the site of brain damage in hemianopes. In contrast, hemianopes exhibited greater activity than controls in the precuneus, and in somatosensory and somato-motor cortices bilaterally. The greater BOLD response in the hemianopic precuneus may indicate greater reasoning and visuo-spatial imagery required to process visual information. Together with increased somato-motor activity, this could represent evidence of compensatory activity within effector circuities following damage early in the visual stream.

23.546

Neurovisual disorder underlying learning disability? Neurological anomaly in two children diagnosed with a learning disability

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In learning disabilities, assessment of neurovisual disorder is usually not performed. Yet, because of the main role of vision in numerous human activities, and especially in learning, one can wonder the implication of a visual disorder in visual cognitive abilities in children.

We report here two cases of children diagnosed and in rehabilitation for a learning disability who indeed presented with a neurovisual disorder.

Case AB: Born prematurely and suffering from amblyopia, this child was diagnosed as dyspraxic at 4 years old, and as dyslexic at 7 years old. For the former impairment he received rehabilitation with an occupational therapist, and for the latter impairment he received speech rehabilitation. After 4 years of unsuccessful rehabilitation, his speech therapist sent him in our department. The neurovisual assessment revealed: a significant right visual field defect, right neglect), and visual agnosia. Finally, the MRI examination confirmed a brain lesion in the left anterior occipital horn.

Case LR: Described as a “clumsy” child, at 4 years old began rehabilitation for motor instability because he “bumped into everything”. At age 10, he was referred for a neuropsychological exam by his ophthalmologist. Neurovisual assessment revealed: tubular vision (Humphrey examination), significant difficulties in smooth visual pursuit especially for upward movements, visual agnosia, and impaired visual attention. Finally, the MRI examination revealed dilatation of bilateral occipital horns.

Although learning disability is traditionally considered as a developmental disorder, our data suggest another possible etiology, such as brain damage. Overall, these cases revealed the necessity to conduct neurological and neurophtalmological assessments in such children, especially to allow for adequate neurological rehabilitation before any classic learning rehabilitation.

23.547

Combined effects of semantic and visual proximity on visual object identification in Alzheimer 's Disease and Mild Cognitive Impairment

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Identification deficits in individuals with Alzheimer's disease (AD) can target specific categories of objects, leaving other categories unaffected. Using line drawings to investigate naming deficits unfortunately carries severe limitations because object form is yoked to object meaning. We therefore used computer-generated stimuli with empirically specifiable properties in a naming paradigm that decouples object form and object meaning. We recruited individuals with Alzheimer's disease, mild cognitive impairment (MCI), as well as healthy matched controls, and asked them to learn to label visually similar and visually distinct novel shapes with the names of semantically similar items (leopard, lion, tiger) or semantically distinct items (donkey, frog, robin). The results revealed that participants confused visually similar novel shapes more often than visually distinct shapes objects, and that they confused shapes labelled with the names of semantically similar items more often than when the same shapes were labelled with the names of semantically distinct items. These main effects were further qualified by interactions with participant group. Differences in confusion errors between visually similar and visually distinct shapes were greatest for AD participants and smallest for healthy age-matched controls. Similarly, differences in confusion errors between shapes associated with semantically similar and semantically distinct labels were greatest for AD participants and smallest for healthy age-matched controls. In conclusion, both visual and semantic similarity contributed to the identification errors of participants. However, the impact of each variable was always smallest for the healthy controls and largest for the AD participants, suggesting a continuum of severity.

Perceptual Organization: Edges, Configurations, and Surfaces

Saturday, May 9, 2:45 – 4:15 pm
Talk Session, Royal Palm Ballroom 1-3
Moderator: Jacqueline M. Fulvio

24.11, *2:45 pm*

A Configural Shape Illusion

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A new illusion – the configural shape illusion (CSI) – is reported in which the shape of a rectangle is systematically distorted by an attached/adjacent contextual region, when both are seen as part of a single configuration. In particular, the rectangle's perceived aspect ratio changes in a direction consistent with the aspect ratio of the whole configuration. We measured the magnitude of this illusion in two ways. First, observers adjusted the height and width of a separate, unattached rectangle to match those dimensions of a rectangle that was part of various configurations. Second, observers adjusted the height and width of the rectangle within various configurations to appear perfectly square. Systematic CSIs were present using both procedures, but their magnitude depended on the spatial and color relations between the rectangle and the adjacent context. The results are consistent with the hypothesis that the illusion is greater to the extent that the elements in the configuration are strongly related by virtue of standard grouping factors, including connectedness, proximity, good continuation, lightness similarity, hue similarity, and shape similarity. Somewhat surprisingly, the illusion was stronger when the contextual region was smaller, suggesting that the magnitude of the illusion may be governed more by the proportion of the entire configuration occupied by the target rectangle than by the aspect ratio of the entire configuration itself. Similar effects are apparent for the aspect ratio of an oval, although the distortions are less pronounced. The relation between the CSI and the occlusion illusion (Kanizsa, 1979; Palmer, Brooks & Lai, 2007) will also be discussed.

Acknowledgement: NSF Grant BCS-0745820 and a gift from Google

24.12, *3:00 pm*

Filling-in regions influence real and interpolated shape via lightness induction

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Purpose. Filling-in regions have recently been shown to affect shape perception, but it is unclear how these regions gain their influence. Here, we consider the possibility that filling-in regions affect shape perception via lightness induction. Method. Subjects discriminated 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 both black and white (mixed). In each of these six conditions, the fat and thin shape alternatives were created by either rotating the

inducer elements clockwise or counterclockwise by 6.4 deg (small rotation condition) or 12.8 deg (large rotation condition). A Quest staircase adjusted signal (inducer) contrast to yield 70% performance for each observer. A classification image (CI) technique revealed correlations between each pixel of noise and response. A region-of-interest (ROI) analysis was performed on the narrow vertical bands of CI pixels that exactly bisected the fat and thin contours on each side of the rectangles. These ROI regions never contained signal, and thus could only correspond to filled-in regions. Results. There were three main results. First, ROI pixels strongly affected shape responses in equal but opposite ways when inducers were all white or all black. Second, when inducers were of mixed polarity, ROI pixels did not affect performance. Finally, ROI pixels affected performance comparably in the small and large rotation conditions. Conclusions. These results suggest that a) filling-in regions influence shape perception, even when those regions are relatively far from relevant contours; b) the direction of this influence depends on lightness induction; and c) the magnitude of the influence does not drop off sharply with distance from shape boundary. These findings, taken together, indicate that lightness induction plays an important role in determining how filling-in regions alter the perception of shape.

Acknowledgement: This work was supported by a UCLA Graduate Research Fellowship awarded to BPK.

24.13, *3:15 pm*

Contour integration under slit-viewing

Shu-Guang Kuai[1] (shuguang.kuai@gmail.com), Wu Li[1], Cong Yu[1]; [1]State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, China

When an object passes through a narrow slit, even though only a small fragment of the object is seen at a given moment, the object can still be perceived as a whole. Little is known about how our visual system temporally integrates fragmented images at the same retina location. As an important constituent of visual object is visual contour, here we examined whether and how discrete contour elements could be temporally integrated under slit-viewing.

Visual contours composed of Gabor patches and embedded in a background of randomly oriented Gabors were moved behind a vertical slit. The contour elements were either parallel ('snake'), orthogonal ('ladder'), or at 45 deg ('acute') to the contour path. A temporal 2AFC method of constant stimuli was used to measure contour detection performance.

We found that: (1) In the 'snake' configuration, even though the slit was narrower than the average distance between neighboring Gabors, the embedded global contours could be reliably detected with an inter-element angle difference up to 20 deg and within a broad range of moving speeds up to 13 deg/s. (2) Contour detection was independent of the spatial phase (in-phase or out-of-phase) of contour elements, excluding the possibility of temporal luminance summation by single spatial filters. (3) 'Snake' paths under slit-viewing were much easier to detect than orthogonal and acute paths.

Our study indicates that the Gestalt rule of continuity governing spatial interaction in full-field viewing still applies to temporal integration under slit viewing. This suggests that the contour-related information under slit-viewing can be extracted locally by an ensemble of visual neurons whose responses are modulated by recent stimulus history, and that long-range collinear interactions are not a unique mechanism in linking visual contours.

24.14, *3:30 pm*

Change detection for objects on surfaces slanted in depth

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Change detection for objects associated with a surface extended in depth might be more difficult than for a frontal surface if it is easier to shift attention within a frontal surface. On the other hand, previous research has shown that ground surfaces have a special role in organizing the 3D layout of objects shown against scene backgrounds. In the current study we examined whether a frontal background or a ground surface background would result in superior change detection performance. Observers were presented with a set of scenes in a change detection flicker paradigm. Each trial consisted of an original scene (250 ms), a blank interval (250 ms) and a modified scene (250 ms), repeated until the observer responded. Each original scene contained 21 3D cylinders against a background of alternating black and white vertical stripes. The backgrounds were frontal-parallel or slanted 63, 79 or 82 deg. The modified scenes were produced by removing one of the cylinders from the original scene. Catch trials were included in which there was no difference between the alternating scenes. The observer's task was to identify whether or not there was a change. Only trials in which the observer correctly identified a change were used in the analysis. The results showed a significant effect of surface slant on the number of exposures required to detect a change. Fewer trials were required to detect a change in the frontal and 82 deg conditions. Detection took longer for intermediate slant values. This suggests that any superiority of frontal plane backgrounds in a change detection task may be equivalent to the superiority of a near-ground plane in organizing a scene, with the lowest level of performance occurring for surfaces that are not frontal but further from a ground surface orientation.

Acknowledgement: Supported by NIH grant EY18334

URL: http://www.cogsci.uci.edu/~mlbrauns/lab/

24.15, *3:45 pm*

Reduced sampling of dynamic trajectories does not increase extrapolation bias

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Purpose. Recent work on visual and motor extrapolation of curved contours indicates that increased uncertainty due to prolonged occlusion leads to "flattening" – the curvatures are systematically underestimated (Singh & Fulvio, 2005, 2007; Mrotek & Soechting, 2007). We wondered whether other sources of uncertainty would have similar effects. We investigated how sampling the trajectories of moving objects affects observers' extrapolation through occluded regions for several trajectory curvatures. Methods. A dot traveled at constant speed across a display and was occluded by a half-disk. Subjects judged whether the dot would reemerge above or below a variable "tick mark" located at the opposite, curved edge of the occluder, responding by keypress. During training, the dot traveled along straight trajectories. In the experimental session, subjects extrapolated lines and four circular-arc trajectories varying in curvature. Trajectory sampling ranged from continuous to less than 50% visible. We used an adaptive staircase to estimate the extrapolation PSE for each of 5 (curvature) by 4 (sampling) conditions. Three observers participated in the task. Results. Across subjects, line path extrapolation accuracy was high during training with no significant effect of sampling (0.59-3.19 deg bias across conditions). In the curves session, the subjects' estimated points of emergence were biased in the direction consistent with "flattening". Path curvature had a significant effect on bias ($p<0.01$): as path curvature increased, curvature underestimation increased from 0.7-5.13 deg (lowest) to 5.08-17 deg (highest) across sampling conditions. Although sampling effects were non-significant, sparser sampling weakly increased curvature underestimation. No interaction was observed. A significant correlation between bias and variability was obtained ($r=0.276$, $p<0.05$) with individual correlations being stronger in the curvature conditions. Conclusions. Consistent with previous work, increased curvature of dynamic trajectories leads to increased "flattening" in extrapolation. Variation in sampling rate across the range considered had no discernible effect.

Acknowledgement: NSF Graduate Research Fellowship (JMF) ONR N 00014-07-1-0937 & NIH EY015261 (PRS) NIH EY02668 (LTM)

Saturday Sessions

24.16, *4:00 pm*

Why features defined purely by color need not be represented at early stages of visual analysis

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The visual system summarizes complex scenes to extract meaningful features (Barlow, 1959; Marr 1976) by using image primitives (edges, bars), encoded physiologically by specific configuration of receptive fields (Hubel & Wiesel, 1962).

We recently proposed a pattern-filtering approach, based on the principle of most efficient information coding under real-world physical limitations (Punzi & Del Viva VSS-2006), that is a good predictor of an early stage of visual analysis. The model, when applied to black and white images, predicts from very general principles the structure of visual filters that closely resemble well-known receptive fields, and identifies salient features, such as edges and lines. A comparison with the performance of human observers showed that human sensitivity closely follows the model predictions (Del Viva & Punzi VSS-2006).

Here, the same approach is applied to a set of colored natural images, in order to consider the role of color in the initial stages of image processing and edge detection. Again, the model identifies salient features in these more complex and realistic images, using both color and luminance information. The model predicts, however, that color information is used in a very different way from luminance information. The results show that equiluminant patterns are far from being efficient coders of information: they are either too common (uniform colored regions) or too rare and therefore are discarded by our approach. These results thus provide a theoretical explanation from first-principles for the presence of cells, in primary visual areas, that do not discriminate between chromatic or achromatic spatial patterns (see for example Johnson et al., 2001).

Acknowledgement: Supported by NIH grant EY-04802

Attention: Tracking and Shifting

Saturday, May 9, 2:45 – 4:15 pm
Talk Session, Royal Palm Ballroom 4-5
Moderator: Julie Golomb

24.21, *2:45 pm*

Targets in RSVP Sentences: Attentional Blinks in Whole versus Partial Report

Mary C. Potter[1] (mpotter@mit.edu), Jennifer Olejarczyk[1], Brad Wyble[1]; [1]Brain & Cognitive Sciences, MIT

Potter, Nieuwenstein, & Strohminger (2008) found that there was an attentional blink for report of the second of two red (or uppercase) words at a short SOA, in an RSVP sentence presented for 93 ms per word. If participants simply reported the whole sentence without looking for targets, they had no difficulty including the same two words along with the rest of the sentence. In new experiments, the task required report of the sentence together with report of the two targets (red words or uppercase words). Although the target words were reported in recall of the sentence, participants again showed an attentional blink--they frequently failed to identify which word had been red (or uppercase). In further experiments, the targets were strings of Arabic digits (e.g., 5555) or written digits (e.g., five). The easily discriminated Arabic digits showed little evidence of a blink in whole report, whereas with written digits there was an attentional blink in both whole report and partial report--and recall of the sentence was poor. Thus, when the targets are not visually distinguished from the words of the sentence and must be selected by meaning, sentence report and digit report are mutually interfering. Notably, in all the experiments there was lag 1 sparing (facilitation of T2 at an SOA of 93 ms) in all the conditions in which there was an attentional blink at lag 2 or 3, in accordance with Wyble's theory of AB (Wyble, Bowman, & Nieuwenstein, in press). Lag 1 sparing results because the attentional episode initiated by T1 extends for about 150 ms, benefiting T1 if it appears in that interval, but leading to an attentional blink at a longer SOA as the first episode is consolidated. Overall, the results show that the attentional blink is a blink of selection, not of perception.

Acknowledgement: Supported by MH 047432

24.22, *3:00 pm*

Distractors in Multiple Object Tracking can be suppressed early or late in processing: 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. We examined the role of visual attention in the MOT task by measuring event-related potentials (ERPs) to probe flashes presented on targets, distractors, or empty background areas. Across three experiments we found evidence of both enhancement of targets and inhibition of distractors. When probes were irrelevant to observers, targets were enhanced and distractors were suppressed at the level of the N1 component. However, when probes were relevant to observers (i.e., a subset of probes required a behavioral response), these early attention effects were not observed. Instead a distractor inhibition patterns was observed in the amplitude of the P300, suggesting that inhibition had been postponed to a later stage of processing. Early attention effects were reinstated, however, when the tracking task was made more difficult even though probes were still relevant. In this case, attention seemed to enhance targets early in processing (i.e., at the level of the N1) but still suppressed distractors at later levels of processing (i.e., at the level of the P300). In sum, these results suggest that attentional selection in MOT is flexibly determined by task demands and that distractor objects may be suppressed early or late in processing.

24.23, *3:15 pm*

The functional nature of motion-induced blindness: Further explorations of the 'perceptual scotoma' hypothesis

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Perhaps the most striking phenomenon of visual awareness to be discovered in the last decade is that of motion-induced blindness (MIB). In MIB, fully visible and attended objects may repeatedly fluctuate into and out of conscious awareness when superimposed onto certain global moving patterns. While frequently considered as a limitation or failure of visual perception, we have proposed that MIB may actually reflect a specific functional heuristic in visual processing for identifying and compensating for some visual impairments. In particular, when a small object is invariant despite changes that are occurring in the surrounding visual field, the visual system may interpret that stimulus as akin to a scotoma, and may thus expunge it from awareness. Here we further explore this 'perceptual scotoma' hypothesis (New & Scholl, 2008, Psychological Science), reporting several new features of MIB, and responding to some apparent challenges. In particular, we explore the role of moving targets in MIB. Though scotomas can be stationary, some ('motile scotomas', or 'floaters' consisting of material within the eye) may frequently move. The character of such movements, however, yielded the unique prediction that moving targets in MIB displays may be more likely to perceptually disappear when they are floating downward vs. rising upward through the same positions — a prediction that was robustly confirmed. In additional experiments, we explored the effects of targets in MIB that moved with vs. against smooth horizontal eye movements. Targets moving with fixation (as would a scotoma) disappeared much more readily. Because this effect occurred when both types of moving targets were present in the display at the same time,

such effects cannot be explained by appeal to microsaccades or attentional effects. These and other new effects each support the idea that MIB reflects an adaptive visual function.

URL: http://www.yale.edu/perception/

24.24, *3:30 pm*

Attentional updating across saccades in retinotopic visual cortex

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A fundamental property of the visual system is the ability to update visual representations across saccades. While representations of transient visual stimuli may update before a saccade is completed, representations of endogenous sustained spatial attention appear to update more slowly. Previous psychophysical work has demonstrated that attention remains in retinotopic (eye-centered) coordinates for 100-200ms after a saccade during a spatiotopic (world-centered) task where attention to retinotopic locations confers no behavioral advantage (Golomb, Chun, and Mazer, 2008, J. Neurosci.). To explore attentional updating in retinotopically-organized visual areas, we conducted an fMRI study in humans using a similar task. Subjects covertly attended to a consistent spatiotopic location ("target" location) for the duration of the experiment. Trials began with a fixation dot appearing in one of four locations surrounding the target location, such that the target location occupied a different visual quadrant for each fixation. After a variable delay, an array of randomly oriented masked Gabors was briefly flashed on the screen. Subjects indicated the orientation of the stimulus appearing at the target location with a button press. On half of the trials, the fixation dot moved and a saccade was executed before the stimuli appeared. Stimuli were arranged to provide equivalent visual stimulation in all four visual quadrants – corresponding to the spatiotopic target, retinotopic non-target, and two control non-targets. In retinotopically-mapped regions representing human V4, BOLD responses were enhanced for retinotopic non-targets appearing 50ms after the saccade, consistent with residual behavioral facilitation. When stimuli appeared 1550ms after the saccade, only spatiotopic targets were facilitated. This novel finding demonstrates that when top-down signals redirect spatial attention to a new retinotopic location, residual facilitation transiently remains in cortical areas representing the previously relevant retinotopic location. These results provide further evidence that the native coordinate system of visual attention is retinotopic.

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24.25, *3:45 pm*

Speed of vision depends on temporal expectancy

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Temporal expectations play an important role in optimizing future perception and behavior, but the nature of the attentional processes affected by our expectations is still widely debated. To investigate effects of expectations on the speed of visual processing, we employed a cued single-letter recognition task with stimuli of varied durations terminated by pattern masks. To obtain an estimate of processing speed unconfounded by motor components, we used accuracy-based measures rather than reaction times.

Eight healthy young subjects completed a total of 4,000 trials each. A symbolic cue at the beginning of each trial induced an expectation about the time when the stimulus letter would appear. Waiting times were not fixed but distributed exponentially. The cue indicated which of two distributions with different hazard rates the waiting time would be drawn from. The hazard rate could be either high (1.33 s-1) or low (0.22 s-1) corresponding to mean waiting times of 750 ms and 4,500 ms, respectively.

The probability (p) of correct report was approximately an exponential function of the stimulus duration (t): p = 1 – exp[-v (t – t0)], where t0 measured the threshold of conscious perception, and v measured the processing speed at times t > t0. Cue type did not affect the threshold of conscious perception in any of the subjects, but all subjects showed a highly significant reduction (on average 30%) in processing speed on trials with low as compared with high hazard rate. This effect was found even though no general decrease in processing speed over time occurred; thus, the observed pattern was independent of the actual duration of the waiting time, but depended entirely on expectation. This seems to be the first time speed of vision – unconfounded by motor components – has been shown to depend on temporal expectancy.

24.26, *4:00 pm*

Binding into sequence: temporal dynamics of sequential movements modulate the attentional pre-selection of subsequent goals

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Chaining movements into sequence is one of the most integral strategies to form complex behaviour. Many actions that we perform everyday are coordinated concatenations of motor primitives. Previously it has been shown that the visual system is involved in the preparation of fluent movement sequences by pre-selecting multiple future goal locations in advance of sequence initialisation. Here, we investigated in several experiments how the pre-selection of subsequent movement goals depends on the temporal dynamics of the planned motor sequence. Specifically, we tested the hypothesis that only in fluently executed movement sequences the motor primitives are chunked together such that visual attention splits in order to pre-select all subsequent movement goals simultaneously. In contrast, interrupted motor sequences may be prepared step-by-step and therefore visual attention is hypothesized to only select the immediate goal location.

In our experiments, participants were instructed to perform double-step eye- or hand movements in certain rhythms, i.e. to voluntarily interrupt the sequence production by predefined inter-movement delays. A secondary discrimination task served as a measure for the distribution of visual attention in the field during the initial motor preparation. The results show that subsequent goal locations were gradually better pre-selected the shorter the inter-movement delay was. Inter-movement delays of 300-500 ms constitute a threshold at which subsequent motor goals were no longer selected by visual attention in advance. This suggests that the visual preparation of intended movement-sequences crucially depends on the temporal dynamics of those motor units. Subsequent goals are only pre-selected if the inter-movement delay is too short for the full preparation of the second movement component.

Memory: Working and Long-term

Saturday, May 9, 5:15 – 7:00 pm
Talk Session, Royal Palm Ballroom 1-3
Moderator: George Alvarez

25.11, *5:15 pm*

Perception, not Working Memory, is All-or-None

Liqiang Huang[1] (lqhuang@psy.cuhk.edu.hk); [1]The Chinese University of Hong Kong

A recent important debate regarding the nature of visual working memory concerns whether it represents a small set of high-resolution representations (the "slot" model, Zhang & Luck, 2008), or all items in parallel (the "resource" model, Bays & Husain, 2008). These two models make different claims regarding how participants store information when faced with a large number of items: the slot model claims that they store high-resolution representations of a subset of the objects and retain no information about the others, whereas the resource model claims that they could store some imperfect information about each of the objects. In this study, we distinguished the two models by asking participants to memorize the colors of six objects, and then testing their recall of each color. The frequency distribution of scores (i.e., the number [0-6] of correct responses) was modeled, and, in terms of the predictions of the two models, the empirical pattern of frequency distribution was found to fit precisely with the resource model, but to differ clearly from the slot model. Furthermore, we showed that the

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all-or-none mode demonstrated by Zhang and Luck (2008) can manifest without any involvement of visual working memory slot limits, and that, therefore, it is probably irrelevant to the mechanisms of visual working memory.

25.12, *5:30 pm*

Adults store up to 3 featurally-overlapping sets in working memory

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Adults can enumerate up to three simultaneously- or sequentially-presented sets in parallel (Feigenson, 2008; Halberda et al., 2006). Critically, the stimulus items in previous studies contrasted in category membership such that each item belonged to only one set—hence observers could store information about three independent sets.

We asked whether observers can also store a single, unified representation for the purposes of later re-parsing, and what the limits of this ability might be. In Experiment 1, observers verbally shadowed while watching a stream of red triangles and circles and blue triangles and circles placed into two buckets in unpredictable, temporally intermixed order. Hence any given object simultaneously belonged to two sets (e.g., the set of red objects, and the set of triangles). Observers successfully judged the relative numerosity of all possible set parsings (i.e, successfully indicated which bucket had more red objects, blue objects, triangles, circles). Because of the 3-set limit demonstrated in earlier work, observers could not have succeeded by tracking all 4 overlapping sets, but instead must have flexibly parsed a representation from memory.

We next probed the limits of this ability. In Experiment 2, observers saw three orthogonal dimensions (colour, shape, topology) and were found to make accurate numerosity judgments for sets defined by all three dimensions (i.e., 6 different sets). In Experiment 3, observers saw four dimensions (colour, shape, topology, size), and failed to make accurate judgments along all four dimensions (8 different sets), thus replicating the 3-set limit of WM.

These findings suggest adults can simultaneously track multiple overlapping sets and repeatedly parse the array while it remains stored in WM. That the previously demonstrated 3-item limit of WM appears to converge with a 3-dimension limit suggests that the units of WM may be objects, sets, or featural dimensions such as those explored here.

25.13, *5:45 pm*

Comparing the Fidelity of Perception, Short-term Memory, and Long-term Memory: Evidence for Highly Detailed Long-term Memory Representations

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Recently we demonstrated that visual long-term memory (LTM) can store thousands of objects with remarkable fidelity, but it remains unclear how the fidelity of LTM compares to the fidelity of short-term memory (STM) or online visual perception. We used color as a case study to quantify the fidelity of LTM, STM, and perception using pictures of real world objects. LTM: 180 real objects were presented one at a time, with their color space randomly rotated. Afterwards, observers adjusted the color of each test item to match the original. STM: 3 objects were simultaneously presented. After a brief blank interval, color memory for all three items was sequentially tested. PERCEPTION: 2 copies of the same object appeared side by side, and observers adjusted the color of the item on the right to match the color of the other item. In all experiments, error was measured as the distance on the color wheel between the chosen color and the actual color of the object. Using a mixture modeling method (Zhang and Luck, 2008) we quantified two parameters of performance: the variability of internal representations of color (SD), and the probability of guessing (PG). As expected, the fidelity of color representations was better for perception (SD = 6.2°) than STM (SD = 18.4°, $p < .001$). Surprisingly, the fidelity of LTM (SD = 20.7°) was comparable to STM ($p = .56$). However, the probability of guessing rose dramatically from 8% in STM to 56% in LTM. These results indicate that observers are much more likely to have no memory at all for the color of an object in LTM, but that when the color is remembered (about half the time), it is represented with the same fidelity as just a few objects briefly stored in STM.

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25.14, *6:00 pm*

The high fidelity of scene representation in visual long-term memory

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The human visual system has been extensively trained with millions of natural images, giving it the opportunity to develop robust strategies to identify exemplars of familiar categories. While it is known that memory capacity for visual images is massive (Standing, 1973), the fidelity of these representations was untested. In a recent study, we discovered that observers are able to remember specific details about thousands of objects (Brady et al., 2008). This suggests a massive memory capacity for object details, but it remains unclear whether this is a general property of memory that will also hold for scenes. Here we showed observers 3000 exemplars of real-world scenes, representing hundreds of common categories of visual environments. Embedded within the stream, there were 1, 4, 16, or 64 exemplars of different scene categories (e.g., warehouses, beaches, streets). Each image was shown only once, for three seconds each. At test, observers were shown an old and a new exemplar of a basic level category (e.g., two streets, two cafes, two beaches) and had to choose which image they saw. As expected, as the number of exemplars in the study stream increased, memory performance decreased. However, the degree of interference from multiple exemplars was minimal, averaging only a 2% drop in memory performance with each doubling of the number of the exemplars in memory: with 64 scene exemplars from a category in mind, observers could still distinguish one of those from a 65th exemplar with 76% accuracy. Even more remarkably, the drop in memory performance was identical to performance in a similar memory experiment involving images of real-world objects. These results suggest that high fidelity storage is a general property of visual long-term memory, and that categorical interference effects are similar for objects and scenes.

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25.15, *6:15 pm*

Evidence for the Role of Visual Short-Term Memory in Conscious Object Recognition

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What happens to a visual stimulus when it reaches the severe bottlenecks inherent to the human information processing system and what are the cognitive resources and neural substrates that limit the amount of information that can be consciously perceived?

Previous research has demonstrated that when visual short-term memory (VSTM) resources are fully occupied, there is a decrease in activity in the right temporo-parietal junction (rTPJ), which can result in inattentional blindness to suddenly presented stimuli. As the rTPJ has been implicated in visual neglect, we have previously demonstrated that a high VSTM load leads to impaired recognition performance for objects presented in the left visual field, mimicking the processing deficits of neglect patients.

In the present study, we used fMRI to examine the neural architecture subserving this effect. In other words, how does VSTM load affect areas that support memory, perception, and attention? Under a low (1 item) or high (3 item) VSTM load, pictures of objects were briefly presented to the left and/or right of fixation during the delay period. Under a low memory load, areas that support the maintenance of items in VSTM (superior IPS, inferior IPS, and ventral occipital areas) showed increased activity to bilaterally presented objects, relative to a single object, indicating that these areas had resources available to process additional information. Under a high memory load, however, activity in these memory regions did not continue to increase, as memory capacity had already been exceeded. Interestingly, when VSTM resources reached capacity, object recognition performance suffered. Strikingly, activity in areas that support VSTM maintenance was a better predictor of object identification performance than activity in the object-sensitive lateral occipital complex (LOC). These behavioral and neuroimaging results demonstrate that the availability of visual short-term memory resources may be critical to the conscious identification of object stimuli.

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25.16, *6:30 pm*

Decoding the contents of visual working memory from activity in the human visual cortex

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Visual working memory provides an essential link between perception and cognition, allowing for active maintenance of information no longer visible. Interestingly, a single visual feature such as orientation can be precisely maintained in working memory over many seconds, with delayed discrimination performance nearly matching that of immediate discrimination (Pasternak & Greenlee, 2005). The neural substrate of this highly faithful memory for specific visual features is not well understood; early visual areas show little evidence of sustained activity during working memory (Offen et al., 2008), but are the most selective for these low-level features. Here, we investigated whether early visual areas might be important for maintaining basic visual features in working memory. Specifically, we used fMRI decoding methods (Kamitani & Tong, 2005) to assess whether orientation-selective activity is present in early visual areas during a delayed orientation discrimination task. Two sequentially presented orientation gratings (~25º and ~115º) were followed by a cue indicating which grating to hold in memory. After an 11-second delay, a test grating was presented for participants to discriminate relative to the cued orientation. Decoding analyses revealed that activity patterns in areas V1-V4 could reliably predict the orientation maintained in memory, even when overall activity levels were low. These orientation-selective activity patterns were sustained throughout the entire delay, and were similar to responses evoked by unattended, task-irrelevant gratings. Additional control experiments ruled out alternative cognitive accounts such as visual expectancy, selection from memory, or reliance on long-term memory. For example, random orientations held in working memory could also be decoded, indicating that this sustained orientation-selective activity found in early visual areas did not depend on long-term memory. Our results demonstrate that early visual areas can retain specific information about visual features held in working memory, over periods of many seconds when no physical stimulus is present.

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25.17, *6:45 pm*

Expecting the unexpected: Dissociating visual similarity from perceptual expectation in neural repetition attenuation

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Repetition is pervasive in our visual experience. For example, we are more likely to re-encounter an object seen moments ago than a new object. The brain takes advantage of these repetitions to facilitate perception, as indexed by reduced fMRI responses in category-specific ventral visual regions. Such 'repetition attenuation' may reflect more efficient neural processing of repeated stimuli. Yet, the mechanisms underlying this repetition effect are controversial. Repetition attenuation may result from stimulus-specific learning revealed when a similar stimulus reappears. Alternatively, repetition attenuation may occur when the reappearance of a stimulus matches expectations for repetition. Here we distinguish these two possibilities by building expectations that two stimuli will be less similar. We performed a rapid event-related fMRI study in which each trial contained three views of a rendered 3D object. In the majority of trials (expected), an object rotated in place through the three views; there was a strong expectation for the third view because it continued the rotation, and because this kind of trial occurred most frequently. In the remaining trials, the third object view was either identical to the second view (similar), or an entirely new object (novel). If repetition attenuation reflects learning, then similar trials should elicit more attenuation. If perceptual expectation is more critical, then expected trials should elicit more attenuation. An object-selective region in the left fusiform gyrus showed robust repetition attenuation for both similar and expected trials, but stronger attenuation for similar trials. Lateral occipital cortex showed reliable attenuation only for similar trials. Left prefrontal regions showed equivalently robust attenuation for both conditions, while other frontal regions tracked expectation. These results suggest that the influence of bottom-up similarity vs. top-down expectation on repetition attenuation differs across brain regions. However, in ventral visual cortex, repetition attenuation is dominated by stimulus-specific learning.

Acknowledgement: Supported by NIH EY014193.

Neural Mechanisms: Cortical Organization

Saturday, May 9, 5:15 – 7:00 pm
Talk Session, Royal Palm Ballroom 4-5
Moderator: Andy Smith

25.21, *5:15 pm*

Peripheral Information in Foveal Cortex: Generalizing across Task and Stimuli

Won Mok Shim[1,2] (wshim@mit.edu), Jason Webster[1,2], Nancy Kanwisher[1,2]; [1]Brain and Cognitive Sciences, MIT, [2]McGovern Institute for Brain Research, MIT

We recently reported that the pattern of fMRI response across foveal retinotopic cortex contains position-invariant information about objects presented in the periphery, and further that this object information is correlated with object discrimination performance (Williams et al, 2008). This finding suggests that during perception of peripherally-presented objects, higher cortical areas feed information back to foveal retinotopic cortex, improving performance, a phenomenon inconsistent with most theories of object recognition, retinotopic cortex, and the role of feedback in visual processing. In order to better understand this surprising phenomenon, we tested its generality across new tasks and stimuli. Specifically, we asked whether the effect occurs only when two stimuli are compared (by testing individual peripheral stimulus categorization), and only for complex stimuli (by testing oriented Gabors instead of objects). On each trial, a single Gabor was briefly presented in a peripheral location. In separate sessions, subjects performed either a color or orientation discrimination task on the Gabor while maintaining fixation. Subjects were asked either to 1) discriminate between two shades of either red or blue, or 2) determine whether the Gabor tilted slightly right or left of the vertical axis, or slightly above or below the horizontal axis. The results show that the pattern of fMRI response in foveal retinotopic cortex contains information about the orientation (vertical vs. horizontal) of the Gabor presented in the periphery. These findings indicate that information about peripheral stimuli is found in foveal retinotopic cortex not only for object shape, but also for orientation, and not only for a simultaneous comparison task, but also for categorization of individually-presented stimuli. However, foveal information about peripheral colors is weak, and foveal information about orientations is apparently less position-invariant than information about objects, providing some clues about the boundary conditions and hence functional significance of this phenomenon.

Acknowledgement: Supported by EY 13455 to NK

25.22, *5:30 pm*

Reorganization of visual processing in macular degeneration is not specific to the "preferred retinal locus"

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Recent work has shown that foveal cortex, deprived of its normal bottom-up input as a result of macular degeneration (MD), begins responding to stimuli presented to a peripheral retinal location. However, these studies have only presented stimuli to the "preferred retinal location", or PRL, a spared part of the peripheral retina used by individuals with MD for fixating, face recognition, reading, and other visual tasks. Thus, previous research has not yet answered a question critical for understanding the mechanisms underlying this reorganization: Does formerly foveal cortex respond only to stimuli presented at the PRL, or does it also respond to other peripheral locations of similar eccentricity? If foveal cortex responds to stimuli at PRL because the PRL has become the functional equivalent of the fovea (the "Functional Fovea" hypothesis), then foveal cortex will not respond to stimuli presented at other locations. On the other hand, if foveal cortex responds to stimuli at PRL because deprived cortex simply responds to any peripheral retinal input, independent of whether input at that retinal location has been chronically attended for months or years (the "Passive Reorganization" hypothesis), then foveal cortex will respond not only to stimuli at PRL, but also other peripheral locations of similar eccentricity. Using fMRI, we found clear activation of foveal cortex to stimuli presented at either the PRL or an iso-eccentric non-PRL location in two individuals with MD, supporting the Passive Reorganization hypothesis. This finding suggests that reorganization is driven by passive, not use-dependent mechanisms.

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25.23, *5:45 pm*

Large-scale cortical reorganization is absent in both juvenile and age-related macular degeneration

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Introduction. Although there is evidence that human visual cortex is capable of reorganization with congenital central retinal lesions, it is controversial whether this capability is maintained later in life. We used fMRI to study visual cortical responses in a relatively large number of patients with macular degeneration (MD). Methods. To determine whether reorganization might be age-dependent, we compared patients from two groups: 8 with age-related MD (mean age 80±6) and 8 with juvenile MD (Stargardt disease; mean age 34±10). Patients were tested at least one year after the onset of bilateral central scotomata. Nidek microperimetry was used to select patients with an established preferred retinal locus (PRL) and no foveal sparing. PRL coordinates were then used to center stimuli on the fovea of the tested eye. Each group was compared with a similar number of age-matched controls. Standard retinotopic mapping checkerboard stimuli were presented to all participants, and central lesions were also simulated in controls. Cortical responses were compared in three anatomically defined regions of interest (ROIs) within V1: (1) LPZ, the expected "lesion projection zone" in MD patients, located at the occipital pole, (2) IPZ, representing eccentric intact retina in patients, located anteriorly in the calcarine sulcus, and (3) a baseline region where no visually elicited activity was predicted, located in non-occipital cortex. Results. Signal amplitudes for the three ROIs were compared using a multivariate ANOVA across groups. In controls, cortical responses in both LPZ and IPZ were significantly different from baseline. In patients and in simulated lesion controls, cortical responses in IPZ, but not in LPZ, differed significantly from baseline. There was no significant difference in responses between the two patient age groups. Conclusion. Large-scale cortical reorganization is not evident in patients with either juvenile or age-related macular degeneration.

Acknowledgement: Medical Research Council, UK

25.24, *6:00 pm*

Spatial organization of spontaneous activities in the human visual cortex

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Spontaneous fluctuations in fMRI BOLD signal have been shown to be temporally correlated across widely distributed brain regions. We investigated the spontaneous fluctuations within the human visual cortex. A standard EPI sequence was used to acquire functional data (3mm isotropic voxels, TR = 1s). Subjects were scanned under a "rest" condition (eyes closed) and four fixation conditions, each consisted of a rotating wedge of high-contrast flickering checkerboard sweeping across one of the four halves of the visual field (upper, lower, left, right) during the entire run. A correlation-weighted cortical labeling method was used to reveal the spatial organization of the temporal coherency. Specifically, we designated a quadrant of V1 (e.g. ventral, left hemisphere) as the reference area, where each voxel was given a numeric label – either the eccentricity value or the polar angle from a separate retinotopy experiment. For a given voxel elsewhere on the cortex, we computed the temporal correlation between its spontaneous activities with those of each voxel in the reference area. The squared correlation coefficients were then combined with the reference labels to obtain a correlation-weighted label for the voxel in question. When eccentricity values were used as reference labels, the maps of correlation-weighted labels resembled eccentricity maps in all quadrants of all visual areas studied (V1, V2, V3) in the "rest" condition, across both horizontal and vertical meridians. The same was observed in the un-stimulated quadrants in the fixation conditions. Correlation-weighted labels continued to show a ring-like structure even when the reference region was stimulated by the rotating wedge or when polar angles were used as reference labels, suggesting that the correlations between spontaneous activities are strongly organized by eccentricity but remain non-specific in other spatial directions. This robust eccentricity organization of the spontaneous activities may reflect a fundamental organizational principle of the visual system.

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25.25, *6:15 pm*

Functional connectivity among cortical regions is shaped by associative experiences

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The emergence of coherent cognition and behavior relies on the coordination of scattered mosaics of functionally-specialized brain regions. However, little is known about how the neural mechanisms that coordinate this distributed brain activity are formed. Hebb proposed that brain regions organize dynamically into functional groups by the temporal structure of their neural activity as co-activation of brain regions leads to the Hebbian strengthening of the functional connectivity between them. To test this hypothesis, we trained subjects to learn the association between photos of houses and Chinese characters, and then examined whether the coherence between BOLD signal fluctuation in the parahippocampal place area (PPA) and that in the visual word form area (VWFA) increased after the learning. We found the training not only improved the behavioral performance in pair-matching task but more importantly increased the functional connectivity between the PPA and VWFA. The increased coherence was not

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due to the mental imagery of the associated stimulus (e.g. words) when a trained stimulus (i.e. houses) was presented, because the activation level of the trained houses in the VWFA was unchanged before and after training. Together, these findings suggest that the functional connectivity between co-activated regions, but not their individual activation, may be the material basis of mental associations. Interestingly, when the PPA was activated by untrained house or scene stimuli, the neural activity in the VWFA fluctuated in a coherent fashion, suggesting that the propagation of the temporal structure in neural activation from one node to another is not stimulus specific. On the other hand, the increased coherence was limited for non-coactivated regions as the connectivity strength between the VWFA and the lateral occipital complex (LOC) and that between the PPA and the LOC were unchanged. In sum, our results provided an example of how large-scale integration is formed through Hebbian learning.

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25.26, *6:30 pm*

Population receptive field measurements in human ventral category-selective cortex

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Introduction: Category-selective regions in extrastriate cortex are conventionally defined by comparing responses to images from different categories (e.g., faces vs. houses). What is the representation of the visual field in these regions? Are separate category-selective regions part of a single map or embedded within a set of distinct visual field maps?

Methods: We scanned seven subjects on separate experiments to localize category-selective regions, and measure visual field maps (GE 3T scanner). For retinotopic experiments, subjects viewed moving bar stimuli containing different stimuli, including slowly drifting checkerboards and frontal face images. The bars extended out to ~14° eccentricity from the fovea, with a width of ~2.6°. We employed a recently-developed method for estimating population receptive fields (pRFs) using fMRI (Dumoulin and Wandell, Neuroimage, 2008), which estimates pRF center and size for each cortical location.

Results: Face-containing bars produced substantially larger responses than checkerboards along the fusiform gyrus, improving our ability to measure visual field maps in these regions. Eccentricity maps revealed two foveal representations, which may correspond to visual field map clusters previously identified as VO and VT (Wandell et al., Neuro-opth. Jpn., 2006). These foveas are within or adjacent to fusiform face-selective regions, and separated by smoothly-varying extra-foveal maps which are less face-selective.

For several subjects, pRF sizes systematically increased with eccentricity in face-selective regions. The distribution of pRF sizes were substantially larger than in earlier visual cortex, but comparable to recent measurements made in lateral occipital cortex. Current work addresses possible effects of low-level visual features (e.g. spatial frequency) and stimulus visibility in driving the observed face-selective retinotopic responses.

Conclusion: We find two spatially separate face-selective regions along the fusiform gyrus, with comparable visual field coverage, separated by a representation of intermediate eccentricities. This indicates these two regions are likely to fall within different visual field maps.

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25.27, *6:45 pm*

Localisation of the human V6 complex and parietal visual areas using egomotion-consistent stimuli

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To obtain a precise demarcation of human visual areas, it is necessary to use functional definitions. Retinotopic mapping routinely identifies many areas, but V6 is usually not among them. A previous study has shown that contrasting responses to egomotion-consistent and –inconsistent stimuli identifies visual areas in the intraparietal sulcus (putative VIP) and the cingulate sulcus visual area (CSv) (Wall and Smith, 2008). We report that this method also reliably identifies V6/V6A, and two parietal areas that may correspond to visual-vestibular regions.

We performed an event-related 3T fMRI experiment in which 10 subjects were scanned using a posterior array coil while looking at egomotion-consistent or -inconsistent stimuli. The display

consisted of moving dots arranged into either a single 50-deg patch (egomotion-consistent; EC) or a 3x3 array of nine patches (egomotion-inconsistent; EI) of time-varying optic flow. Each stimulus was presented for 3 sec and inter-trial intervals varied between 2-10 sec.

Single-subject analysis was conducted by fitting a GLM with regressors representing the two stimulus categories and six movement parameters. The statistical contrast [EC > EI] revealed consistent activations across subjects in three regions in addition to VIP and CSv. One, evident in 19 hemispheres, is at the dorsal margin of the postcentral sulcus, within or close to somatosensory cortex. The second, evident in 18 hemispheres, is in the medial parietal operculum, described by Antal et al. 2008 as PO/PT, and possibly corresponding to PIVC. The third, readily seen in all hemispheres, is a region of the parieto-occipital sulcus, medial to V3A and consistent with the description of human V6 (Pitzalis et al, 2006). Differential activation was sometimes also observed in the MT complex.

We show that these stimuli provide a simple and reliable localiser for the V6 complex and we suggest that V6 may be involved in the computation of egomotion.

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Color and Light: Lightness and Brightness

Saturday, May 9, 2:45 – 6:45 pm
Poster Session, Royal Palm Ballroom 6-8

26.301

A high resolution, high dynamic range display for vision research

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Electronic display systems have been a boon to vision researchers for their flexibility as stimulus generators. However conventional displays only produce moderate luminance levels and limited contrast ranges. This constrains their utility as tools for exploring visual response over the vast levels and ranges we experience in the real world. Fortunately high dynamic range (HDR) displays are being developed that can produce luminance levels and contrasts on the order of those encountered in real world scenes. Typically, these displays use a LCD front panel with a spatially modulated backlight produced by a digital projector or LED array. One consequence of this design is that the backlight only shows a low frequency image, which limits the range of spatial frequencies that can be produced at high luminance contrasts. This reduces the value of these displays as visual stimulus generators. To address this problem we have developed a high resolution, high dynamic range display system for vision research that is capable of producing high luminance contrasts across a broad range of spatial frequencies. The display's front panel consists of a 30" Apple LCD monitor with 2560x1600 addressable pixels. The backlight image is produced by a tiled array of DLP projectors that we have corrected geometrically and colorimetrically using custom camera-based calibration software. The display is capable of producing spatial frequencies up to 12 cycles/degree (24" viewing) at luminance contrasts up to 40,000:1. We are using the display for material perception studies, where high intensity specular reflections are important, and for low vision research, where deficits often appear at extreme luminance contrasts. This display represents a useful new tool for vision research that can be constructed using commodity display hardware and standard image tiling methods.

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26.302

Inferring characteristics of stimulus encoding mechanisms using rippled noise stimuli

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Several psychophysical studies have used masking techniques to infer characteristics of stimulus encoding mechanisms underlying early visual processing. These studies typically suggest the existence of multiple frequency- and orientation-selective filters or 'channels'. To evaluate the usefulness of such a multiple channel encoding front-end in more general models of pattern vision, knowledge about various channel properties is required. Notably, estimates of channel characteristics such as shape and bandwidth vary considerably among studies. One problem is that inferring encoding mechanism characteristics requires (often unwarranted) assumptions regarding various aspects of the visual system (e.g., linearity of contrast processing). Differences in estimates of the channels may reveal important nonlinearities that need to be taken into account. In the present study, we start from reported channel characteristics and traditional assumptions to generate predictions for a new class of stimuli. More specifically, assuming linearity in strong visual noise, the psychophysical channel shape proposed by previous studies can be approximated by a discrete Fourier series. Thus, under the linearity assumption, any given channel shape corresponds to a specific set of Fourier coefficients. A novel kind of stimulus, i.e. rippled noise, is introduced in the present study to estimate these Fourier coefficients. Rippled noise, characterised by a sinusoidally-modulated frequency spectrum, has been used before in hearing research but not in spatial vision. Channel estimates resulting from this new detection-in-noise method will be presented and compared to estimates reported in previous studies.

26.303

An ideal observer model predicts lightness matches

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Background: We seek general principles that allow prediction of perceived lightness for a large class of images using measurements of a small subset of images. Here we consider the class of grayscale checkerboard images.

Psychophysics methods: Observers viewed 25-square checkerboard images presented on a high-dynamic range computer display. Observers matched the lightness of the center square to grayscale surfaces presented in a separately illuminated booth. The remaining 24 squares defined the viewing context for the center square. For each context, we measured the full mapping between center square luminance and matched reflectance.

Model methods: We formulated a Bayesian algorithm that estimates surface reflectance and illuminant intensity. Algorithm estimates were driven by prior distributions over surface reflectance and illuminant intensity. Priors allowed both surface and illuminant properties to vary with spatial location, but contained a bias that favored more slowly varying illumination. The algorithm was converted to a model via the linking hypothesis that two checkerboard squares have the same lightness when the algorithm estimates their surface reflectance to be the same.

Results: A number of distinct factors of the checkerboard context were varied. These include highest square luminance, lowest square luminance, distribution of square luminances, and the spatial arrangement of the squares within the contextual checkerboard. All of these factors affected the mapping between central square luminance and matched reflectance. The psychophysical data were used to determine a small number of parameters that characterized the Bayesian algorithm's priors. The resulting model provided a good account of performance.

Conclusions: We present a quantitative model for lightness perception in arbitrary checkerboard scenes. Although the current model does not account for lightness phenomena that arise with more complex geometric arrangements, the surface-illuminant estimation principles that drive it are general, and thus have the potential to be elaborated to include such phenomena.

26.304

Color provides leverage to assess theories of lightness

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A growing body of data has revealed a variety of phenomena that demonstrate the strong dependence of perceived lightness on context. Extensive debate continues over the underlying processes responsible for these effects. Some theories advocate that the visual system explicitly decomposes the image into layered representations, whereas other theories do not. Recent work from our lab has shown that the scission of images into transparent layers can induce strong transformations in both perceived lightness and color. This suggest the possibility that if scission qua transparency contributes to a transformation in perceived lightness, that similar effects should also arise for purely chromatic stimuli. To assess this possibility, we studied two stimuli, one that evokes a strong percept of transparency (Adelson's "tips and strips" illusion), and another that does not (Todorovic's "checkerboard-gradient" illusion). We compared the achromatic induction observed in each display to equiluminant chromatic variants of the same pattern. Each pattern can be treated as a superposition of two elements: a background ("strips", or gradient); and targets ("tips" and diamond, or checkerboard); for the Adelson and Todorovic displays (respectively). The observer's task was to match perceived color or lightness of a matching display presented on a neutral random-dot background with one of two target elements in the test display. Our results revealed that a similar pattern of induction was observed for the chromatic and achromatic display that evoked a clear percept of transparency (Adelson's tips and strips display). However, a clear difference emerged for Todorovic's checkerboard-gradient illusion: whereas the effect for the checkboard + gradient was significantly larger than either component alone in the achromatic condition, the chromatic gradient alone produced essentially equivalent induction as the combined condition. We suggest that color may provide theoretical leverage to distinguish different models of how context affects perceived lightness.

26.305

Perception of the highest luminance under extremely low illumination levels

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We tested the claim by anchoring theory that the highest luminance in the visual field always appears white, using Mondrian patterns under extremely low illumination. Observers were brought into a very dark lab and seated in front of a very dimly illuminated Mondrian that contained the highest luminance in the room. Observers first reported which patch appeared to be the brightest and then gave a verbal description of its lightness. Then the observer turned away and was shown a Munsell chart under bright illumination (xxx) and made a match from immediate memory. Ten naïve observers served in each experiment. In the first experiment, a 28 patch Mondrian pattern was presented on an LCD screen. Median match for the highest luminance patch (0.89 cd/m2) was Munsell 9.0. Experiment 2 tested a paper Mondrian with a truncated luminance range of 4:1 containing 24 patches ranging from only black and middle gray. Median match for the highest luminance patch (0.068 cd/m2) was Munsell 9.0. Experiment 3 tested a 33-patch paper Mondrian with a full black to white range (30:1). Median match for the highest luminance patch (0.055 cd/m2) was Munsell 8.5. Experiment 4 employed a 29-patch Mondrian with a full range

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and luminance levels in the scotopic range. Most of the patches were colored and the highest luminance was 0.001 cd/m2. No colors could be seen; indeed nothing could be seen for the first few seconds. Median match for the highest luminance was Munsell 8.5, regarded by most subjects as a white, if a poor white. The highest luminance rule holds across a vast range of illumination. It fails, if at all, only weakly, and that at extremely low luminance values.

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26.306

Lightness constancy and illumination contrast discounting

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The luminance contrast produced by a reflectance edge was judged as apparently equal to almost three times higher luminance contrast produced by an illumination edge (Logvinenko, AIC, 2005). Such illumination contrast discounting was subject to large inter-individual variability. As lightness constancy also exhibits considerable individual differences, we decided to ascertain whether lightness constancy and illumination contrast discounting are related to each other.

The stimulus consisted of a large sheet of black paper with a rectangular spotlight projected onto the lower half and 40 squares of different gray shades printed on the upper half. The luminance ratio at the edge of the spotlight was 25:1 while that of the squares varied from 2:1 to 16:1.

Observers were asked to find a square in the upper half which (1) had the same luminance contrast as the illumination edge (contrast match) and (2) which looked as if it was made of the same paper as that on which the spotlight fell (lightness match). Each observer made ten matches under each instruction.

The median luminance ratio for the contrast match was 9.2. Hence, the luminance contrast produced by illumination was underestimated by a factor 2.75. While the tasks were different, the median match for the group of 40 observers was the same for both, Friedman's ANOVA showing no significant effect of the task (Chi-sq=1.04, df=1, p=0.31). Only for 14 observers the lightness match significantly differed from the contrast match according to a Kruskal-Wallis test (p > 0.05). The Brunswick ratio for the lightness match varied from 0.44 to 0.88, the median being 0.68. A perfect correlation was found between the two indices: the higher the Brunswick ratio, the higher the illumination contrast discounting.

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26.307

Simultaneous contrast is size dependent but does not scale with eccentricity

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Purpose: Simultaneous contrast demonstrates that a uniform grey is seen as darker on a white background than on a black background. The phenomenon can be easily understood in terms of centre-surround mechanisms known to exist throughout the visual system. The sizes of these mechanisms are known to increase with eccentricity. Therefore, we ask whether the strength of the simultaneous contrast illusion changes with stimulus size and eccentricity.

Method: Stimuli comprised five square regions stacked to form a vertical rectangle. Region 2 (the standard) was of fixed luminance (.5) and subjects adjusted the luminance or region 4 (the match) to match that of region 2. Regions 1 and 5 contained luminance gradients from 0 to 1 [/] and region 3 contained a luminance gradient going from 1 to 0 [\]. Therefore, the cross-section of a stimulus going from top to bottom would be: [/ — \ — /]; i.e., region 2 was surrounded by white and region 4 by black. Stimuli were presented at 9 logarithmically spaced sizes ranging from 102 to 1152 pixels at eccentricities of 0, 1, 2, 4 to 8° in the right visual field.

Results: Under free viewing conditions (stimuli presented nominally at 0°) matches were veridical (.5) at small sizes and decreased (e.g., to .30) as stimulus size increased; i.e., the standard illusion was seen at large stimulus sizes. Similar results were found when subjects maintained fixation on a small dot and stimuli were presented at 0 to 8°. Unlike standard size scaling results, however, the functions relating stimulus size to match luminance were not shifted versions of each other on a log size axis. The curves at 0 to 4° were essentially superimposed and that at 8° was shifted rightward.

Conclusions: Although simultaneous contrast is size dependent it does not show typical eccentricity dependence.

Acknowledgement: This research was supported by NSERC grants to Rick Gurnsey

26.308

Long-range argyles and spatial-scale models of brightness

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Shapiro et al (2007; 2008) demonstrated that most brightness illusions can be accounted for by removing low spatial frequency content from the image. Here we examine the ability of this approach to account for a class of phenomena we refer to as Long-Range Argyles (LoRA). LoRA elements are diamonds divided into four quadrants: two gray, one black, and one white (black and white quadrants are on opposite sides of the diamond). The diamonds are arranged in columns (or rings), with black quadrants facing each other and white quadrants facing each other. When the columns are close together on a gray background, the display is the same as Adelson's Argyle illusion (the gray area between the white quadrants appears dark; the gray area between the black quadrants appears bright). In LoRAs, however, the columns can be moved independently of each other. We demonstrate that the brightness effects 1) occur over large spatial distances (i.e., when columns are separated by more than 15 deg); 2) are fast, relative to standard induction (i.e., the effect can be seen when white and black quadrants modulate at 8 Hz); 3) do not depend on sharp edges (i.e., the effects in LoRAs occur when one or more columns are blurred; this is important because under such conditions, the columns appear to be in different depth planes); 4) can occur simultaneously at different spatial scales; and 5) appear in the presence of other long-range spatial interactions (i.e., a column that swings horizontally appears to shift vertically when flanking columns are present). A high-pass filter model with a single cutoff spatial frequency can account for some aspects of LoRA phenomena, but not at all spatial scales simultaneously, and not at spatial ranges much larger than the diamonds. We discuss the role of a separate contrast pathway (Shapiro, 2008).

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URL: www.shapirolab.net/LoRA

26.309

Effects of global and local stimulus configurations on brightness perception within articulated surrounds

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[Purpose] A brightness difference between two identical gray targets on uniform light and dark surrounds becomes larger when the surrounds are replaced by articulated surrounds of the same average luminances. Here, articulated surrounds refer to the ones composed of many small squares having different luminances (Adelson, 2000). This study introduced the perception of transparency over the articulated surround by manipulating global stimulus configuration alone, and investigated its effects on brightness perception of the target on the surround.

[Methods] By adding a contiguous region of lower luminance to the dark surround, the perception of transparency (i.e., being covered with a larger dark filter or shadow) was produced under the transparency condition. Under the no-transparency condition, the perceived transparency was eliminated by making gaps at the border between the surround and the contiguous region in Experiment 1, and by separating the dark from the light surround and also by introducing gaps at the border of the dark surround in Experiment 2. Local stimulus configuration within the surround was kept constant under the two conditions. Both spatially uniform and articulated fields were used as the light/dark surround. The spatially-averaged luminances of the light and dark surrounds were 1.16 and 0.38 log

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cd/m2, respectively. The target luminance was either 0.6 or 0.45 log cd/m2. Observers matched the brightness of the target by adjusting the luminance of a comparison stimulus.

[Results and Discussion] With the uniform surrounds, the target on the dark surround appeared brighter under the transparent condition than under the no-transparency condition. In contrast, the brightness difference was not found with the articulated surrounds in both experiments. These findings suggest that the brightness perception on the present articulated surround was determined almost exclusively depending upon local computation of brightness, although the manipulation of global configuration substantially changed the appearance of the articulated field.

26.310

The effects of contrast on the achromatic watercolor illusion

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The watercolor illusion involves color spreading generated by patterns formed by two touching thin lines with different colors. Usually the color spreading is more salient on the side of the line that has lower contrast against the background. According to Pinna & Grossberg (J Opt Soc Am A; 2005 22(10):2207-21) the watercolor effect results from a combination of weakening of boundary signals from local competition between line representations and filling-in of illusory color across weakened boundary signals. Most previous studies of the watercolor effect used chromatic stimuli and reported color saturation matches to non-illusory stimuli. It is difficult to study the effects of contrast in a chromatic setting, so in this study, we develop a series of achromatic stimuli that have a similar configuration to classic watercolor stimuli and generate measurable achromatic watercolor effects. Further, we use a precise matching paradigm to quantitatively explore the achromatic watercolor illusion, whereby the lightness of a watercolor surface region is compared to that of a non-illusory region bounded by a single dark line. The measure of strength of the illusion is the amount of luminance change in the non-illusory stimulus that is needed to generate a lightness match to a watercolor stimulus. The achromatic watercolor effect seems to be stable with only small variability as the contrast of the lines changes greatly. Our results thus help constrain the search for possible neural mechanism underlying the phenomenon.

26.311

Illusory contours in a White's display

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Purpose: When the grey target of a White's display overlaps a pair of adjacent black and white stripes, an illusory contour appears as the continuation of the border between the stripes, but with the contrast polarity reversed. This effect accounts the hypothesis that when two aligned contours undergo a discontinuous change in the magnitude of contrast, but preserving the contrast polarity, the lower contrast region is decomposed into two causal layers. In order to analyze the plausibility of this hypothesis we studied the strength of the illusory effect.Methods: Using a forced choice method with constant stimuli, we measured the luminance of the gray target half over the white stripe that had been matched in brightness to the gray target half over the black stripe which had a constant luminance value. In order to avoid aftereffects a test presentation time of 0.5 s and an ISI of 1.5s was adopted. A control experiment was made considering a similar measurement with a grey target centered over a half white-half black background. Six subjects were evaluated.Results: As we had expected, brightness matches show a slightly but systematic increment (mean of 8.6%) in the half part of the target overlapping the black stripe. In the control experiment, we surprisingly found a similar result to the main experiment, a brightness increment in the half part of the target surrounded by a black background (mean of 7.6%). This last result indicates that the illusory contour could be also explained by mean of a depth cue introduced by the T-junction and a posterior simultaneous contrast mechanism.Conclusion: We present a new visual illusion that consists in an illusory contour that appears in a target embedded in a White's display. The two previously proposed high level processes could explain the illusion.

26.312

Craik-O'Brien Cornsweet effect occurs after binocular fusion

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When a homogenous luminance field is divided by the opposing light and dark luminance gradients ("COC edge"), the field appears to be divided into two uniform fields of different lightness (Craik-O'Brien Cornsweet effect; COCE). This phenomenon does not occur when the luminance field with a COC edge is embedded in the larger background of same physical luminance as the original luminance field (Purves et al., 1999). The illusion is restored when the target regions are specified as a surface by contours. Here, we examined whether the surface with a COCE is formed before or after binocular fusion. Observers fused a vertical COC edge on a uniform gray background in one eye with a rectangle consisted of thin black lines in the other eye. When the two dichoptic images were adequately fused, the regions surrounded by a black rectangle frame was divided into two regions of the same shape. Observers were asked to compare the perceived lightness of the two areas divided by the COC edge while the physical luminance difference between the two areas was systematically varied. If a COCE is observed, it suggests that the COCE is derived at a level after binocular fusion. In a control experiment, observers also binocularly viewed COC edges and rectangle frames. Results showed that the COCE was robustly observed among all conditions. The magnitude was virtually the same for binocular and dichoptic presentation conditions. These results suggest that the underlying mechanism of the COCE is located after the level of binocular fusion.

26.313

Illusory Brightness Priming Occurs Without Awareness

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Our visual systems are usually confronted with large quantities of information, but due to processing constraints, only a small subset of this information enters awareness. Thus, one issue of fundamental importance in vision is whether conscious and unconscious visual representations differ. The current experiments assessed whether real and illusory brightness processing can proceed in the absence of visual awareness by measuring unconscious priming with metacontrast masking. To assess whether real brightness processing occurs without awareness, a dark or bright priming disk was presented on a neutral gray background and then masked by a dark or bright annulus. In the illusory brightness conditions, a neutral gray priming disk was presented on either a dark or bright background to induce an illusory brightness of the disk via simultaneous brightness contrast. Using a disk to mask stimulus onset asynchrony that resulted in approximately equal numbers of aware and unaware trials, we found that reaction times to the brightness of the masks were significantly faster when the disk and annulus were identical in luminance than when the disk was bright (or dark) and the mask was dark (or bright), for both the aware and unaware trials. When the neutral gray disk was presented on a dark (or bright) background, such that the gray disk could be consciously perceived as bright (or dark), reaction times were significantly faster to the bright (or dark) annulus than to the dark (or bright) annulus. Surprisingly, this illusory brightness priming occurred in both the aware and unaware trials. Additional analyses and a control experiment indicate that these effects cannot be explained by independent effects of the background or adaptation. These results demonstrate that both real and illusory brightness contrast can be represented unconsciously and suggest that simultaneous brightness contrast occurs at very early levels of visual input.

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26.314

Invisible context modulates conscious perception

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There is now considerable evidence that invisible stimuli can undergo cortical processing and influence behaviour. However, whether such unconscious processing can causally influence conscious perception is less well understood. Many visual illusions rely on the influence of a spatially distinct context on perception of a central element. For example, in Simultaneous Brightness Contrast, the perceived brightness of a central disk is influenced by the luminance of a spatially distinct surround, such that a disk on a dark background is perceived as brighter than the same disk on a light background. Here, we rendered the background invisible and examined whether people could still perceive illusory or real brightness differences in such a central disk. This was achieved by Continuous Flash Suppression, where a Simultaneous Brightness Contrast stimulus was presented to one eye while the other eye was stimulated by a brightly coloured flashing pattern with a central hole. This effectively rendered the background of the Simultaneous Brightness Contrast stimulus invisible, while allowing the observer to view the central disk through the 'hole' in the Continuous Flash Suppression stimulus. In initial experiments, observers continued to report that disks presented on a now invisible dark background appeared brighter than disks of identical luminance presented on a now invisible light background. Our results suggest that, for at least some classes of contextual visual illusion, invisible context can nevertheless modulate conscious visual perception.

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Eye Movements: Cognition and Social Cognition

Saturday, May 9, 2:45 – 6:45 pm
Poster Session, Royal Palm Ballroom 6-8

26.315

The effect of theta TMS over the FEF on fMRI activations

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We have examined the effects of theta burst on the neuronal activity of oculomotor cortex during eye movements. By combining fMRI and theta TMS, we studied the effect of theta TMS on not only performance, but also measured neuronal activity at the same time. This approach allowed us to investigate whether neuronal activity of an area is suppressed after theta burst TMS; whether the activity level of remote areas (i.e. non stimulated areas) is influenced; and whether effects on neuronal activity are task dependent. We applied theta burst TMS just before the start of the fMRI part. Subjects particpated in three session. Subjects received theta TMS targeting either the Right, or Left Frontal Eye Field (FEF), or a sham control side. After the TMS, subjects were moved into the MRI scanner. Blocks of voluntary saccades, reflexive saccades, and a manual key press task were presented in the MRI. The data suggests (N=4) that TMS over the right, but not the left FEF resulted in a reduced BOLD response. Interestingly, this was true only during voluntary saccades. In other words, the effect seemed to be task dependent. The other striking finding was that there was a trend towards a reduced activity level throughout the whole oculomotor cortical network.

We now seek to confirm this finding in a larger group of subjects.

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26.316

Gaze orienting, and novelty vs. familiarity preference

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We have shown a segregation of memory effect on preference choice between object categories: familiarity preference for faces and novelty preference for natural scenes (Shimojo et al., '07, '08; Liao & Shimojo, '08 VSS). It has also been shown that in preference choice, the gaze is biased towards the picture that will be chosen, called "gaze cascade effect" (Shimojo et al., '03 Nat. Neurosci.). Considering that novelty elicits orienting reflex (van Olst, '71), we aim to see whether gaze orienting is directed to novel pictures initially, and whether the initial gaze bias interacts with the later gaze cascade effect between object categories and choices (familiar or novel stimulus). Eye movements were recorded while the subject performed a two-alternative force-choice (2AFC) preference task between an old and a new pictures. The picture that was pre-rated as median attractive was used as the old picture and paired with a new picture in each trial. The results showed that as the trial repeated, the old face was chosen more frequently whereas the new natural scenes were more preferred, replicating our previous findings. Eye movement data showed a general initial gaze bias towards novel pictures, especially for natural scenes, but later on, the gaze patterns differed. For faces, the gaze bias reversed towards familiar pictures to overcome the initial novelty bias in most trials. For natural scenes, on the other hand, the gaze remained on the new picture to bias further towards the final choice. These results suggest that initial gaze bias towards novel pictures contributes to the preference for novelty, but not directly to the preference for familiarity. Indeed, the initial gaze towards novel stimulus is more pronounced in the trials with a final novelty preference for natural scenes, but not for faces.

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26.317

An Oculomotor Simon Effect

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The Simon Effect is traditionally observed in manual responses when a peripheral imperative stimulus, which presumably attracts attention, dictates a response with the contralateral limb. Such"incongruous" responses have been found to have longer latency than "congruous"responses, with an ipsilateral limb response (Simon and Rudell, 1967; Lu and Proctor, 1995). We examined whether such a Simon effect was also evident for saccadic eye movements, such that a saccade directed contraversive to a peripheral imperative stimulus would be of longer latency than a saccade directed ipsiversively (also see Sheliga et al, 1997). Subjects viewed a CRT display controlled by Vision Shell software routines while eye position was monitored by videooculography at 500 frames/s (Eyelink II, SR Research). Trials began with presentation of a central fixation point alongside two white squares, 8 deg. to the left or right of fixation. 500-800 ms later, a red or green "figure 8" appear 8 deg to the left or right of fixation (i.e. superimposed on one of the small peripheral squares). In manual trials, a red (green) figure 8 indicated a left (right) button press ('z' or '/' key on a standard keyboard). In the saccade task, stimulus presentation was identical; the red (green) figure 8 indicated a left (right) saccade. Subjects were instructed to respond as quickly and rapidly as possible. Across subjects, saccade and manual response latency depended similarly on response congruity. But, strikingly, the error rate for saccadic responses was considerably higher than that for manual responses. These results indicate that the Simon Effect is stronger for saccadic than manual responses, and suggest that the link between attention and saccade programming is stronger than that between attention and manual motor programming.

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Saturday Sessions

26.318

Conscious perception of intrasaccadic displacements is deficient in a patient with a focal thalamic lesion

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In everyday life, we continuously sample our visual environment by rapid sequences of saccadic eye movements and intervening brief fixations. For the successful integration of visual information into a coherent scene representation the brain needs to deal with these constant self-induced displacements of the visual scene on our retinae. An internal "forward" model (Miall and Wolpert, 1996; Sommer and Wurtz, 2008) may decisively contribute to the latter problem: The brain may use an internal monitoring signal associated with the oculomotor command to predict the visual consequences of the corresponding saccadic eye movement and compare this prediction with the actual postsaccadic visual input.

Recent neurophysiological studies in primates identified one candidate pathway for an internal monitoring signal that ascends from the superior colliculus to the frontal cortex, relayed by medial parts of the thalamus (Sommer and Wurtz, 2002). Whereas its pharmacological inactivation suggests a role of this pathway for movement planning, a more general role in perceptual-motor integration can be expected. Here, we studied the dynamics of transsaccadic space perception in young patients with focal thalamic lesions. We utilize the phenomenon of "saccadic suppression of displacement" (SSD), i.e., the observation of elevated thresholds for the conscious detection of location changes during saccadic eye movements.

In this task, a patient with a right medio-dorsal thalamic lesion exhibited markedly elevated thresholds of conscious displacement detection for saccades directed in the hemi-field ipsilateral to lesion side. By contrast, corrective saccades were properly performed to the intrasaccadic target step. Our finding highlights the relevance of internal monitoring signals for perceptual-motor integration and conscious visual perception in general. Internal monitoring signals may be critically important for the correct attribution of self-induced versus externally imposed changes in the continuous flow of our sensory experiences.

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26.319

Objective characterization of square-wave jerks differentiates progressive supranuclear palsy patients from 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 gaze. Here we focus on the most common type of saccadic intrusion: square-wave jerks (SWJs). SWJs are characterized by one small horizontal saccade 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 healthy volunteers, during visual fixation of a small target. Our results show that, whereas SWJs were common in both PSP patients and normals, SWJs in the PSP group had significantly higher rates and magnitudes, and were more markedly horizontal in direction. Using ROC (receiver operator characteristic) analyses we determined that the deviation from horizontal direction is the parameter that best distinguishes the PSP patient population from the population of healthy volunteers. The objective characterization of SWJs may provide a powerful tool in the differential diagnosis of oculomotor disease.

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26.320

Screening Attentional-related Diseases based on Correlation between Salience and Gaze

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Several studies have shown that eye movements and certain complex visual functions are influenced by diseases such as Parkinson's Disease (PD), Attention Deficit Hyperactivity Disorder (ADHD) and Fetal Alcohol Spectrum Disorder (FASD). 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 five groups of observers (16 control children, aged 7-13; 14 ADHD children, aged 9-15; 10 FASD children, aged 9-15; 16 control elderly, aged 66-82; and 11 PD elderly, aged 53-73) while they freely viewed MTV-style videos. These stimuli are composed of short (2-4 seconds) clips of natural scenes, strung together without semantic continuity, which may 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 were built for each feature contributing to 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) among ADHD, FASD and control children; (2) between PD and control elderly. The best classification accuracy of individual classifier in experiment 1 and 2 were 67.5% and 88.9% respectively. Classifiers were combined by a majority-vote boosting strategy to increase the classification accuracy (experiment 1 - 95%; experiment 2 - 100%). This study demonstrates that bottom-up attention mechanisms are greatly influenced by PD, ADHD and FASD, and the difference can serve as a probable screening/diagnosis tool for clinical applications.

26.321

Simulated low vision with young and old adults: How do they see?

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Purpose: The fovea plays a crucial role in human vision, but various conditions (e.g., Age-related Macular Degeneration) can cause an irreversible loss of central visual functioning. How well can people utilize peripheral visual function to perform visual tasks when their central visual field is impaired? Does age make a difference in how people adjust to a loss of central vision? How do compensatory eye movement patterns affect visual performance? To what extent can we dissociate attention from foveal vision? Method: We used a gaze-contingent technique to generate a simulated central scotoma to obscure observers' central visual field while they were performing a variety of computer-generated (MATLAB) visual tasks. Young and old observers with normal vision participated. Tasks included shape-from-texture identification, and discriminations of orientation, motion direction and velocity. Eye movements were recorded with an eye tracker. We measured task performance and many eye movement parameters with scotomas of different sizes. Results: We found rapid perceptual learning in both young and old groups. Observer's fixation position shifted as a function of scotoma size (only along X-axis). Visual performance in terms of dwell time, fixation duration, number of saccades, and saccade amplitude was significantly different between young and old observers. Old observers also had greater difficulties to initiate a first response when we used the largest scotoma (8 deg). Conclusion: Without a functioning central visual field, observers were still able to use the periphery to perform a variety of visual tasks that are usually performed with the intact fovea. Although it was more effortful to complete tasks, especially for old observers, young and old observers were both able to respond accurately to identification and discrimination tasks. This implies that the peripheral visual field can be trained relatively quickly to perform various qualitatively different tasks.

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26.322

The different effects of a visual target in the blind hemifield of hemidecorticate patients on the latency of antisaccades

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It is thought that the phenomenon of blindsight in hemidecorticate patients requires the superior colliculus (SC) (Leh et al. 2006). Using a task that maximally solicits the SC, we investigate whether an unseen visual probe stimulus in the blind hemifield can alter the timing of an ongoing antisaccade in a hemidecorticate patient.

Each trial began with a central fixation point, followed by a brief presentation of a visual stimulus (cue) in the seeing hemifield. A cue was presented alone (86ms), or was accompanied by a probe (86ms) in the blind hemifield at a location different from the mirror location of the cue. The probe was presented simultaneously with the cue, or after a random delay of 86ms, 136ms, or 186ms with respect to cue onset. The patient was required to make a saccade away from the cue to its mirror location (antisaccade). We found that in all of the conditions the latency of the antisaccade was positively correlated with the distance in collicular coordinates between the probe's location and the mirror location of the cue; specifically, as the distance increased so did the SRT. Furthermore, delaying the probe after the offset of the cue significantly reduced the latencies of the antisaccades compared to the condition where the cue and the probe were presented simultaneously.

These findings suggest that presenting the probe in the blind hemifield, after a cue has already been presented to the seeing hemifield, increases cue-driven neuronal activity in the ipsi-lesional SC and drives it over the threshold for antisaccade initiation, resulting in a faster antisaccade to the intended location in the blind hemifield. However, the degree of increase in neuronal activity depends on the distance on the SC map between the cue-driven and probe-driven activity loci.

26.323

The effects of a distractor on the visual gaze behavior of children at signalized road crossings

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Children are over-represented in pedestrian injuries. This may be explained, at least in part, by poorer attentional mechanisms at the roadside compared with skilled adults. We have recently shown that children are more likely to attend to task-irrelevant features of the environment such as buildings and trees compared with adults (Egan et al., 2008; Perception, 37, p. 149). Here, we examined the effects of a specific distractor (ice cream) on the visual gaze behavior of 8-year-old children (N=9) during an active, real-world, road-crossing task (within-subjects, repeated measures design). Participants were taken to signalized road crossings and asked to cross when they felt it was safe, while wearing a portable eye tracker, worn in a small backpack (Mobile Eye, ASL). After the participants had crossed a series of signalized crossings they were given an ice cream of their choosing and asked to cross the roads again in the same order. Gaze fixations were analysed using frame-by-frame coding. In the final 3 seconds before crossing, children fixated only 12% of the time on traffic signs and signals in the distractor condition compared with 22% in the control condition. During the distractor condition, children focused their visual search significantly more ($p<.05$) in the central visual field (79%), rather than looking at traffic to the left or right, compared with the control condition (62%). The results suggest that the presence of a distractor causes children to attend significantly less to relevant parts of the road-crossing environment. These findings concur with those of previous studies and further suggest that children's poorer ability to ignore irrelevant information may contribute to the over-representation of children in pedestrian injuries.

26.324

The power of eyes: the eye region is explored even when there are no eyes in faces

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The eyes are known to attract attention. Visual exploration of faces is primarily centered on these internal features. The present study investigated the impact of altering the face configuration on face visual exploration, by removing the eyes and presenting faces upside-down.

Young adults (n=16) were presented with a series of face photographs, displayed for 4 seconds, once in each of four blocks. Faces were presented upright or inverted, with or without eyes. Participants were told to study each face for a later test, to ensure they attended to the`stimuli, but no test was given. Eye movements were monitored throughout the task.

The average number of fixations made to a face did not differ as a function of orientation (upright vs. inverted) but markedly decreased for stimuli without eyes. Decreases in the number of fixations were observed across blocks for all stimulus conditions. However, the proportion of fixations that were allocated across different face features did not change across blocks. Thus learning and development of stored face representations were reflected in a decrease of fixations with no change in the visual exploration pattern.

In contrast, the proportion of fixations allocated across face features varied with both inversion and presence of the eyes. More fixations were directed to the right versus the left eye area for inverted compared to upright faces. This effect could reflect a larger engagement of the left hemisphere with inversion. For the no-eye conditions, more fixations were directed to the nose region while fewer were directed to the eyes. However, although no eyes were present, 15% of the fixations were still directed to the eye regions. This surprising finding suggests visual exploration is largely based on subjects' expectations and face representations in memory rather than being solely driven by bottom-up stimulus features during perception.

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26.325

Following the masters: Viewer gaze is directed by relative detail in painted portraits

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A painted portrait differs from a photo in that the artist intentionally selects only certain regions for fine detail while leaving other areas less well defined. Although artists and art critics have claimed that these choices guide the viewer's gaze, this claim has not been thoroughly tested. Past studies involving the viewing of original artwork are confounded by unsystematic variation of the regions of fine and coarse detail (e.g., whether they are foreground or background). Here we monitored the gaze of participants viewing original photos and paintings of the same model posing as one of Rembrandt's subjects (e.g., Self Portrait with Beret, 1659). The paintings were rendered with a non-photorealistic technique designed to mimic Rembrandt's painting style (Di Paolo, 2007). Each painting contained four regions of interest in which the level of detail was systematically varied: left versus right eye region in finer detail and left versus right collar region in finer detail. Both original and mirror image views were tested to control for side biases. Participants viewed each portrait along with many other portraits that encompassed a wide range of artistic styles, creating a context in which participants could compare and rate the portraits for "artistic merit."

Saturday Sessions

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Analyses revealed that overall fewer fixations were made when viewing paintings than photos, and viewers' gaze was attracted to and held longer by an eye region in the portrait rendered in finer detail. Even regions of paintings that were rarely fixated (i.e., collar regions below the face) nevertheless guided gaze by enhancing the salience of a finely detailed eye on the same side of the portrait as a coarsely detailed collar region. This implies that Rembrandt and other portraitists incorporate an implicit understanding of how gaze is directed by relative detail.

26.326

Emotion Affects Oculomotor Action

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Many theories of emotional processing posit that the automatic detection of threat in the visual environment is only an adaptive function if this affects subsequently performed actions. Interestingly, little evidence of this relationship between emotional perception and action exists. To shed some light on this relationship, the present study investigated the relationship between emotional encoding and oculomotor programming in saccadic eye movements. Specifically, the effectiveness of the motor programming of saccades was examined after the presentation of either a facial display of fear or its neutral counterpart. Our hypothesis was that the fearful face would cause attention to shift into the periphery such that a subsequent target would be encoded more efficiently, which in turn would allow for more effective motor programming (and thus require less on-line control). To determine the effectiveness of motor programming, we measured the spatial position of the eye at specific kinematic markers (KM) during each saccade (peak acceleration, peak velocity, peak deceleration). Levels of explained variance (R2) between eye position at each KM and saccade end point were computed for each trial, with higher levels of R2 being indicative of more effective motor programming. Consistent with our hypothesis, we found that saccades did have higher R2 values following the presentation of a fearful face, indicating that such saccades used more effective motor programs than did saccades that followed the neutral faces. Results are discussed in terms of heightened perceptual vigilance in relation to oculomotor program generation.

26.327

Social experience does not abolish cultural diversity in eye movements for faces

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A burgeoning body of literature has shown that people from Eastern and Western cultures process information and perceive the world in fundamentally different ways. Adults from Western cultures process information analytically whereas adults from Eastern cultures process information in a more holistic manner (e.g., Nisbett & Miyamoto, 2005). Importantly, rather than merely reporting cultural variances, it is claimed that culture itself may be responsible for manufacturing the observed differences.

Recently, such findings have been extended to the domain of face processing. Western Caucasian (WC) adults typically fixate the eye and mouth regions during face learning and recognition. However, Blais et al. (2008) reported a striking cultural contrast. Contrary to expectations, East Asian (EA) observers predominantly fixated the nose region during face processing tasks. Consistent with previous observations in visual perception, Blais et al. (2008) attributed the reported differences to cultural factors. However, the possibility that genetic factors might underlie the divergent strategies has not yet been ruled out. In order to explore this option, we tested a group of British Born Chinese (BBC) adults. This population is genetically Chinese, but culturally Western. If culture is truly responsible for driving differences in fixation strategies, then BBCs should fixate the eye and mouth regions.

Consistent with previous cross-cultural studies where Easterners had some experience in a Western culture, BBC observers showed an intermixed pattern of results. However, analyses performed at the individual level offered novel insights into our findings. Across the 21 adults tested, the majority displayed an 'Eastern' strategy, with the rest showing a 'Western' strategy during face learning and recognition. To further clarify these findings, questionnaires were administered to assess the cultural outlook and backgrounds of our population. The variation in observed strategies, ranging from Eastern to Western, is explained in relation to the data yielded from the culture questionnaires.

26.328

Cultural Diversity in Eye Movements Extends Across Biological and Artificial Visual Categories

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Since the seminal work of Yarbus (1967), it had long been thought that the information humans require to individuate conspecifics was extracted universally. More specifically, studies had consistently revealed systematic analytical sequences of fixations over the eyes and the mouth during face processing. These robust scanpaths observed in Western Caucasian (WC) observers suggested a universal, biologically-determined information extraction pattern for faces. However, contrary to intuition Blais et al. (2008) reported a strikingly different central fixation strategy in East Asian (EA) observers. Rather than fixating the eyes and mouth, EA observers predominantly fixated the nose. A possible explanation for these findings is that Easterners consider it rude to look a person in the eyes during social interaction (Argyle & Cook, 1976). By contrast, Westerners typically consider it rude to not make eye contact during social interaction. Thus, it is possible that the differences observed for faces will not extend to non-human face stimuli.

We investigated this hypothesis with human faces and two additional stimulus categories for which both groups of observers had comparably little visual experience: one biological (sheep faces) and one artificial (Greebles). Remarkably, WC and EA observers showed fixation differences for all three stimulus categories during both learning and recognition phases of an old/new recognition task. For human and sheep faces, WC observers fixated the eyes and mouth, whereas EA observers fixated centrally. Equally, marked fixation differences were found for Greebles. Overall, WC observers displayed an analytical processing style, fixating on individual features. EA observers' processing style was more holistic, with fixations in the centre of all stimuli. These findings suggest gaze avoidance alone cannot explain the central fixations for faces in EA observers. Critically, they show that cultural diversity in eye movements are not limited to human faces and may reflect more general feature-extraction differences between cultural groups.

Spatial Vision: Mechanisms

Saturday, May 9, 2:45 – 6:45 pm
Poster Session, Orchid Ballroom

26.401

Confidence in crowded stimuli

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Although the never-ending flux of UFO sightings shows that people sometimes have undue confidence in their own visual system, in a lot of everyday occurrences we seem to have a good sense of the limits of our own visual perception. It is unclear how uncertainty is evaluated by the visual system. For example, we know we do not see well in the dark, but is that because we have associated under-lit scenes with bad performance, or because we recognise that we do not have enough "sensory evidence" to reliably infer what the scene is?

To address this issue, we used low-contrast target objects in different crowded conditions to modulate observers performance while maintaining stimulus information. The uncertainty of the observers was evaluated in an objective task, the forced choice of uncertainty paradigm (Barthelmé & Mamassian, VSS '07). They were shown two successive targets surrounded by flankers, positioned in the periphery. Targets were Gabor patches, slightly tilted from the vertical. The observers were asked first for which of the two targets they felt they were more confident giving an orientation judgement. They were then asked to make that judgement for the target they picked. The two targets could have different contrast levels and different flankers, and the observer's goal was to choose the target for which expected performance was highest. Each target was surrounded by orthogonal or parallel flankers, with the latter inducing a strong crowding effect because of their similar orientation to the target.

A high-contrast, crowded target had a larger expected performance than a low-contrast, uncrowded target so an ideal strategy could not be based on contrast or crowdedness alone. Observers were able to balance the two factors, showing that their evaluation of visual uncertainty took into account the effects of crowding, and not just contrast.

26.402

Crowding in multi-element arrays: regularity of spacing

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When a peripheral target is flanked by distracting elements, identification and discrimination of the target's attributes are impaired. This phenomenon is known as crowding. According to Bouma's law, the effectiveness of the distractors depends on their distance from the target, the "critical spacing" being roughly half the target eccentricity.

We have previously reported that the strength of crowding in multi-element arrays (e.g., a row of Gabor patches) depends critically on the spatial layout of the stimuli. In displays where the target forms a coherent texture with the distractors, crowding is strong. When the target stands out from the array because of a difference in for example length, crowding is weak.

Here, we asked whether element spacing in multi-element arrays has a similar effect on crowding. We measured orientation discrimination thresholds for a peripheral target (a line segment or a Gabor patch). The target was flanked on both sides by several distractors that were always vertical but otherwise identical to the target. Discrimination was measured with different element spacings. First, we used regularly spaced arrays, with either relatively tight or relatively wide inter-element spacing. Then, the regularity of the spacing was perturbed by jittering the positions of some or all of the distractors, or by introducing additional distractors into the regularly spaced arrays.

Tight, regular spacing produced stronger crowding (i.e., smaller threshold elevations) than wide regular spacing, as expected. However, with irregular spacing crowding was often weaker than with regular spacing. The average distance of the distractors from the target, or the number of distractors within the critical spacing, did not completely predict crowding strength. Thus, in addition to the effects of element distance, also the regularity of element spacing plays an important role in crowding.

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26.403

Perceptual estimation of variance in orientation and its dependence on sample size

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Previous research on statistical perception has shown that subjects are very good at perceptually estimating first-order statistical properties of sets of similar objects (such as the mean size of a set of disks). However, it is unlikely that our mental representation of the world includes only a list of mean estimates of various attributes. Work on motor and perceptual decisions, for example, suggests that observers are implicitly aware of their own motor / perceptual uncertainty, and are able to combine it with an experimenter-specified loss function in a near-optimal manner. The current study investigated the representation of variance by measuring difference thresholds for orientation variance of sets of narrow isosceles triangles with relatively large Standard Deviations (SD): 10, 20, 30 degrees; and for different sample sizes (N): 10, 20, 30 samples. Experimental displays consisted of multiple triangles whose orientations were specified by a von Mises distribution. Observers were tested in a 2IFC task in which one display had a base SD, and the other, test, display had a SD equal to ±10, ±30, ±50, and ±70% of the base SD. Observers indicated which interval had higher orientation variance. Psychometric curves were fitted to observer responses and difference thresholds were computed for the 9 conditions. The results showed that observers can estimate variance in orientation with essentially no bias. Although observers are thus clearly sensitive to variance, their sensitivity is not as high as for the mean. The relative thresholds (difference threshold SD / base SD) exhibited little dependence on base SD, but increased greatly (from ~20% to 40%) as sample size decreased from 30 to 10. Comparing the σ of the cumulative normal fits to the standard error of SD, we found that the estimated σ's were on average about 3 times larger than the corresponding standard errors.

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26.404

Orientation integration in complex visual processing

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How does the visual system integrate local features to represent global object forms? Previously we quantified human orientation sensitivity in complex natural images and found that orientation is encoded only with limited precision defined by an internal threshold that is set by predictability of the stimulus (VSS 2007). Here we tested the generality of this finding by asking whether local orientation information is integrated differently when orientation noise was distributed across a scene, and in an object identification task for natural images that were reconstructed from a fixed number of Gabor wavelets. In the noise discrimination task, subjects viewed pairs of images where orientation noise was added to all the elements of only one or both images, or was distributed evenly between the two images, and were required to identify the noisier pair of images. Sensitivity to orientation noise with the addition of external noise produced a dipper function that did not change with the manner in which noise was distributed, suggesting that orientation information is integrated consistently irrespective of the distribution of orientation information across the scene. In the identification task, subjects identified an object from four categories, randomly selected from a total of 40 categories. The proportion of signal Gabors, whose orientation and position were taken from the object, and noise Gabors, whose positions were randomly assigned, was adjusted to find the form coherence threshold for 75% correct object identification. Signal elements consisted of pairs of adjacent Gabors whose orientation difference was low (contour-defining), high (corner-defining), or randomly selected. Thresholds for image identification were only slightly elevated compared with earlier discrimination results, and were equal for all types of signal elements used.These results suggest that orientation information is integrated by perceptual templates that depend on orientation predictability but not on the complexity level of the visual task.

26.405

Perception of global textures based on joint-orientation statistics

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Texture information is useful for segmenting objects and identifying different types of natural textured surfaces. A number of psychophysical studies suggest that rapid segmentation of abutting textures is primarily determined by differences in 2nd-order image features such as local orientation and size. Here, we examine the role of higher-order orientation statistics in the perception of a single texture region. Human observers were presented with textures comprised of adjacently paired Gabor elements with

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a particular orientation difference and relative angular position, but with absolute orientation randomized, and were required to discriminate these textures from ones consisting of random, i.e. spatially uncorrelated orientations. Observers were particularly sensitive to textures containing paired elements that formed collinear curves, parallel lines, V, T, and L shapes. These features are similar to Julesz's textons but are also characterized in terms of the degree of collinearity. We find that textures consisting of two populations of features such as curves and V shapes, but not straight lines and curves, often look like a random texture. This indicates opponent interactions among specific features, e.g. collinear (lines and curves) vs. non-collinear (parallels and V shapes) patterns. In support of this notion, we introduce a novel aftereffect in which a random texture appears to be structured following adaptation to a structured texture. For example, adaptation to a texture of randomly-oriented V shapes makes the subsequently viewed random texture appear to contain many smooth curves. We also demonstrate an analogous simultaneous-contrast illusion. These findings support the existence of visual mechanisms that process global texture-surface information on the basis of texton-like orientation statistics or collinearity.

26.407

The role of divisive inhibition in Glass pattern discrimination

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A Glass pattern consists of randomly distributed dot pairs (dipoles) whose orientations are determined by a geometric transform. To perceive the spatial structure in a Glass pattern, an observer needs to group dipoles to get overall shape. To understand this grouping effect, we investigated how the discrimination threshold between a concentric Glass pattern (target) and a random-dot pattern can be affected by the presence of another Glass pattern (mask). The Glass patterns contained randomly distributed dipoles who orientation were arranged to produce concentric, radial, vertical, and spiral global forms. We used a 2AFC paradigm in which a mask was presented in both intervals while the target was randomly presented in one interval and a random dot pattern with the same number of dots as the target in the other. We measured the target dot density required for an observer to detect the target at 86% correct level (density threshold). For the concentric and the spiral masks, the target threshold first decreased (facilitation) then increased (masking) as mask density increased. The radial and vertical masks only produced masking effect at high mask density. The concentric and the spiral mask also produced a greater threshold increase at high density than the radial and vertical masks. Both the facilitation and masking effects decreased with the curvature of the spirals. The data can be explained by a divisive inhibition model. In this model, the global form detector sums the responses of the local dipole detectors whose preferred orientation conforms that of a concentric pattern. The response of the form detector is this summed input raised to a power and divided by the sum of an additive constant and an inhibition input that is a nonlinear combination of all local responses. Our result suggested that divisive inhibition played an important role in global form perception.

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26.408

A Neurophysiologically Plausible Population-Code Model for Human Contrast Discrimination

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The pedestal effect is the improvement in the detectability of a sinusoidal grating in the presence of another grating of the same orientation, spatial frequency and phase – usually called the pedestal. The pedestal, or "dipper" effect, as it is sometime called, has typically been attributed to contrast transduction and/or gain-control mechanisms operating within a single spatial-frequency-tuned channel. Recent evidence casts doubt on the single-channel assumption: the pedestal effect disappears in the presence of notched noise. Notched noise forces observers to use information near the spatial frequency of the grating they are trying to detect and thus prevents their using information carried in channels tuned to spatial frequencies that are much different from the signal frequency. Consequently, the disappearance of the pedestal effect in notched noise suggests that the pedestal effect stems from off-frequency looking. Here we consider a network consisting of units whose contrast response functions resemble those of the cortical cells believed to underlie human pattern vision and demonstrate that, when the outputs of multiple channels are combined by simple weighted summation – one implementation of off-frequency looking – the network produces contrast-discrimination data consistent with psychophysical observations: the pedestal effect is present without noise and in broadband noise, but almost disappears in notched noise. One important implication of these findings is that many channels with a wide heterogenity in spatial-frequency tuning are engaged even in processing low-contrast sinusoidal gratings.

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26.409

A comparison of the pedestal effects in the 1st- and 2nd-order patterns

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Purpose. Human visual system is sensitive to both luminance (the first-order) modulations and contrast (the second-order) modulations in an image. A linear-nonlinear-linear (LNL) model is commonly used to explain the visual process of the 2nd-order stimuli. Here we used pattern masking paradigm to compare the 1st-order and the 2nd-order visual mechanisms and to characterize the nonlinear properties of their underlying mechanisms. Methods. The stimuli were a high frequency horizontal grating (8 cyc/d) either added to (1st–order stimuli) or multiplied with (2nd-order stimuli) a vertical low frequency (2 cyc/d) Gabor function. The discrimination threshold of the target was measured with pedestals whose spatial properties as that of the target except contrast (1st–order pedestal) or modulation depth (2nd–order pedestal) of either the low or the high frequency components. Results. The threshold function showed a typical dipper shape for both the 1st- and the 2nd-order stimuli: the threshold first decreased (facilitation) and then increased (suppression) with pedestal contrast or modulation depth. The results for the 1st-order stimuli were well explained by divisive inhibition model in which the facilitatory input was divided by the sum of broadband inhibitory inputs. The results for the 2nd-order stimuli were also well explained by a modified that operated on modulation depth rather than contrast in the input images. Conclusion. Our result suggests that divisive inhibition is required to explain visual discrimination in both the first- and the second-order patterns. However, the source and the nonlinearity of the divisive inhibition may be different for these two types of patterns.

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26.410

Parameterization of Contrast Detection and Discrimination in 1/f Noise

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Contrast sensitivity for a pattern in the presence of broadband 1/f spatial structure appears to be qualitatively different than would be predicted on the basis of established properties of contrast sensitivity measured using isolated, narrowband patterns. The effect of pattern orientation is different, with horizontal effects obtained at particular spatial frequencies rather than oblique effects, and the peak of the contrast sensitivity function is shifted towards higher spatial frequencies (Haun and Essock VSS 2008). In this experiment, threshold-versus-contrast functions were measured for oriented, 1.5 octave bands of spatial noise either against a mean lumi-

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nance background, or against a background of broadband 1/f noise which did not include the target band frequencies and orientations. Seven central spatial frequencies and four central orientations were included. The effect of 1/f noise on the parameters of the familiar d' function for contrast detection and discrimination was measured. Sensitivity differences, with or without masking noise, are carried by anisotropies in the semi-saturation constants, the detection exponents of the d' function, and the height of the function. The effect of a 1/f noise mask on sensitivity is largely localized to an increase in the semi-saturation constant, though at lower spatial frequencies increased channel uncertainty and increased susceptibility to stimulus noise might also play a significant role in elevating thresholds, this influence measurable in the low-contrast exponent of the d' function: therefore several approaches must be considered in modeling the data. Suprathreshold parameters, including the height of the d' function and the compressive high-contrast exponent, appear to be unaffected by the presence of 1/f noise.

26.411

Two modes of hiding suprathreshold stimuli in complex patterns

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A single light disk within an intersection in a grid of dark tetragons is especially difficult to detect (the "vanishing disk"). Detection is made even more difficult by curving the alleys defining the grid. In previous work (VSS 2008), we explored temporal aspects of the curvature effect. High contrast light disks were detected during the initial part of each trial, regardless of whether the alleys started straight and became curved or vice versa. Dark disks, on the other hand, had higher thresholds when synchronous with the curved alleys. This suggested that light disks and dark disks were affected by different mechanisms.

If the obscuring effects occur in primary cortex, orientation selectivity is expected. We therefore measured thresholds for pairs of parallel lines in intersections. Thresholds for light vertical or horizontal lines were significantly higher than for diagonal lines when the alleys were straight. With increasing curvature of the alleys, thresholds for diagonal lines increased while those for vertical or horizontal lines remained essentially unchanged; with sufficient curvature, the thresholds converged. This is consistent with components of the grid affecting targets with similarly oriented components.

When this experiment was repeated with dark lines (comparable to the dark disks that do not suffer the vanishing disk illusion), no orientation selectivity was found. Thresholds for all orientations were essentially identical, increasing with increasing curvature. As was found for disks, there is a difference between light and dark lines. This may be interpreted as different modes for the illusory effect of the vanishing disk versus the simple obscuring of disks by complexity. Alternatively, there could be a difference between the system detecting increments and that detecting decrements, or an interaction between the two when the polarities of target and grid differ. We will present preliminary results bearing on these possibilities.

URL: http://tigger.uic.edu/~mikel/

26.412

Cause of asymmetries in center-surround and surround-center masking

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Olzak, Gabree, Saarela, and Laurinen (under review) performed center-surround masking experiments with suprathreshold sinusoidal gratings, and observed asymmetries in masking. When making judgments on the center component they showed that adding an abutting annulus (surround) mask decreased performance relative to a control task. However, when judgments were based on the surround, an abutting center mask had no effect on performance. Eye tracking experiments, using identical stimuli, indicated different locations of fixation for the two different judgments (center or surround). When making judgments on the surround observers fixated around the outer perimeter of the annulus, where as when making judgments on the center observers fixated on locations much more central to the stimulus. This different pattern in the results may be caused by a difference in the organization of the mask and test components. When performing discrimination tasks on the center the test stimulus is masked on all sides. Conversely, when performing discrimination tasks on the surround, the test stimulus is masked on only one side. To test whether the organization of components affected performance we conducted a masking experiment with rectangular sinusoidal stimuli. The test stimulus was a rectangular sinusoid masked on one side (top, bottom, left or right) by a constant abutting grating of the same size. This organization closely replicates the possible conditions under which surround judgments were made. In all participants, masking still occurred irrespective of the location of the abutting grating. These results indicate that the asymmetries that have previously been reported are not due to mask-stimulus organization, but may be due to the segmentation of components into independent objects.

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26.413

Overlay and Surround Suppression Both Show a Horizontal Effect Anisotropy

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Visual processing of images that contain broadband spatial content (e.g., a natural scene) is anisotropic (e.g., Essock, DeFord, Hansen, and Sinai, Vision Res., 2003) -- horizontal content is perceived less well than content at other orientations and oblique content is seen best. That is, when typical scenes are being viewed, oblique content is most salient and has highest sensitivity, and salience and sensitivity is least at horizontal. This 'horizontal effect' has been linked to anisotropic low-level contrast gain control. Previously (Kim, Haun and Essock, VSS 2008), we have shown that separate gain control pools exist for low-speed ("sustained") and high-speed ("transient") mechanisms and that both show a horizontal effect. In the present experiments, we show that when overlay and surround suppression mechanisms can be isolated, both types of suppression yield horizontal effects. Using a grating target at two spatial frequencies (1cpd and 8cpd) and four orientations (0°, 45°, 90°, and 135° clockwise from vertical), contrast thresholds were measured for the gratings in the presence of either an overlaid (same-size) or annular surrounding patch of oriented 1/f noise at the same orientation as the target. Stimuli were presented at fixation or at one of several eccentric locations. Targets and masks were presented either with a slow Gaussian temporal waveform, or flickered at 16Hz. We found that at fixation, overlay masking dominates and yields a horizontal effect, while surround masking is relatively weak. Meanwhile, at increasing horizontal eccentricities, surround masking appears for the horizontal stimuli, is somewhat less for the vertical targets, and is barely present for oblique targets. Together with other findings, these results suggest that the horizontal effect is ubiquitous, and that wherever masking by 1/f noise is measurable, the anisotropy will appear.

26.414

Processing cues to discrimination in center-surround stimuli

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Fine spatial discriminations made on center-surround stimuli show lateral masking effects. Unlike overlaid (spatially coincident) masking patterns, these effects are asymmetric; the surround affects the center but not vice versa. Also unlike effects found with overlaid patterns, there seem to be no higher level circuits that sum (or difference) responses from cues in two different components, demonstrated in a two-cue, single-response configural (Olzak & Thomas, 1991) effect test. In the current study, we tested the hypothesis that cues to discrimination in center and surround portions

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of a stimulus are in fact processed independently, with no excitatory or inhibitory interactions, and no correlation in noise. We used a concurrent response paradigm and associated multivariate SDT analyses to identify the underlying response space and to test whether an independence model adequately describes how two cues to discrimination, one in the center and one in the surround, are processed. The stimuli were patches of 4 cpd vertical sinusoidal grating, arranged in a center-surround configuration (40 min center, 20 min width surround). Observers either made discriminations based on spatial frequency or on orientation, in different experiments. A cue to discrimination was presented in both center and surround on each trial. Four stimulus types were created and intermingled in a single session of 160 trials (40 of each stimulus): 1) both center and surround tilted left slightly (or were of slightly lower frequency), 2) both tilted right, 3) center titled left, surround titled right, and 4) center tilted right, surround tilted left. Observers made separate decisions on center and surround patches following each trial, rating their certainty that each component was tilted left or right on a 6-point rating scale. The results supported the notion of no higher-level summing circuits, but strongly rejected a bivariate-Gaussian independence model.

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26.415

Lateral facilitation demonstrated dichoptically for luminance- and contrast-modulated stimuli

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Lateral facilitation for detection using luminance-modulated targets, unlike contour integration, has been suggested to be a purely monocular phenomenon (Huang, Hess & Dakin, Vis Res, 2006). However facilitation for detection of contrast-modulated targets in normal vision, does not occur in amblyopes (Wong, Levi & McGraw, Vis Res, 2005), suggesting that this facilitation requires normal binocular processing. We determined whether facilitation occurred dichoptically using luminance-modulated and contrast-modulated Gaussian stimuli to assess its neural locus.

Foveal detection thresholds for luminance-modulated and contrast-modulated Gaussian blobs in the presence of visible, laterally placed blobs (separations of 0-6 deg) were measured monocularly and dichoptically in observers with normal vision. Blobs were constructed by adding or multiplying random-dot dynamic noise with a Gaussian (σ=0.25 deg). Data were collected using a method of constant stimuli and temporal 2AFC paradigm. Psychometric function slopes were analysed in order to assess the role of uncertainty reduction in lateral interaction effects.

Monocular detection thresholds measured for luminance-modulated blobs and contrast-modulated blobs in the presence of visible flankers follow a standard pattern of lateral interaction. Masking occurs for overlapping blobs, followed by facilitation when they are completely separated (1-3 deg). Dichoptic viewing produces a similar pattern of results but with some differences. For both luminance-modulated and contrast-modulated blobs, there is more masking dichoptically for overlapping blobs. For luminance-defined blobs, threshold facilitation of 15-30% is demonstrated dichoptically. For contrast-defined blobs, more robust facilitation of 30-50% is demonstrated dichoptically. Psychometric function slopes were analysed and were not consistently shallower in the facilitation region. Thus facilitation is likely to reflect neural processing.

Lateral facilitation is not purely a monocular phenomenon and cannot be simply explained by uncertainty reduction. Facilitation for contrast-defined stimuli appears more robust dichoptically than for luminance-defined stimuli, which may suggest a more binocular locus for neural processing for these stimuli.

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26.416

Reduced Second-Order Contrast Discrimination Under Dichoptic Viewing

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Purpose. Past studies have shown that second-order contrast discrimination under monocular and binocular viewing produces a 'dipper function' similar to that seen for first-order contrast. Here we investigate second-order contrast discrimination under dichoptic viewing. We expected a reduced dipper function, likely attributable to interocular gain mechanisms acting on the first-order carrier.

Methods. Four observers (two naïve and the two authors) participated. Stimuli were presented via computer and the CRT was viewed through a mirror haploscope with septum. Second-order stimuli were amplitude-modulated sinusoids (carrier 8 c/deg, envelope 1 c/deg, $\sigma = \lambda$, 4° diameter patch, sinusoids horizontal). We used a temporal 2-AFC (500 msec intervals) with the MOCS. We measured increment thresholds for a range of pedestal contrasts (0.1–4.0) for three normalized carrier contrasts (2.5x, 5x and 10x contrast detection threshold (CDT)) under monoptic (control) and dichoptic viewing.

Results. Observers on average showed facilitation of target detection at subthreshold and near threshold pedestal contrasts, with monoptic viewing producing more facilitation than dichoptic viewing. The dichoptic effect was dependent on carrier contrast: on average, the maximum facilitation produced by the 2.5x, 5x, and 10x CDT was 5–25%, 0–22%, and 0–10%, respectively. That is, lower carrier contrast produced greater facilitation of second-order contrast detection. In contrast, the monoptic effect was independent of carrier contrast: maximum facilitation 0–17% for all CDT. Furthermore, suprathreshold pedestal contrasts produced similar trends: monoptic viewing produced marked suppression (maximum 150–330%), dichoptic viewing produced less suppression (maximum 0–110%), and only dichoptic showed dependence on carrier contrast.

Conclusions. The results suggest that discrimination of second-order contrast is dependent on the carrier (first-order) contrast for dichoptic viewing but much less for monoptic viewing. This likely reflects an increase in contrast gain for interocular combination of first-order contrast that limits the input to the second-order stage.

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26.417

Binocular summation for luminance- and contrast-modulated noise stimuli

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The magnitude of measured binocular summation can provide information about the locus of processing for different tasks or for different types of stimuli.

We measured 1) monocular and binocular detection and discrimination thresholds (i.e. dipper functions) for luminance-modulated and contrast-modulated Gaussian blobs (σ=0.25 deg) and 2) monocular and binocular detection thresholds for luminance-modulated and contrast-modulated Gabors (σ=1.0 deg; modulations of 0.5, 1, 2, 4, 8 and 16 cpd). Luminance- and contrast-modulated Gaussian blobs were constructed by adding or multiplying a Gaussian profile to a binary, random-dot, dynamic noise background. Gabors were constructed from the same noise background. Data were collected using a method of constant stimuli and temporal 2AFC paradigm. Four adults with normal vision participated.

For both luminance-modulated and contrast-modulated Gaussian blobs, we obtained detection thresholds that were binocularly on average 45% lower than monocular thresholds and on average 55% lower in the facilitation region. Discrimination thresholds for higher pedestal visibilities were similar monocularly and binocularly for luminance-modulated Gaussian blobs but slightly better binocularly for contrast-modulated Gaussian blobs. Slopes in the masking region were similar for all stimuli with exponents around 0.7.

For luminance-modulated Gabors (0.5 cpd) binocular summation reached around 70%, decreasing substantially for higher spatial frequency modulations. For contrast-modulated Gabors, binocular summation was more consistent across modulation frequency. Binocular summation ratios for these stimuli were equal or higher than those measured for luminance-modulated Gabors for all modulation frequencies above 0.5cpd.

In combination with our previous results, where dichoptic viewing had a greater effect on the discrimination of contrast-modulated Gaussian stimuli (Waugh & Hairol, VSS2008) and indirect evidence of others (Wong, Levi & McGraw, Vis Res, 2001), we propose that contrast-modulated stimuli are likely processed at a more binocular site than luminance-modulated stimuli.

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26.418

Dichoptic and Monoptic Spatial Integration of Second-Order Contrast

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Purpose. Past flanking studies using monocular viewing suggest that the second-stage neurons understood to encode second-order contrast receive substantial binocular input (Wong et al., 2005, Mansouri et al., 2005). Here we investigate the binocular nature of second-order processing more directly by using a flanking paradigm under dichoptic and monoptic viewing.

Methods. Four normal adults and one non-binocular/non-amblyopic (NBNA) adult participated. Observers detected an amplitude-modulated sinusoid alone (carrier 8 c/deg @ 3x contrast detection threshold (CDT), envelope 1 c/deg, $\sigma = 1.5\lambda$, 2° diameter patch, sinusoids vertical) and with two vertically aligned flanks (6′ edge separation or 0.5° overlap). Flanks consisted of the target sinusoids, normalized carrier (3x CDT) and envelope (1.5x and 2.5x CDT) contrast, and were vertical, horizontal or carrier-only (control). Flanks were presented monoptically and dichoptically. Stimuli were presented via CRT and 2-AFC paradigm (500 msec intervals) with the MOCS, and viewed through a mirror haploscope with septum.

Results. For normal observers, on average the near-abutting oriented flanks facilitated contrast detection, slightly greater under monoptic than dichoptic viewing, and was contrast dependent (2.5x CTU produced greater facilitation). Dichoptic presentation of all oriented flanks overlapping the target produced suppression of contrast detection. For all views the carrier-only flanks produced no effect. For the NBNA observer, under monoptic and dichoptic viewing, the near-abutting oriented flanks at 1.5x CDT generally produced no effect and at 2.5x CDT produced suppression. Dichoptic presentation of all oriented flanks overlapping the target produced suppression. For all views the carrier-only flanks generally produced suppression.

Conclusions. Second-order contrast is substantially integrated interocularly across space but less than uniocular integration. Interocular integration was not shown by the non-binocular, non-amblyopic observer. The distinct binocular nature of second-order processing is supported by findings of non-integration of interocular first-order contrast across space (Huang et al., 2006).

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Motion: Biological

Saturday, May 9, 2:45 – 6:45 pm
Poster Session, Orchid Ballroom

26.419

Depth ambiguities and adaptation aftereffects in perception of point-light biological motion

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Using adaptation, we studied a previously under appreciated form of perceptual bistability associated with viewing point-light (PL) animations portraying biological motion. Without depth cues, conventional PL sequences are ambiguous with respect to depth ordering of the limbs. For some animations, this ambiguity is perceptually evident: one experiences alternations over time between two conspicuously different directions of heading of a PL walker, the alternatives being mirror reversals of one another in depth (e.g., either 30° or 150° with respect to an observer's line of sight). We had observers track reversals in a bistable walker's perceived heading direction following 90s exposure to a walker whose limb positions, and hence heading, were unambiguously defined by stereo-disparity (oriented unambiguously either at 30° or 150°). Following stereo adaptation, observers experienced a strong, consistent aftereffect: the bistable walker appeared to face predominantly in the opposite, unadapted direction. Aftereffects were not found, however, following adaptation to a phase-scrambled walker, in which individual dots maintained the same disparity-defined trajectories as in the intact display, but lacked global temporal coordination. In contrast, aftereffects did occur when adapting and test walkers differed in size. Evidently, the adapted representation is tied closely to the underlying human form and cannot be explained by local, disparity-specific motion adaptation. Aftereffects also occurred when adapting and test walkers appeared on opposite sides of fixation, and fell off with increasing differences between adapt/test heading directions. These results underscore the importance of kinetic depth in the perception of PL animations, and imply strong interactions among signals specifying form, motion and depth in the representation of biological motion. Models of biological motion perception based on an analysis of the kinematics or postures portrayed by PL displays should incorporate mechanisms to disambiguate the inherently ambiguous depth relations that exist in these stimuli.

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26.420

Adaptation of early ERP responses to biological motion by both form and motion

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The apparent ease with which human observers recognize biological motion has led to considerable research into the perceptual and neural mechanisms underlying these processes. One component of biological motion that contributes to recognition is the local motion of different elements. Evidence also suggests that observers can detect biological motion when local motion cues are ambiguous or completely absent, as long as form cues are intact, suggesting that the configuration of the moving elements also plays a role in recognition. However, the relative contribution of form and motion, and the time course of their contribution to biological motion processing, has not yet been determined. Here we investigated the contribution and timing of form and motion processing to the adaptation of early visual event-related potential (ERP) responses to biological motion. Subjects (N = 15) were presented with an adapter consisting of either intact biological motion, scrambled biological motion, a static frame from the intact biological motion, or no adapter, for 3sec prior to a biological motion stimulus presented for 1.5sec. Results revealed that the P1 response increased in amplitude across all adaptation conditions relative to no adapter. After correcting for these P1 effects, results revealed that

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the amplitude of the N1 ("N1bm") was reduced by all three adapters, with significantly greater adaptation in the intact biological motion relative to scrambled biological motion or the static frame. These results provide further support for the claim that the processing of biological motion requires the integration of form and motion cues. These findings also suggest that this integration occurs within the first 200ms of visual processing, possibly as part of a feedforward sweep of neural activity.

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26.421

The effects of retroreflectivity and biological motion on the visibility of pedestrians at night

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One factor that has been causally linked to nighttime pedestrian-vehicle collisions is pedestrians being insufficiently conspicuous to drivers. Placing retroreflectors on pedestrians' major joints in configurations that facilitate the perception of biological motion has been shown to enhance pedestrians' conspicuity. Retroreflector luminance, however, decreases with time as dirt accumulates and the retroreflector deteriorates. The impact of retroreflected luminance on pedestrian conspicuity in the presence and absence of biological motion was tested. For this on-road study 121 participants (18-23 years) were taken on a short drive and pressed a button when they were confident that a pedestrian was present. A test pedestrian either walked in place or stood still on the shoulder of a dark road while wearing all black clothing plus 200 cm2 retroreflective material that was either placed on the torso or on the wrists and ankles. The retroreflective material was at a high, medium or low level of retroreflective intensity (581, 138 or 10 cd/lux/m2). Response distances were significantly greater when the pedestrian was walking and wearing retroreflectors on the wrists and ankles (119 m) compared to walking and wearing retroreflectors on the torso (24 m). Participants responded to the walking pedestrian wearing the high intensity retroreflectors at a marginally significant greater distance (92 m) compared to the walking pedestrian wearing the low intensity retroreflectors (47 m). Responses to the standing pedestrian wearing retroreflectors on the wrists and ankles were not significantly greater than responses to the standing pedestrian wearing retroreflectors on the torso. Participants responded to the standing pedestrian wearing the low intensity retroreflectors at a marginally significant greater distance (21 m) compared to the standing pedestrian wearing the high intensity retroreflectors (4 m). The results illustrate that the presence of biological motion has a greater impact on increasing pedestrian conspicuity than increasing retroreflective intensity.

26.422

Dances with Gabors: Contour integration and form in biological motion

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The heightened ability of humans to perceive the characteristic motion of humans and animals, even from points of light marking only the major joints, has led to suggestions of specialised perceptual mechanisms for 'biological motion'. However, recent work has suggested that form information, which persists in biological motion stimuli, plays an important, possibly dominant, role in processing. Biological motion perception does not rely on the local motions of individual dots; rather, it has been suggested that the motion relationships between dots are a counterpart to the static form information expressed by the configuration of those dots. This 'opponent motion', expressed through the integration of a number of dots' local motion signals - especially those of limb pairs – has recently been suggested as critical to the analysis of biological motion. By creating a point light walker (PLW) composed of Gabor patches instead of dots at the major joints, and yoking the orientation of each Gabor to the path of its opponent motion, we manipulated the strength of the opponent motion signal. Using a detection-in-noise task and a novel form-degradation task, where the centroid of each dot's local motion was displaced independently, we found an advantage for orienting the carrier of the Gabor patches orthogonally to their opponent motion paths. However we found the same advantage for orthogonal orientation of Gabor carriers in static presentations of both tasks. We suggest that the improved contour integration resulting from this orthogonal carrier orientation explains the performance in our biological motion task. Rather than the characteristic animate motion, the structure conveyed by the configuration of the PLWs dots may provide the basis for processing of biological motion stimuli.

26.423

Spatio-temporal "Bubbles" reveal diagnostic information for perceiving point-light and fully illuminated biological motion

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Humans can quickly and efficiently organize point-light stimuli into a compelling global percept of biological motion. Point-light animations have been used extensively to study visual perception of animated motions, in part because of the ease of control over kinematic and form content. In contrast, fully illuminated depictions have received considerably less attention until recent years. Nonetheless, both point-light and fully illuminated depictions clearly contain useful kinematic and structural information, with fully illuminated versions being more ecologically similar to real-world biological motion. Here we use the "Bubbles" technique (Gosselin & Schyns, 2001) to investigate the spatio-temporal dynamics of diagnostic information for discriminating human walkers. In this experiment, we present randomly selected intervals of walkers masked with white noise, but visible through a number of Gaussian apertures. Using the limited stimulus information presented on each trial, observers were instructed to discriminate the walking direction of the target walker. We used reverse correlation to compute dynamic classification images using statistical techniques from random field theory (Chauvin et al., 2004) to illustrate the spatio-temporal pattern of critical information for perceiving point-light and fully illuminated biological walkers. Overall performance varied sinusoidally across the gait cycle. This is similar to previous reports (Thurman & Grossman, 2008) and evidence for diagnostic information at regular intervals in the gait cycle. This diagnostic interval was slightly delayed in the point-light versions as compared to the fully illuminated. Space-time classification images of fully illuminated walkers show that observers tend to rely extensively on the upper body, while in contrast, for point-light walkers the upper body carries little diagnostic information. Instead the most significant information for point-light depictions is found spread around the extremity dots (i.e. hands and feet). These results highlight the different strategies for perceiving biological motion from point-light and fully illuminated representations of human actions.

26.424

Spatial pattern analysis in biological motion

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Humans show better recognition of moving shapes presented through stationary multiple slits than of static shapes, as well as a remarkable ability to recognize biological motion from impoverished inputs. This study investigated whether spatial pattern processing in shape recognition of a human figure can be influenced by motion processing, or whether the two processes are independent.

A walker stimulus consisted of a silhouette of a person walking on a treadmill. The stimulus was viewed through a set of thin slits (1-pixel width) separated by noise-corrupted masking fields. Observers were asked to identify the person's facing direction. Experiment 1 included three conditions: a single frame of the walker rigidly translated horizontally back and forth, a forward walker, and a backward walker. Vertical slits moved

towards the left or right. No difference in judging the walker's facing direction was found between forward and backward walking conditions. However, we found poorer recognition of a biologically moving human figure compared to recognition of a rigidly translating human figure. This impairment diminished when the walker was inverted. In Experiment 2, we found similar impairment of biological motion perception for both static vertical slits and moving vertical slits. But when the slits were horizontal and static, recognition performance was more accurate in walking conditions than in the rigid translation condition. Facilitation was reduced when horizontal slits moved upward or downward.

The discrepancy between vertical and horizontal slits can be explained by the need for interpolation between accelerating and decelerating fragments separated by space and time in the former but not the latter case. These results provide clear evidence that the visual system uses motion mechanisms to modulate shape interpolation along the trajectory of object movement. For biological motion, integration of spatial pattern information is affected by trajectory complexity due to deformation or articulation.

26.425

Correlation between neural decoding and perceptual performance in visual processing of human body postures: generic views, inversion effect and biomechanical constraint

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We have reported that perceived body postures could be decoded/classified from cortical EEG signals (Kitazaki et al, 2008, ECVP). The classification of upright and inverse postures was performed at about 80% either with natural postures or unnatural postures that we cannot take. The classification of natural and unnatural postures was more accurate with upright postures (63%) than inverse postures (55%). The purpose of the present study was to compare performance of neural decoding with performance of behavioral/perceptual experiments to see correlation between neural signals and perception. We conducted two behavioral experiments: discrimination of orientations (upright and inverse postures), and discrimination of biomechanical naturalness (natural and unnatural postures). One of human body postures (256 gray-scale computer graphics) was presented on a CRT display and 10 participants were asked to discriminate orientation or naturalness as quickly and accurately as possible. Independent variables were the orientation (upright and inverse postures), the naturalness (natural and unnatural postures), and the viewpoints (0:front, 45, 90: side, 135, 180:back deg). In results, behavioral/perceptual performance was higher both in correct rate and reaction time for the orientation discrimination than the naturalness discrimination. The discrimination of naturalness was easier with upright postures than inverse postures, and deteriorated with accidental views (0 and 180 deg). The EEG data during observation of the identical postures were re-analyzed to decode the orientation and the naturalness of postures for different viewpoints. The accuracy of neural decoding was higher for generic views (45 and 135 deg) than the accidental views. These results indicate good correlations between the performance of neural decoding and behavioral/perceptual experiments for the effects of generic views, inversion, and biomechanical constraint. It is suggested that neural decoding of EEG signal can be a useful tool for quantitatively predicting perceptual processing in brain.

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26.426

Automatic attention to local life motion signals

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Using scrambled point-light walkers as attentional cues, we demonstrate that upright local biological motion signals, compared to inverted ones, can automatically attract observers' spatial attention, without observers' explicit knowledge about the uprightness of the local motion signals. The location of each moving dot in the point-light walkers was spatially scrambled such that the global form and global motion information was entirely disrupted. Two sets of these scrambled moving dots, one from upright and the other from inverted walkers, were presented for 500 ms to the left and right sides of fixation respectively, serving as attentional cues in a Posner cueing paradigm. Following the cues, a small Gabor patch was presented for 100 ms either to the upright or inverted biological motion side to assess the attentional effect. Although none of the naive observers could discriminate which motion sequence was upright and which was inverted, their performance was significantly better when the test probe (Gabor patch) was presented to the upright scrambled biological motion side compared with when the same probe was presented to the inverted scrambled biological motion side. No consistent attentional effect was evident when the upright and inverted intact biological motion stimuli were presented as attentional cues. EEG measures further showed that the visual dorsal pathway responded to local properties of biological motion as early as 160 ms following the stimulus onset, prior to the processing of global biological motion information in the MT-pSTS. Together these results suggest an automatic and specialized brain mechanism of detecting local life motion signals, which presumably is important for an organism's survival.

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26.427

Identification of point light walkers exhibits an attentional blink

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In a real-world context, brief glimpses of moving forms, especially people, are both prevalent and salient. Yet in studies of search and selective attention, targets are typically static stimuli, such as characters, words, or pictures. In the present experiments, targets were briefly presented point-light walkers (PLWs), each consisting of a coherent set of moving dots that outline a person carrying out one of four actions (Serre & Giese 2007). The attentional blink (AB) is a deficit in reporting the second of two targets with an SOA of about 200 to 500 ms. The question being addressed was whether attention exhibits a blink for actions defined by coherent motion.

In a series of experiments, participants were shown a sequence of stimuli that included one or two PLWs. Subjects had to name the action of each target (climber, boxer, runner, walker). In experiment 1 target actions were presented for 120 ms and followed by 120 ms masking stimuli created by sampling dot vectors from the different actions and scrambling their starting positions. At an inter-target SOA of 240 ms, report of T2 was strongly impaired compared to report of T1 or an isolated target. In a second experiment in which one or two actions were presented for 166 ms amid a rapidly presented stream of motion masks the blink was found to recover gradually over 700 ms.

This research contributes to ongoing evaluation of a computational model of working memory and attention (eSTST; Wyble, Bowman & Nieuwenstein in press) which proposes that the AB reflects a mechanism for parsing visual input into episodic packets prior to entry into working memory.

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Using PLWs performing complex sequences of actions, it will be possible to test the model with stimuli that naturally convey information over time rather than with the use of artificially rapid static image presentation.

26.428

Peripheral Sensitivity to Biological Motion is Unaffected by Dividing Attention

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Previous research has shown that stimulus magnification is sufficient to equate sensitivity to biological motion across the visual field. However, this research used point-light walkers with fixed direction differences that make it impossible to judge whether the limits of walker direction discrimination change with eccentricity. We addressed this question by measuring walker direction-discrimination thresholds at a range of sizes from 0° to 16°. We found asymptotic thresholds, at all eccentricities, to be ±1.14 degrees from straight ahead. The psychometric functions at each eccentricity were shifted versions of each other on a log size axis. Therefore, when we divided stimulus size at each eccentricity (E) by an appropriate F = 1 + E/E2 (where E2 is the eccentricity at which stimulus size must double to achieve equivalent-to-foveal performance) all thresholds collapsed onto a single psychometric function. Therefore, stimulus magnification was sufficient to equate sensitivity to walker direction across the visual field. The average E2 value required to achieve this was 1.02. We also examined the role of attention in eccentricity-dependent sensitivity loss using a dual-task procedure in which participants were asked to judge first the colour (red or green) then the direction of the point-light walker. The difficulty of the colour judgment, and hence the level of attentional-engagement, was controlled by maintaining colour contrast at threshold levels. The dual-task returned a single E2 value of 1.20 for walker direction discrimination, suggesting that there is no effect of splitting attention between colour and direction at either fixation or 16°. Although there were no costs of splitting attention in the present study, it may be that such costs would be seen when subjects have to divide attention either between (i) two different spatial aspects of a stimulus or (ii) two different locations.

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26.429

Selective attention to superimposed biological and tool motion: a combined fMRI and ERP study

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The effects of selectively attending to moving stimuli appear to depend on the type of motion involved; while some high level motion relies on attending to the stimuli other, lower level motion requires minimal attention. However, it is unclear whether perception of biological motion, a complex yet apparently automatic process, requires attention and if so, where in the processing stream do attention's effects occur? Here we used functional magnetic resonance imaging (fMRI) and high-density event related potentials (ERPs) in the same subjects (N=13) during separate testing sessions to examine the role that selective attention plays in modulating the response to biological motion. Participants viewed point-light animations of spatially overlapping human and tool motion or either category of motion overlapped with scrambled versions of the other category of motion. Attention was directed to either human or tool motion in separate blocks using a 1-back task. Group analysis of fMRI data indicated that right superior temporal sulcus and left intraparietal lobule showed greater response to biological motion than tool motion. Alternately, there was greater response to tool motion in bilateral ventral temporal areas and left middle temporal gyrus compared to biological motion. However, the response in these motion category-preferring regions did not appear to be reduced when attention was directed away from the preferred motion category. ERPs showed a similar pattern of results and revealed larger N1 response to biological than tool motion ("N1bm") over left centro-parietal and right temporo-parietal sites. A polarity-reversed component at a similar latency to the N1bm was observed over midline posterior sites that was greater to tool motion than biological motion. Consistent with the fMRI data, the early responses were not dependent on attention; instead, attention modulated responses after 400ms. These results indicate that initial responses to biological motion and tool motion are not reliant on attention.

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26.430

Feature integration and sensitivity to synchronicity for biological motion impaired by amblyopia

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Spatio-temporal processing may be impaired in strabismic amblyopes (Asper et al., 2000; Popple & Levi, 2008; Roelfsema et al., 1994). The goals of this experiment were two-fold. First, we examined whether the amblyopic visual system retains the higher-level processing capabilities to detect biological motion. Second, we established whether synchronicity sensitivity (detection of synchronized versus desynchronized interactions) is impaired in amblyopic observers relative to normal control observers. We showed point-light displays generated from the trajectories of the major joints of two human agents performing a dancing routine. We used the method of constant stimuli to present the biological motion stimulus at five different stimulus levels, varying the strength of biological motion by varying the number of dot trajectories. Synchronized and desynchronized trials were randomly presented. Each trial consisted of two intervals, 'target' and 'non-target'. In the non-target interval, the dot trajectories of one agent were scrambled. Observers were asked to indicate the target interval that showed two agents dancing. Our results show that the ability to detect biological motion requires more samples (dot trajectories) in both eyes of strabismic amblyopes than in normal control observers. The increased sample threshold is not the result of low-level losses (dot trajectories were visible) but may reflect losses in feature integration due to undersampling in the amblyopic visual system (Levi et al., 1987; Levi et al., 1999; Levi & Klein, 1986). However, like normal observers, amblyopes are more sensitive to synchronized versus desynchronized interactions, indicating that higher-level processing of biological motion remains intact, as previously reported (Neri et al., 2007; Thompson et al., 2008). In contrast, synchronicity sensitivity is impaired in the amblyopic visual system, because disruption due to desynchronization is especially strong. The presence or absence of binocular function may determine whether or not an observer possesses normal sensitivity to synchronicity.

26.431

Aging disrupts the processing of point-light walkers presented in noise

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Previous studies have shown that older subjects have a decreased ability to discriminate the walking direction of point-light walkers. The current experiments examined the cause of this age difference. Younger (18-32 years) and older (>60 years) subjects discriminated the walking direction of upright and inverted walkers across a range of stimulus durations. In Experiment 1, walkers were embedded in scrambled-walker noise. This type of masking forces observers to discriminate the walker's direction on the basis of the global configuration of the walker's points. Older subjects performed significantly worse than younger subjects, especially when the walkers were inverted. Similar results were obtained in Experiment 2, in which walkers were embedded in a dynamic random noise mask. To investigate whether older people rely more on local motion information than young observers, in Experiment 3 we examined performance with three kinds of walkers that provided observers either with only local motion information, only global form information, or both kinds of information

(normal walkers). All walkers were presented in the absence of any noise. There was only a marginally significant effect of age, but overall, older observers performed significantly worse for inverted walkers in all conditions. In addition, older observers exhibited decreased performance for normal walkers, which could mainly be ascribed to the inverted condition. Manipulation of the sources of information on upright walkers had similar effects on response accuracy in older and younger subjects in all conditions. Overall, the results suggest that the age-related decrease in performance for discriminating point-light walkers is mainly due to a decreased ability for older observers to extract relevant information from noisy or unfamiliar displays, and not necessarily because older and younger subjects use different kinds of information available in the stimulus.

26.432

Biological motion targets have to be further away in virtual space for older versus younger adults to maintain good performance

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Human ability to perceive biological motion pattern is well established. Furthermore, it has been shown that older observers can be quite efficient at detecting biological motion. Recently, Legault & Faubert (VSS 2008) showed that young adult biological motion perception is influenced by distance in virtual space. Observers obtained good performance when a 1.8 meter biological motion target was located 1 meter or further but performances decreased dramatically at the shorter distance (less than a meter). The purpose of the present study was to determine if there is a difference between younger and older adult's performances when biological motion patterns are presented at different distances in virtual space. To create our setup, we used a full immersive virtual reality environment (CAVE), giving the observers an immersive 3D experience. 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 and it was shown at virtual distances from the observer of 0.50, 1, 2, 4 and 16 meters. 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 which was generated by randomly selecting dots with biological motion patterns and repositioning them in 3D space. Threshold mask density was determined using an adaptive staircase procedure. The results showed that older adults are influence by distance and that their performance begins to decrease at a distance of 4 meters, compared to young adults who perform well down to a distance of 1 meter. In other words, biological motion detection in noise, in upright and inverted conditions, depends on how far the walker is positioned in 3D virtual space and the critical distance where biological motion judgements break down highly depends on observer age.

26.433

Intact biological motion processing in adults with autism

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A number of recent studies on biological motion perception in people with autism have produced conflicting results with respect to the question whether biological motion perception is impaired in people with autism spectrum disorder (ASD) or not. We designed two experiments which probe two different aspects of biological motion and tested a group of 13 adult, high functioning people with autism as well as a group of age matched control subjects. The first experiment required observers to indicate whether a display showing a mask of scrambled walkers also contained a coherent walker or not. Solving this task requires the observer to perceptually organize the dots constituting the walker into a coherent percept. The second task required the observer to indicate perceived facing direction of a walker presented in sagittal view. In the critical condition, the walker was scrambled. Solving this task requires intact processing of the cues contained in the local motion of individual dots which signals direction and animacy to normal observers. In both experiments, stimuli were shown both upright and inverted and the degree of the inversion effect which observers experience was quantified. In both tasks, human and non-human (cat, pigeon) walkers were employed.

Results reproduced general effects of inversion, masking, and the nature of the walker, all of which have been shown earlier. However, they did not reveal any main group effect nor any interactions that involved the between-subject factor. In both experiments, the overall performance, the degree of the inversion effect, the sensitivity to mask density, and differences in the processing of human vs. non-human walkers were the same between the two groups. However, for the ASD group, in the direction task, we found a significant positive correlation between subjects' IQ and overall performance and a negative correlation between subjects' IQ and sensitivity to stimulus inversion.

URL: http://www.biomotionlab.ca

26.434

Stimulus magnification compensates for eccentricity dependent sensitivity loss for first and second order biological motion stimuli

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Purpose: Size scaling compensates for eccentricity-dependent sensitivity loss in a point-light-walker (PLW) direction discrimination task (Gurnsey et al., Vision Research, 2008) and PLW direction discrimination thresholds reach similar asymptotically low levels at large sizes for eccentricities of 0 to 16° (Gurnsey et al., submitted). Here we ask how PLW direction discrimination thresholds change as a function of stimulus size and eccentricity for first and second order stimuli.

Methods: On each trial a PLW was shown moving left or right at an angle (±α°) from straight ahead. An adaptive threshold procedure was used to determine threshold α at a range of stimulus sizes (uniform magnifications) at eccentricities from 0 to 16° in the right visual field. Second order walkers comprised uniform luminance dots embedded in dynamic noise (SO1) or vice versa (SO2). First order walkers were structurally identical to the second order walkers but had a higher mean luminance in the uniform luminance region; FO1 and FO2, respectively.

Results: Within each condition dividing stimulus size at each eccentricity (E) by an appropriate $F = 1 + E/E2$ (where E2 is the eccentricity at which stimulus size must double to achieve equivalent-to-foveal performance) collapsed all thresholds onto a single psychometric function. The average E2 values were: E2(S01) = 2.85, E2(S02) = 2.03, E2(F01) = 1.50 and E2(FO2) = 0.80; asymptotic thresholds averaged ±3.91°, ±3.83°, ±3.90° and ±4.17° respectively. However, SO1 stimuli could not be discriminated at 8 and 16° and had to be much larger at fixation in order for thresholds to be measured.

Conclusions: Second order signals can elicit PLW direction discrimination thresholds similar to first order signals. For second order stimuli, noise dots in a uniform background convey information about walker direction at much smaller sizes than do uniform dots in a noise background.

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26.435

Relationship between sexual dimorphism and perceived attractiveness in the perception of biological motion

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The human perceptual system extracts socially-relevant information from biological motion, and observers can perceive emotions, gender and attractiveness even from point-light displays. Attractiveness is an evolutionary important social trait, which has been studied extensively with static pictures of faces. Previous work shows that individuals acrossdifferent cultures tend to agree on which faces are attractive, and it has been hypothesized thatevolutionary pressure explains the preference for average, symmetrical,

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and feminized faces. For female faces perceived attractiveness and femininity are closely related: Feminized faces are consistently ratedas more attractive, both by male and female raters. This raises the question how gender and attractiveness are related for dynamic stimuli, such as gait patterns. METHODS: We investigated the relationship between sexual dimorphism and perceived attractiveness in gait patterns by presentation of movies showing volumetric puppets with standardized body shape, which were animated using motion capture data. Perceived attractiveness and gender for the individual movies were rated by 10 male and 10 female observers on 7-point likert scales. RESULTS: Gender and Attractiveness were consistently rated and the correlation between these ratings was very small and non-significant ($r = 0.038$, $p > 0.5$). Inspired by this result, exploiting motion morphing methods, we constructed a stimulus set that permits an independent variation of the attractiveness and gender of walkers. Controlling for the influence of gender, attractive walks are characterized by high symmetry and regularity, while unattractive walks showed strong asymmetries and often resembled pathological gaits. CONCLUSION: We failed to find the relationship between sexual dimorphism and attractiveness in dynamic patterns that was previously reported for faces. Instead, attractiveness and gender seem to form separate dimensions in the encoding of social traits in dynamic gait patterns. This implies potentially different constraints for the communication of social signals by faces and body motion.

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26.436

Learning to anticipate the actions of others: The goal-keeper problem

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When humans observe the actions of others, they can often accurately anticipate the outcome of those actions. This ability is perhaps best exemplified on the sports field, where athletes must anticipate the actions of their opponents based in part on the complex movement of the opponent's body. In this study, we investigated the process by which actors learn to better anticipate the actions of others. Specifically, we tested the hypothesis that learning in this domain can be understood in terms of the ability to perceptually tune to more reliable sources of information. We investigated this matter within the context of blocking a penalty kick in soccer. Because of the extreme time constraints in a soccer penalty kick situation, the goal-keeper must anticipate the direction in which the ball is kicked before the ball is contacted, forcing him or her to rely on the movement of the kicker. We used a motion capture system to record the joint locations of experienced soccer players taking penalty kicks. The data were then used to create videos that depict the keeper's view of a point-light kicker approaching and kicking a ball. Each trial in the experiment displays a video that terminates upon foot-to-ball contact. The subject's task is to judge whether the ball was kicked to the left or right. The stimulus set included kicks from one individual or many individuals, and feedback was provided in some conditions but not others. By correlating judgments with a previously identified set of candidate cues, we can investigate changes in the sources of information upon which observers rely with practice, as well as differences between experienced and inexperienced players. We will also discuss ongoing efforts to use machine-learning techniques as an assumption free method to extract non-local cues that reliably specify the intended action.

26.437

Influence of spatial and temporal congruency between executed and observed movements on the recognition of biological motion

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Action recognition and execution are tightly linked, and action execution modulates by action recognition and vice versa. The involvement of dynamic motor representations in action recognition would predict a critical role of the exact temporal and spatial matching between executed and recognized action. METHOD: In a VR-setup point-light stimuli of waving actions embedded in a scrambled mask were presented to observers. The motion of the presented point-light stimulus was controlled in real-time by motion-captured movements of the participants. Recognition performance was measured by threshold determination varying the number of masking dots. An additional control condition required the detection of the visual stimulus without concurrent motor task. The relationship between visually perceived and executed movement was modified introducing temporal delays (280 and 560ms) between both movements (experiment 1), and by changing their spatial congruency, showing the observer's arm or its mirrored representation without time delay (experiment 2). RESULTS: Compared to the control condition without motor execution, biological motion detection was significantly improved (facilitation) when observed and executed motions were in temporal synchrony compared to the conditions with time delays. Performance deteriorated with increasing delays ($F_{1,14}=10.66$; $p<0.001$), and was significantly worse for the largest delay (560ms) than without motor task (interference). Comparison between the identical and the mirror-reflected arm revealed a critical influence of the spatial congruence between the presented and the executing arm ($F_{1,13}=13.01$; $p=0.003$). Facilitation occurred only in the spatially congruent condition. CONCLUSIONS: Timing and spatial matching between observed and self-generated movements are critical factors for action recognition. Simple explanations, such as the matching of rhythms between both actions, could be ruled out regarding the lack of recognition modulation in the mirrored-arm condition. Present experiments aim to clarify the different functional roles of multi-modal congruency (visual and acoustic), proprioceptive information and dynamic internal motor presentations on action-perception.

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26.438

Evidence for object-centered coding of biological motion

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It has recently been shown that prolonged or repeated viewing of particular biological motion patterns, such as male or female gait, produce strong adaptation effects selective to the adapted gait pattern. We previously reported that such gait-specific adaptation depends on the configuration of the adapter and test stimuli – an adapter that is configured with an intact body shape can produce adaptation of both an intact test stimulus and an apart stimulus, while an adapter with the arms and legs separated from the torso does not produce adaptation of an intact test stimulus (Hussey & Thompson, 2008). In this study we examined the effects of inversion in gait-specific adaptation. As in our previous study, participants (N=11) 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 upright or inverted. We determined the point of subjective equality (PSE) between the two gaits for upright and inverted test walkers, before and after 2mins (plus 5secs/trial top-up) adaptation to one of the gaits. Participants adapted to upright and inverted figures in sessions separated by at least 48hrs. Results revealed strong within-stimulus adaptation, with the upright walker adapting the upright test walker, and the inverted walker adapting the inverted test walker. In contrast to our previous findings of configuration-dependent gait adaptation, however, we found that the upright and inverted adapters produced similar levels of adaptation of the upright test stimulus (36% vs 30%, n.s.). Both upright and inverted adapters also produced similar levels of adaptation in the inverted test stimulus (30% vs 37%, n.s.). Combined with our previous results, these findings suggest an object-centered visual coding of specific gaits that is dependent on the intrinsic relationship between body parts, rather than a viewer-centered, orientation-dependent coding.

Face Perception: Development and Disorders

Saturday, May 9, 2:45 – 6:45 pm
Poster Session, Orchid Ballroom

26.439

Using innate visual biases to guide face learning in natural scenes: A computational investigation

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Newborn infants preferentially orient to and track human faces. While multiple studies have confirmed the existence of an early preference for natural and schematic face stimuli, there is as yet no clear agreement as to the underlying mechanism supporting this preference. In particular, two competing theories (known as the "structural" and "sensory" hypotheses) conjecture fundamentally different biasing mechanisms to explain this behavior. The structural hypothesis suggests that a crude representation of face-specific geometry (three dots specifying eye and mouth locations) is responsible for the exhibited preference. By contrast, the sensory hypothesis suggests that face preference may result from the interaction of several generic visual preferences for qualities like dark/light vertical asymmetry ("top-heaviness"), midline symmetry, and high contrast. Despite a wide range of experimental manipulations designed to tease apart these two conjectures, a key issue regarding these proposals has yet to be addressed: Can a robust "face concept" be learned using mechanisms like these? In particular, are they useful for finding faces in cluttered natural scenes?

In the current study, I describe a computational investigation of how well different biasing mechanisms support face learning given naturalistic inputs. Specifically, I adopt a computer vision approach to assessing the utility of multiple visual biases for finding faces in complex, natural scenes. Each candidate mechanism was applied to a large database of images containing faces and performance was measured in terms of the proportion of "face fragments" successfully retrieved by the mechanism in question. The results demonstrate that the intersection of multiple generic visual constraints (with no explicit face template) is more selective for faces than the classic 3-dot pattern of 1st-order face geometry. Moreover, the properties of the face fragments recovered by each mechanism suggest novel lines of inquiry regarding the nature of infants' "face concept."

26.440

Support for an exogenous account of left visual field biases in infants

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A large body of literature reports a left visual field (LVF) bias in adult populations when viewing face stimuli. Adults tend to use the information from the right side of the owner's face (falling onto the LVF) to make decisions about identity (Gilbert & Bakan, 1973), gender, expression, attractiveness, age (Burt & Perrett, 1997) and lip-reading (Campbell, 1986). What remains unclear is how early this LVF bias emerges and whether it is exogenously driven by the stimulus or endogenously driven by the perceiver.

Experiment 1 examined potential visual field biases in infants between 6 and 9 months of age (M age = 239.60 days) with the use of an eye-tracking system. The faces in the 30 second video clips varied along two dimensions: familiarity (mother versus female stranger) and the presence or absence of mouth movement (talking versus not talking). Video presentation was counterbalanced for familiarity and talking. Strangers' faces were matched to the ethnic background of the mother.

Videos were coded off-line for fixations falling on the adult's face. Results revealed a visual preference for the right side of the owner's face corresponding to the LVF, $F(1,15) = 8.38$, $p < 0.5$. Additionally, infants looked more at the eyes during the no talking condition and at the mouth during the talking condition. There was no effect of familiarity.

Experiment 2 investigated the driving source of the LVF bias (stimulus versus perceiver). An additional group of 6- to 9-month-old infants were shown mirror reversals of the original video clips. Analyses revealed a significant decrease in the LVF bias. These findings suggest a stimulus driven component to the LVF bias in infants.

Overall, the LVF bias characteristic of adult face processing appears to emerge within the first year of life. Furthermore, these findings also lend support to an exogenous account of the LVF bias in infants.

26.441

Do infants recognize the Arcimboldo images as faces? Behavioral and Near-infrared spectroscopic study

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Arcimboldo images are the portraits painted by Giuseppe Arcimboldo. Despite the fact that only nonface objects such as vegetables and fruits are painted, Arcimboldo images induce perception of faces when shown in upright. The perception of face in the Arcimboldo images demonstrates our remarkable sensitivity to upright facial configuration. In the present study, we examined whether infants recognize a face in the Arcimboldo images by using preferential looking technique and by using near-infrared spectroscopy (NIRS).

In the first experiment, we measured infants' looking preference between the upright and inverted Arcimboldo images in 5-6 and 7-8-month-old infants. We hypothesized that if infants detect face from Arcimboldo images, infants would prefer the upright images to inverted image. We found that only 7-8-months significantly preferred upright images, suggesting that they could detect faces from upright Arcimboldo images.

In the second experiment, we measured hemodynamic responses by using NIRS. Based on the behavioral data, we hypothesized that 7-8 months would show differential neural activity for upright and inverted Arcimboldo images as what have shown in the case of adults (Rossion & Jacques, 2008). Therefore, we measured hemodynamic responses from 7-8-month-olds while they were looking at upright and inverted Arcimboldo images by using NIRS. The responses were compared to the baseline activation during the presentation of individual vegetable. We found that the concentration of oxy-Hb increased in left lateral area during the presentation of the upright images compared to the baseline period. The results of two experiments suggested that (1) the ability to detect the face based on configurational information develops by 7-8-months of age, (2) processing of the upright Arcimboldo images related to the left lateral area.

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26.442

Sensitivity to Posed versus Genuine Expressions: Are Children Easily Fooled?

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Adults are sensitive to the authenticity of facial expressions. They evaluate t-shirts more positively when worn by a model displaying a genuine smile than a posed smile or a neutral expression (Peace et al., 2006). They are more likely to say that a model displaying genuine happiness is feeling happy than a model displaying posed happiness, but fail to recognize that an expression is posed about 50% of the time (Miles & Johnson, 2007). We conducted two experiments to determine whether children are sensitive to the authenticity of facial expressions. In Experiment 1, 7-year-olds and adults (n=48 per group) first ranked 6 beach balls held by a female model displaying genuine happiness, posed happiness, or a neutral expression (n

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= 2 balls per expression) in order of preference. In a subsequent show/feel task, participants indicated whether each of 12 models displaying genuine happiness, posed happiness, or a neutral expression (n = 4 per expression) was showing happy and whether each was feeling happy. Both 7-year-olds and adults reported that genuine models were feeling happy more often than posed models (p <.01). However, unlike adults, 7-year-olds showed no evidence of sensitivity to facial expression on the beach ball task (p > .20), perhaps because they failed to attend to the faces. In Experiment 2, we initially covered the 6 beach balls in the ranking task to ensure that the children viewed the faces prior to ranking the beach balls. Data to date (28 7-year-olds, 22 9-year-olds) indicates that, like adults, children rank beach balls paired with genuine expressions more favorably than beach balls paired with posed or neutral expressions, p <.01; there is no age x expression interaction, p > .5. We conclude that by age 7 years, children are sensitive to the authenticity of expressions and that this sensitivity can influence their evaluation of products.

26.443

The role of experience during childhood in shaping the other-race effect

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It is well known that adults' face recognition is characterized by an "other-race effect" (ORE, see Meissner & Brigham, 2001), but few studies have investigated this ORE during the development of the face processing system. Here we examined the role of experience with other-race faces during childhood by testing a group of 6- to 14-year-old Asian children adopted between 2 and 26 months in Caucasian families living in Western Europe, as well as a group of age-matched Caucasian children. The latter group showed a strong ORE in favour of own-race faces that was stable from 6 to 14 years of age. The adopted participants did not show a significant reversal of the ORE, unlike a recently reported study (Sangrigoli et al., 2005), but rather comparable results with Asian and Caucasian faces. Their pattern of performance was neither influenced by their age of adoption, nor by the amount of experience they accumulated during childhood with other-race faces. These results indicate that the balance of performance with Asian and Caucasian faces can be modulated, but not completely reversed, in children whose exposure to own- and other-race faces changes drastically during the period of maturation of the face recognition system, depending on the length of exposure to the new face race. Overall, experience appears as crucial during childhood to shape the face recognition system towards the most predominant morphologies of faces present in the environment.URL: http://www.nefy.ucl.ac.be/Face_Categorisation_Lab.htm

26.444

Face discrimination in infants and adults: the role of contrast polarity of the eyes

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Humans are the only primates that have a white sclera that contrasts with the darker colored iris (Kobayashi & Kohshima, 1997). While color and darkness of skin, hair, and iris vary widely among humans, the color of sclera is universally white and lighter than the iris. Hence, all human faces share a common contrast polarity relationship between the sclera and iris, in addition to the first order spatial relationships between the facial features (two eyes above a nose, which is above a mouth). Here, we test the possibility that the contrast polarity relationship between the sclera and iris plays an important roll in facial processing by infants.

By independently manipulating contrast polarity of the eye ball region and other facial regions, we created the following four image conditions: Positive Face condition (original grayscale image), Negative Face condition (fully negated image), Negative Eyes condition (positive facial image with negated eyes), and Positive Eyes condition (negative facial image with positive eyes). We compared infants' ability to discriminate between faces under these four image conditions.

Forty-eight 7-8 month-old-infants participated in the present study. We employed a familiarization/novelty preference procedure to test face discrimination in infants. During familiarization phase, infants were repeatedly shown a female face for six 15 sec trials. Then, they were shown the familiarized female face and a novel female face side by side for two 10 sec trials. Infants showed a significant looking preference for novel face only in the Positive Face and Positive Eyes conditions. These results show that infants only discriminate between the faces when the contrast polarity of the eyes is preserved, irrespective to the contrast polarity of facial surface and is consistent with a critical role for the contrast polarity of eyes in infants' face perception. We will present further data from adult participants.

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26.445

Deficits in face and object processing manifest differently in normal aging and developmental prosopagnosia

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Are deficits in face recognition in healthy older adults (OA) similar or different from those in young adults with developmental prosopagnosia (DP)? In the Cambridge Face Memory Test (Duchaine & Nakayama, 2006), OAs performed worse than young controls but their average score was well within 2SD of the young control mean. DPs (n=5, age range=21-46) showed a severe impairment in the memory test compared to both young controls and OAs. Both OAs and DPs demonstrated a strong face inversion effect in the memory test. Groups also differed on a sequential matching task which presented one of the stimulus categories including unfamiliar faces, greebles (Gautheir & Tarr, 1997) and simple geometric figures composed of two elements. In each trial, a first stimulus was displayed for 500 ms, followed by a mask, then a second stimulus was shown. Viewpoints between the first and second stimuli were varied (no change or 30° change). With face and greeble stimuli, OAs performed worse than young controls in all viewpoint conditions. Additionally, they were poor at detecting a feature change in simple geometric figures. DPs demonstrated a deficit for faces and simple geometric objects only when there was a change in viewpoint. With greebles, DPs' accuracy was comparable to that of young controls in all viewpoint conditions but reaction time was significantly slower. Overall, the data suggest that face perception is more affected by aging than face memory and that age-related decline extends to object categories. In contrast, face processing deficits in the DPs appear to arise at higher levels, which may reflect a disruption in building a view-invariant representation and transferring it to long-term memory.

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26.446

Probing the face-space of individuals with prosopagnosia

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A useful framework for understanding the mental representation of facial identity is face-space, a multi-dimensional cognitive map in which individual faces are coded relative to the average of previously encountered faces, and in which the distance among faces represent their perceived similarity.

We examined whether this framework is useful in understanding prosopagnosia, a disorder characterized by an inability to recognize familiar faces, despite normal visual acuity and intellectual abilities. We tested the mental representation of faces in 6 patients with congenital prosopagnosia (CP) and 1 patient with acquired prosopagnosia (AP), and compared their performance to 14 age- and gender-matched control participants. We used digital images of male and female faces and morphed them relative to an average face. To assess whether faces are coded relative to an average face, we examined face identity aftereffects: a shift in perceived identity in the direction opposite to the adapting face, relative to average. To assess the layout of face-space, we measured perceived similarity and distinctiveness of caricatures and anti-caricatures relative to the veridical image. In addition, we used multi-dimensional scaling to analyze the similarity ratings of non-morphed identities. Across 5 behavioral tasks, CP patients revealed a remarkably intact face-space, whereas the AP patient's performance deviated significantly from the control and CP groups. The findings provide distinctions between the behavioral profiles of CP and AP patients, and provide constraints on the utility of the face-space framework in describing how familiar faces are recognized.

26.447

Non-face visual memory impairments in developmental prosopagnosia

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Developmental prosopagnosia (DP) is an important test case regarding modularity and structure of the visual system. Duchaine et al (2005) demonstrated that some cases of developmental prosopagnosia show deficits highly selective for faces. Duchaine et al also found a large family with both face and within category object deficits, indicating multiple causes of face deficits. To explore this issue in a wider sample, we tested 18 DPs and 14 age matched control subjects. Face memory was assessed by the Cambridge Face Memory Test. Two tests of non-face visual memory were administered – one using abstract art images and the other using within category discrimination of objects. Verbal memory was assessed using a written word paired associates test. DPs were severely impaired in the Cambridge Face Memory Test (Cohen's d= 3.9) confirming their face recognition deficits. They were also impaired on the abstract art and the within category object memory test, with a Cohen's d of 1.6 and 1.63 respectively. There was an insignificant difference with the verbal task, with the DPs scoring slightly higher than the control group.While the developmental prosopagnosics did not show deficits in verbal memory, in most cases they did show general visual memory deficits.

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Structural differences in developmental prosopagnosia

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Developmental prosopagnosia (DP) is a condition in which individuals experience severe difficulties recognizing faces despite no history of neurological damage. We tested 17 DPs and 18 matched controls to investigate structural brain differences in DP. Voxel based morphometry showed that the DPs had smaller grey matter volume in bilateral regions of the superior temporal sulcus and in a region of the right anterior inferior temporal lobe. Differences in grey matter volume can be caused by a variety of factors, one of which is grey matter thickness. To examine this possibility, we compared cortical thickness between the two groups and found that DPs had decreased cortical thickness in the right anterior inferior temporal lobe. Finally, we tested all participants with a large battery of behavioural tests and will discuss the significant correlations of these results with grey matter volume and cortical thickness. Our results reinforce previous studies suggesting that all three of these areas are important for face processing.

26.449

Disconnection of cortical face network in prosopagnosia revealed by diffusion tensor imaging

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Current anatomic models of face processing propose a 'core' system (occipital face area - OFA, the fusiform face area - FFA, and superior temporal sulcus - STS) and a multi-modal 'extended' system, which includes anterior temporal cortex. Classic models of prosopagnosia suggest that disruption of face processing may occur from disconnection within such a network, though most current studies have focused on damage to the modules themselves. In this report we describe the white matter changes in a prosopagnosic patient with only modest cortical damage.

Patient R-AT1 acquired prosopagnosia following a right amygdalohippocampectomy for epilepsy, which resulted in lesion of the anterior part of the inferior longitudinal fasciculus (ILF). We used functional MRI (face-objects comparison) to localise regions in the core system, all of which were still present in R-AT1, and then performed diffusion tensor imaging (DTI) tractography to visualise tracts extending from these regions in R-AT1and 8 healthy controls. Tracts from the OFA of R-AT1's intact left hemisphere extended along the ILF, towards the anterior temporal lobe. In the lesioned right hemisphere of R-AT1, tracts from posterior occipitotemporal regions did not extend far anteriorally. Compared to controls, a region of reduced fractional anisotropy (FA: DTI index associated with white matter structural integrity) was found in the patient's right hemisphere ILF, adjacent and superior to the patient's FFA.

These inter-subject and inter-hemispheric differences may reflect a retrograde degeneration of ILF tracts in the patient's lesioned right hemisphere. Hence, disruption of connections in the face-processing network between posterior occipitotemporal face-selective areas and anterior temporal cortex may contribute to R-AT1's prosopagnosia, particularly since the amount of cortical damage in R-AT1 is modest and in a location unusual for prosopagnosia.

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26.450

Use of a Correlative Training Method in the Rehabilitation of Acquired Prosopagnosia

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No effective treatment is known for acquired prosopagnosia. We investigated a novel rehabilitative training strategy, based on work with neural network models showing that correlating a weak cue with a strong cue during training can help a network learn tasks that would otherwise not be possible. Many prosopagnosic subjects can recognize facial expressions despite their problems with identity. By correlating expression with identity during early training stages, we can pair a strong cue (expression) with a weak one (identity). With repeated training, this correlation should increase the perceived difference between these novel faces, eventually allowing recognition of identity even when expression is no longer correlated.

We trained two prosopagnosic subjects (R-AT1 and B-AT1) with anterior temporal lesions and intact recognition of facial expression. During the correlative method, subjects learned five frontal-view faces, initially all with

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unique expressions. Once they achieved a criterion success rate, a modest degree of variability in expression was introduced, and more again once criterion was achieved, until expression was eventually uncorrelated with identity after several weeks of thrice-weekly training. Additional training runs were performed with hair removed, and external contour removed. As control experiments, we had subjects learn five other faces over a similar time period, but without any correlation between identity and expression.

Subjects learned to recognize these small sets of faces, even without hair or external contour, and showed high levels of retention even two months later. However, subjects also learned the faces in control experiments, suggesting that repeated exposure was also effective. fMRI scanning in one subject showed a significant increase in peak-voxel significance and the number of face-selective voxels in the fusiform face area after training. These results show that prosopagnosics can learn to recognize a small set of faces with at least some invariance for expression.

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26.451

Holistic processing of diagnostic 3D face shape as compared to 2D surface reflectance: evidence from face inversion and acquired prosopagnosia

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Behavioral studies have shown that in addition to three-dimensional (3D) shape, two-dimensional (2D) surface reflectance information 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). In this context, it has been recently reported that inversion equally affects face individualization based on shape or surface reflectance information (Russell et al. 2007). While this can be taken to support the view that inversion affects face processing quantitatively, 3D global shape information variation was relatively minimized in this latter study by cropping of the face contour. Here we reinvestigated this question by means of face stimuli in which natural global shape variations were preserved. To do so, we used a 3D morphable model (Blanz & Vetter 1999) to create paired face stimuli that differed in 3D shape, 2D reflectance, or both. Twenty-four participants performed a delayed face matching task with both upright and inverted faces, in which discrimination between the target and distractor faces was possible based on shape information alone (shape-different), reflectance information alone (reflectance-different), or both (different). Whereas inversion impaired performance for all conditions, the effect was significantly larger when discrimination was on the sole basis of 3D shape information. A second experiment with upright faces showed that a patient with acquired prosopagnosia (PS, Rossion et al., 2003) suffering from holistic face perception impairment performed significantly better in the reflectance-different condition than in the shape-different condition. Altogether, these observations suggest that 3D shape information is more dependent on holistic face processing than 2D surface reflectance. They also support a qualitative view of face inversion (Rossion, 2008) and concur with recent findings of a right hemispheric dominance in processing diagnostic 3D shape cues from faces (Jiang et al., submitted).

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Effects of face inversion and noise in persons with schizophrenia

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There is substantial evidence that people with schizophrenia show alterations in several domains of visual processing, including deficits in face processing and a reduced face inversion effect compared to healthy controls. However, the mechanisms underlying this observation are not yet known. Eye movement studies have found that people with SCZ do not concentrate on the most informative regions for face identification (e.g., the eyes). Consequently, people with SCZ may be less able to extract relevant information, suggesting a decrease in calculation efficiency. Previous research with non-face stimuli also suggests that SCZ is associated with increased levels of cortical internal noise. Moreover, both calculation efficiency and internal noise have been shown to be important mechanisms underlying face perception among healthy observers. The current study applies noise masking to upright and inverted faces to determine if face processing differences in SCZ are a result of changes in efficiency, internal noise, or both. Groups of community-based controls (n=24) and patients with SCZ (n=23) were presented with a target upright or inverted face, embedded in low or high levels of Gaussian white noise, for 200 ms. The target was followed immediately by the presentation of two faces and the task was to select the face corresponding to the target. A threshold was estimated by varying the contrast of the target face. Groups were matched for age, sex, and education. Similar to previous results, compared to controls, people with SCZ exhibited higher thresholds with upright and inverted faces, but also showed a reduced face inversion effect. Manipulation of noise had a smaller effect on performance in people with SCZ. Overall, the results suggest that people with schizophrenia have decreased calculation efficiency and increased internal noise compared to controls: Both factors act to impair face discrimination and reduce the face inversion effect in people with schizophrenia.

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26.453

fMRI activation during face processing: Differential effects of spatial frequency manipulation in healthy controls and people with schizophrenia

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People with schizophrenia demonstrate perceptual organization impairments, and the potential contributions of such impairments to face processing in schizophrenia are not known. In the current study we sought to examine the neural substrates of emotionally-neutral face processing in schizophrenia by examining neural activity under three stimulus conditions: normal faces, faces with low-spatial frequency information removed ("High condition"), and faces with high spatial frequency information removed ("Low condition"). Face perception in the High condition may be more reliant on local feature integration processes, whereas perception in the Low condition may require more reliance on global form processing. Past studies of perceptual organization in schizophrenia indicate that patients perform more poorly with degraded stimuli, but also, when global information is absent (which is detrimental to performance for controls), patients perform better than controls. fMRI data from 14 patients and 13 controls was acquired using a 3.0-Tesla whole body scanner and was processed using SPM2. Images were spatially normalized to the MNI template and smoothed. Using a block design, the BOLD response during a gender-discrimination task under each condition was compared to a resting baseline with center fixation. Whole brain subtractions between patients and controls were examined for each condition, controlling for type I error. Areas of significantly different activation between groups were identified across all three conditions. Of note, in both degraded conditions, patients demonstrated greater activity in the fusiform gyrus compared to controls, suggesting that impairments in basic integration abilities may be compensated for by relatively increased activity in the fusiform gyrus under these degraded stimulus conditions. Behavioral data indicated high levels of accuracy for both groups, with a trend toward an interaction involv-

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ing higher patient performance in the high condition and poorer patient performance in the low condition. Implications of these findings will be discussed.

26.454

Perceptual Reversal Patterns in Individuals with Asperger Syndrome

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When viewing ambiguous figures, individuals can exert selective attentional control over their perceptual reversals (e.g., Strüber & Stadler, 1999). In the current study, we replicated this finding and also found that ambiguous figures containing faces are processed quite differently from those containing objects. Viewers' were able to divide their attention equally between the two face interpretations of Boring's young girl-old woman, and showed a face preference when viewing Rubin's vase-face. When instructed to alternate quickly between competing interpretations, their reversal rates were much quicker for these two figures than for figures containing only objects (Maltese cross, Necker cube), a finding that might reflect greater use of a holistic processing strategy when viewing figures involving faces. This was examined by comparing reversal behaviours for upright and inverted versions of Rubin's vase-face and looking for inversion effects (i.e., alterations in reversal behaviours associated with inversion). Viewers spent more time perceiving the face than the vase interpretation with upright but not inverted stimuli, and made faster reversals with upright than inverted displays. These findings suggest that face inversion influences how we attend to faces, in addition to how we perceive and process them. Describing the perceptual reversal patterns of individuals in the general population allowed us to draw comparisons to behaviours exhibited by individuals with Asperger Syndrome (AS). The group data suggested that these individuals were less affected than neurotypical controls by figure type or stimulus inversion. Examination of individual scores, moreover, revealed that the majority of participants with AS showed atypical reversal patterns, particularly with ambiguous figures containing faces. The majority also showed an atypical rather than a diminished or absent inversion effect. Together, our results show that ambiguous figures can be a valuable tool for examining face processing mechanisms in the general population and other distinct groups of individuals.

3D Perception: Shape, Shading and Contours

Saturday, May 9, 2:45 – 6:45 pm
Poster Session, Vista Ballroom

26.501

Spatial patterns of cortical responses to shape from shading: a steady-state VEP study

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Previous studies have shown activity related to the processing of shape from shading in early visual areas, such as V1 and V2 (e.g. Humphrey, et al., 1997; Lee et al., 2002), and relatively higher areas, such as intra-parietal cortex (Taira et al., 2003). Some researchers infer that shading information is first processed in lower visual areas and then integrated with other depth cues such as binocular information in intra-parietal cortex (Taira et al., 2003; Mamassian et al., 2003). However, spatial pattern of cortical responses over the whole scalp are still unclear. This study examined spatial distributions of steady-state visual evoked potentials (VEPs) to shape from shading. A horizontal black-white grating underwent phase shifts relative to a zig-zag outline envelope to create two different appearances (Hou et al., 2006). In the 3D condition, the shifts appear as a 3-D corrugated surface defined by shading, alternating with a flat striped surface. In the 2D condition, the shifts of the grating appear to take place on a flat surface behind an aperture. We recorded VEP signals from 128 channels while subjects were observing these stimuli, and analyzed the mean amplitude of the component at the fundamental frequency (F1) of the pattern alternation. The findings suggest that adults' F1 amplitude under the 3D condition is significantly larger than that under the 2D condition, indicating a response specific to shape-from-shading. Furthermore, this F1 amplitude in the occipital region was larger than those in temporal and parietal areas. We will report results on 6- and 7-month-old infants using the same procedure as for the adults, and will discuss the implications of these results for the development of neural systems underlying the perception of shape from shading.

Saturday Sessions

26.502

Infants' ability to perceive 3D shape from pictorial cues : Transfer-across-depth-cues study

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The purpose of this study was to explore the development of the infants' ability to perceive 3D shape from pictorial depth cues. The method investigated whether spatial information provided by one depth cue was available when the infant was presented with a novel and familiar layout provided by a different depth cue. (Yonas, Arterberry & Granurd, 1987; Yonas & Pick, 1975). Previous studies used habituation (Imura et al., 2006, 2008; Kavsek, 1999) and preferential looking methods (Bertin & Bhatt, 2006; Bhatt & Bertin, 2001; Bhatt & Waters, 1998), however, these methods did not provide clear evidence that infants perceived the 3D shape of the stimuli. While these methods allow us to infer that infants can discriminate between displays, they do not rule out the possibility that infants discriminate between the proximal stimuli but not the distal stimuli. To rule out this possibility and examine infants' ability to perceive 3D shape from pictorial depth cues, we employed a "transfer-across-depth-cues" method. In this method, we examined the transfer between two pictorial depth cues: shading and surface contours. Infants were habituated to a 3D shape specified by one cue, and then presented with the same shape and a novel-shape, both specified by the other depth cue. In this case, infants could distinguish the familiar shape and the novel shape only if they perceive 3D shape from the pictorial depth cues, despite the shift in the type of the pictorial cues. Results indicate that six-to-seven-month-old infants showed a significant novelty preference despite the shift in the type of the pictorial cue. On the other hand, four-to-five-month-old infants did not. The results clearly indicate a significant improvement in responsiveness to the pictorial cues between the younger and the older age group.

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26.503

The perception of 3-D shape from shadows cast onto curved surfaces

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In a natural environment, cast shadows abound. Objects cast shadows both upon themselves and upon background surfaces. Previous research on the perception of 3-D shape from cast shadows has only examined the informativeness of shadows cast upon flat background surfaces. In outdoor environments, however, background surfaces often possess significant curvature (large rocks, trees, hills, etc.) and this background curvature distorts the shape of cast shadows. The purpose of this study was to determine the extent to which observers can "discount" the distorting effects of curved background surfaces. In our experiments, observers viewed deforming or static shadows of naturally-shaped objects that were cast upon flat and curved background surfaces. The results showed that the discrimination of 3-D object shape from cast shadows was generally invariant over the distortions produced by hemispherical background surfaces. The observers often had difficulty, however, in identifying the shadows cast onto saddle-shaped background surfaces. The variations in curvature that occur in different directions on saddle-shaped background surfaces cause shadow distortions that lead to difficulties in object recognition and discrimination.

26.504

Contextual lighting cues can override the light-from-above prior

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When the direction of illumination is unknown, the human visual system uses a light-from-above prior to infer the shape of ambiguous shaded images. Can this prior be overridden by contextual lighting cues that indicate the true lighting direction in a specific scene? Previous studies have given mixed results. We re-examined this question using realistic renderings of complex scenes under a range of lighting conditions.

METHODS: Stimuli were computer-rendered scenes of geometric objects. Simulated lighting in each scene consisted of a distant point source and an ambient source. The direction of the point source varied from scene to scene. The strength of the directional lighting cues was varied by modulating the relative strength of the point and ambient sources. Observers judged whether ambiguously shaded disks shown on the geometric objects at various orientations were convex or concave. We used these judgements to infer what lighting direction observers' shape-from-shading mechanisms assumed to be dominant in each scene.

RESULTS: When scene lighting was direct (i.e. point source strong, ambient source weak), the lighting direction assumed by observers closely tracked the true lighting direction. When lighting was diffuse, large individual differences appeared: some observers' shape judgements of ambiguous shaded disks were independent of disk orientation, and some observers had preferred lighting directions that were neither directly above nor in the direction of the direct component of the light source.

CONCLUSIONS: Strong directional lighting cues can override the light-from-above prior: observers interpret ambiguous shaded objects as if illuminated from the direction indicated by the lighting cues. Weak directional lighting can also override the light-from-above prior: surprisingly, the light-from-above prior does not guide shape judgements even in the presence of directional lighting cues that are insufficiently strong to guide observers' estimates of the dominant lighting direction in a scene.

26.505

The role of second-order vision in discriminating shading versus material changes

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Human vision is sensitive to both first-order information (luminance modulations, LM) and second-order information as conveyed by modulations of the local luminance contrast (CM) or amplitude (AM) of a visual texture. However, the role of second order vision is not yet clear. Johnson and Baker (JOSA-A, 21, 913-925, 2004) found that first- and second-order cues are correlated in natural images, but Schofield (Perception, 29, 1071-1086, 2000) showed that the sign of this relationship varies from image to image, suggesting that the phase relationship of the two cues may be an important environmental factor. We studied perceptual responses to mixtures of LM and AM (Schofield et al, Vision Research, 46, 3462-3482, 2006). Observers saw in-phase mixes (LM+AM) as strongly undulating surfaces via shape-from-shading. Negative (anti-phase) mixes (LM-AM) were also seen as undulations when presented alone. However, when LM-AM was presented together with LM+AM in a plaid the anti-phase cue was seen as flat – like strips of material laid across an undulating surface. Crucially, the perception of LM-AM depends on the context in which it is presented. It is tempting to suppose that these contextual effects have a high-level origin, but we now show that our results can be predicted by a simple, filter-based, bottom-up model. Images are passed through two linear channels with orthogonal preferred orientations and through two non-linear, filter-rectify-filter channels whose second-stage properties match those of the linear channels. Linear and non-linear channel outputs are combined by addition within each orientation and then subjected to mutual, cross-orientation inhibition prior to a final summation stage. The model outputs a shading map from which we estimate surface undulations. Both LM+AM and LM-AM produce undulations when presented alone, but for plaids, the LM+AM component dominates the LM-AM component and the latter cue does not produce undulations.

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26.506

Interaction of Contour, Shading and Texture in Natural Images

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The assessment of three dimensional shape perception from monocular images continues to be an open problem in the vision science community. What features and processes mediate shape perception in natural images? Previous studies have investigated the effects of shading, texture and contour in artificial stimuli. In this experiment, however, we choose to investigate how these cues interact in the context of natural images such as a vase, a human face, or a landscape scene.

We degraded a set of natural images to measure the influence of shading, texture and contour on shape perception. The first degradation is a gaussian blur kernel applied to the stimulus set. To create the second degradation, human subjects manually segment the images, and the distinct regions in the human segmentations are replaced with the region's average color and luminance. The first degradation intends to reduce the influence of shading and texture, while the second intends to completely eliminate any influence. Nine subjects were tested in this experiment, where each subject was presented each image in one of three different conditions: normal, degradation 1, degradation 2. Subjects made surface normal settings at a large number of sample points on each image using the elliptical gauge figure paradigm introduced by Koenderink et al. (1992). The subjects' task is to adjust the elliptical disks so that they appear maximally aligned with the local surface shape.

Subjects' responses display a surprising robustness to shading and texture degradations in natural images. Although images subjectively look flatter under the degradations, subjects are able to make surface normal settings by ignoring the fact that shading and texture indicate flatness. This is an example of cue integration where the false cue can be ignored, and these results indicate the primacy of the contour cue in shape perception of familiar object categories.

26.507

The dependence of perceived 3D relief of 2D shaded figures on the shape of their 1D bounding contours

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The spatial pattern of luminance across the image of an object (shading) is an important cue for the recovery of its 3D shape (relief). However, perceived relief does not depend only on the luminance distribution in the interior of a shaded figure, but also on the shape of its bounding contour (Witkin & Tenenbaum, 1983; Ramachandran, 1988). I have investigated this little studied effect using images consisting of vertically oriented three-cycle smooth luminance gratings with rectilinear lateral boundaries, by varying the shapes of their top and bottom boundaries. A variety of boundary geometries were used, mainly involving portions of sinusoid-like shapes with different frequencies and phases, generating figures with several types of spatial congruencies between photometric features of the shading patterns (luminance maxima and minima) and geometric features of the boundaries (peaks, troughs, inflections, cusps). These manipulations had strong and occasionally multi-stable perceptual effects: figures with essentially identical luminance profiles exhibited saliently different perceived relief and apparent illumination direction, not only in the vicinity of the top and bottom boundaries but fully throughout their interior. Some figures looked as uniformly colored, unitary illuminated highlighted shapes, whereas others appeared non-uniformly colored, and under multi-directional or unnatural illumination, similar to photographic negatives. A new class of ambiguous / reversible figures was constructed by using top and bottom boundaries with mismatched shapes. The relief-related observations were confirmed and quantified in an experiment in which 69 subjects were asked to match 24 presented figures with one of 10 provided relief profiles. Some figures induced high consensus among observers, whereas others generated a variety of perceived profiles. The results are generally consistent with a simple physics of illumination, highlight the role of boundary-induced constraints on recovering 3D shapes from ambiguous shading patterns, and are relevant for shape-from-shading algorithms and neural foundations of 3D shape perception.

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26.508

Perceptual asynchrony between sinusoidally modulated luminance and depth

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Many observations show that the simultaneously presented visual events lead to temporally asynchronous percept. A few studies have focused on whether the asynchronous inner experience is related to the difference in neural processing time or to the temporal structure of the stimulus presentation. In the present study, our aim is to get a perceptual handle on the neural processing time for depth and luminance by eliminating a potential confounding factor, namely, temporal structure of stimulus presentation. To accomplish this, we used sinusoidal modulation of depth and luminance, because such modulation has gradual turning points. Our data show that the simultaneous sinusoidal modulation of depth and luminance at same or different locations inevitably results in a perceptually narrow and precise temporal difference, despite the fact that the nature of the turning points in both visual attributes were designed to be the same. Therefore, the temporal difference can be interpreted to stem from neural processing time. Our measurement shows that to get the perceptual synchrony, subjects adjust the relative phase of luminance and depth as if luminance peak is perceived ahead of depth peak.

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26.509

Orientation effects in the horizontal-vertical illusion

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The horizontal-vertical illusion has often been interpreted in a three dimensional context, namely that the vertical bar in a 'T' figure is perceived as longer because it refers to a line slanted in depth. Therefore, this illusion might be useful to investigate perceived depth in brain damaged patients, who might be specifically impaired in processing 3D scenes. Before using this illusion as a probe in to 3D perception, we were interested in measuring the 3D component in this illusion. For this purpose, we asked normal observers to compare the vertical and horizontal lengths of three figures ('T', 'L', '+') at different orientations (0°, 90°, 180°, 270°). We used the method of constant stimuli where we manipulated the aspect ratio of the figure. Participants had to judge which line (horizontal or vertical) was the longest and we estimated the point of subjective equality from the psychometric function. We found that two parameters - a vertical/horizontal parameter (p) and a bisecting parameter (q) - could explain all conditions presented. Parameter p refers to an overestimation of the vertical segment relative to the horizontal one, and parameter q to the tendency to overestimate the dividing line relative to the divided line, irrespective of their orientation. Participants showed consistent behaviors through all conditions. On average, parameter p corresponded to 5% of overestimation and parameter q to 17% of overestimation. If parameter p is related to a depth illusion, it would correspond to a figure presented in a plan slanted at about 18°. This dissociation between two independent parameters supports the use of the horizontal-vertical illusion to study more accurately the mechanisms involved in neglect patients and suggests it could be a useful tool to diagnose this population of patients.

26.510

Figure Contour Binds the Depth-After-Effect

Katinka van der Kooij[1] (k.vanderkooij@fss.uu.nl), Susan te Pas[1]; [1]Experimental Psychology, Utrecht University, Helmholtz Institute

The retinal image constantly changes due to head, eye and object movement. Yet, perception of three-dimensional structure is strikingly stable. Thus, depth relations have to be bound to a constant for temporal integration. Recent studies show that depth-after-effects do not depend on the stimulated retinal location and can be specific for spatial location or an object property such as colour. We address the extent to which depth relations are encoded bound to figure contour or spatial location.

Observers adapted to a disparity-defined figure in front of a constant background. Next, they indicated whether a test figure was located further form the background than a reference stimulus (two dots). The test stimulus was either the same checkerboard ('identical' condition) as the adaptation stimulus, or the inverse checkerboard, which shares only figure contours with the adaptation stimulus but has no surfaces at the same spatial location ('contour' condition). If depth relations are bound to spatial location one would expect a depth-after-effect only in the 'identical' condition, but if depth relations are bound to figure contour, a depth-after-effect could occur in both conditions as the figures shared their outline.

Perception of the test figure's distance to the background was biased in the direction opposite to the distance of the adaptation figure (a depth-after-effect) in both the identical and the contour conditions.

From this we conclude that encoding of depth relations can be bound to figure contour. We will proceed to investigate the extent to which the depth-after-effect is specific to the figure contour or figure-ground relations in general.

26.511

Three-dimensional shape from second-order orientation flows

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In images of textured surfaces, orientation flows formed by perspective convergence invariably convey 3-D shape. We examine whether second-order orientation flows convey 3-D shape, whether they induce 3-D shape aftereffects, and whether these aftereffects are invariant to how the flows are defined. Three sets of surface textures were used: a full contrast 2.6 cpd luminance-modulated horizontal-vertical plaid (LM); a 2.6 cpd vertical full contrast grating contrast-modulated by an equal-frequency horizontal grating envelope (CM); and a horizontal abutting grating illusory contour stimulus (IC). These textures were mapped onto carved sinusoidal concavities and convexities that varied in depth as a function of horizontal position. For these surface shapes, orientation flows are formed by horizontal components of the surface texture. Baseline measurements show that the perceived flat point for each of the three sets of stimuli was close to physical flatness, indicating that CM and IC orientation flows convey 3-D shape. For all three sets of stimuli, adapting to curved stimuli caused 3-D shape aftereffects on subsequently presented test stimuli, quantified by a shift of the perceived flat point away from the baseline. Adapting to LM orientation flows induced robust 3-D shape aftereffects on CM and IC tests. Aftereffects using CM and IC adapting stimuli on LM tests were substantially weaker, but were robust when adapting/test stimuli were both CM or both IC. These results can be explained by the adaptation of 3-D shape-selective neurons in extra-striate regions that invariantly extract first- and second-order orientation flows from striate and extra-striate signals. The asymmetry of aftereffect strengths can be explained by stronger input to these shape-selective neurons from neurons selective for orientation defined by first-order differences.

26.512

Line Junctures Create a Powerful Illusion of Moving Surfaces

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Normally line drawings of objects are presented on a flat pictorial surface and viewed binocularly. Cues for the flatness of the surface are in conflict with the 3-D information provided by lines and junctures. As a result, the experience of objects in space created by line drawings is weaker as compared to stereoscopically presented displays. To test this notion, a line display was created using a wire object that presented three sides of a skeletal cube pointing away from the viewer. We have observed (2008 VSS Demo Night) that this object can create several illusions. When presented monocularly, it is almost always perceived as convex. When the viewers move, motion parallax should indicate the concave nature of the object, but surprisingly line cues dominate. Instead of perceiving the object as static, it is seen as rotating so that the vertex follows the moving viewer. In addition, the white background surface is perceived as coming forward in depth with solid internal surfaces moving with the wire frame.

Twenty-three participants took part in the study to test the consistency of this illusion. They were asked whether the object was convex or concave, static or moving, a solid object or an empty frame. Participants viewed the object monocularly against a white background and binocularly against a striped background. In the binocular condition, viewers reported the object as concave (93.5% of trials), static (84.8%), and empty (95.7%). However, in the monocular condition, viewers reported the object as convex (89.1%), moving (89.1%), and solid (98.9%). In addition, participants in the monocular condition reported that subjective surfaces of the object moved with the wire frame (81.5%). When information for the pictorial surfaces is removed, line drawing cues can generate a powerful illusion of 3-D structure and can overcome the effects of motion parallax.

26.513

A computational model on 3D shape recovery

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Last year we presented a model that could recover a 3D shape from a single 2D image by applying simplicity constraints (e.g., symmetry, planarity, maximum compactness, minimum surface). This model was tested on randomly generated polyhedra. The model's performance was very similar to the performance of human subjects. Both, the subjects and the model recover the 3D shape accurately for most shapes and most viewing directions. This model has been elaborated and now it can be applied to real images of real objects. The new model is different from the old one in several ways. First, we apply the least squares method to correct the points on the image in order to reduce the effect of noise. Second, the model applies the maximum compactness and minimum surface area constraints in a different way. Unlike the previous version, the new model computes the convex hull of the recovered 3D shape, and then computes the compactness and surface area of the convex hull. Thirdly, we derived a new likelihood function. The likelihood function is defined as the reciprocal of the rate of change of projected image when a 3D shape is rotated around its center. Finally, we are exploring whether the simplicity constraints (maximal compactness, minimum surface area and maximum planarity) can themselves be represented as a likelihood function, and whether using this combined likelihood will further improve shape recovery. We are now testing the interaction between binocular disparity and a priori constraints in 3D shape perception. The subjects view binocularly or monocularly the stereoscopic images of symmetric polyhedra, with several different slants of the symmetry plane, and with several viewing distances. We expect that binocular disparity and simplicity priors combine non-linearly in producing accurate 3D shape perception.

26.514

Recovering symmetric and asymmetric 3D shapes from a single 2D image

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The percept of the shape of a 3D object produced by a single 2D image is veridical enough to recognize the object from a different viewpoint (i.e. to achieve shape constancy). Recovering and recognizing 3D shapes are very important tasks for the human visual system. Recovering a 3D shape from a single 2D image is formally an ill-posed problem: infinitely many 3D shapes can produce the same 2D image. In order to recover a unique and veridical 3D shapes, a priori constraints about the 3D shape are required. Last year we presented a model for 3D shape recovery using priors that restrict the 3D shapes to be symmetric (Li, Pizlo, & Steinman, 2008) or, at least, approximately symmetric (Sawada & Pizlo, 2008). However, there are 3D asymmetric shapes whose every 2D image is consistent with a symmetric interpretation. Interestingly, the human observer can almost always recognize the 3D shape as asymmetric, even when only a single 2D image is presented. How can the observer reliably discriminate between symmetric and asymmetric 3D shapes, when every 2D image of every shape allows for 3D symmetric interpretation? I will present a new, generalized computational model for recovery of symmetric and asymmetric 3D shapes. The model first recovers symmetric 3D shapes. Next, the model distorts the recovered shape so that it jointly satisfies the following constraints: symmetry of the 3D shape, planarity of faces, minimum surface area, and 3D compactness. Performance of the model was tested with the same 2D images that were used in psychophysical experiments. Performance of the model was as good as that of the subjects.

Acknowledgement: DOE, NSF

URL: http://psyclops.psych.purdue.edu/~tsawada/

26.515

Processing of 3-D Illusions influences Preferences for Symmetry

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Preference for visual symmetry (unity ratio, 1:1) over other proportions is documented using area relationships in divided, two-dimensional black-and-white shapes (Davis & Jahnke, 1991) and, despite the presence of a simultaneous color contrast, in divided two-dimensional colored shapes (Davis, 2007). The present experiments sought to determine visual preferences for an illusion produced by a three-dimensional stimulus. Participants viewed six height-to-width ratios for each of six shapes, varying in dimension (2- or 3-D), illusion and symmetry. Shapes included a nonsymmetrical shape, Necker cube, Necker cube with an alteration, two-dimensional Necker cube, bi-stable diamond illusion, and a cylinder. Experiment 1 utilized a stimulus booklet, where ratios of a shape including unity and the golden section (1:1.618) were presented on each page. The six shapes were represented several times within the booklet. Participants indicated which ratio of a shape they found to be most aesthetically pleasing. Experiment 2 utilized a booklet, consisting of all shapes and ratios used in Experiment 1. A 5-point Likert-type scale assessed aesthetic preference for each shape x ratio stimulus presented singly on a page. Analysis of Experiment1 revealed a preference for the unity ratio for all but one shape (cylinder), even when an illusion was present, $\chi 2\ (25) = 188.116$, $p < .05$. Despite its historical significance, there was no preference for the golden section (1:1.618) in any shape. Results for Experiment 2 were mixed; the unity ratio was preferred in the Necker cube illusion, but not in weaker versions. These results have two implications: processing of illusions may be easier when unity (and, often, symmetry) is present; and, methods used to assess preference differences using more complex three-dimensional shapes are impacted

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diversely by the availability of information to make comparisons. Relative judgment procedures provide more information, including the range of possibilities, than absolute judgment procedures.

Binocular Vision: Depth, Bistability, and Memory

Saturday, May 9, 2:45 – 6:45 pm
Poster Session, Vista Ballroom

26.516

Neural modulations during perceptual bi-stability away from equi-dominance are common to two different ambiguous displays

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Perceptual bi-stability occurs when a stimulus offers two distinct, plausible interpretations. Although recent studies significantly advanced our understanding of the neural basis of bi-stability, it remains unclear whether there is a central mechanism of perceptual decision that weights sensory signals for all types of stimuli, or whether switches originate from competition in stimulus-specific networks. To address this question we employed the observation that the prevalence of each competing interpretation - the fraction of time it is dominant - varies continuously with stimulus parameters. While previous fMRI studies used bi-stable stimuli where the two interpretations were roughly equi-dominant, we studied neural activity for parametric configurations away from, as well as at equi-dominance. We used two different types of ambiguous stimuli with correspondingly different, stimulus-relevant parameters: for plaids (Wallach, 1935), increasing the angel between gratings' motion directions increases the prevalence of the transparent-gratings percept; for the occluded diamond (Lorenceau&Shiffrar, 1992), increasing the contrast of the occluders increases the prevalence of the whole-diamond percept. Three different parametric values were used for each stimulus type, chosen so that one interpretation was dominant 75% of the time (prevalent), 50% (equi-dominant), and 25% (non-prevalent), in separate 5 minute runs. In visual cortex, modulations were tied to percept identity (e.g., more active during 'coherency'), regardless of prevalence (i.e., both when 'coherency' was dominant 75% and when it was dominant 25% of the time). In contrast, more anterior regions showed modulations tied to prevalence, not percept - some more active when the prevalent percept was dominant (STS) while many others showed the opposite modulation pattern (pITS, IPS, PoCS, CS, IPrCS, LS). The prevalence-modulation maps were remarkably similar for the two stimulus types, supporting the hypothesis that, additionally to stimulus-specific modulation in sensory cortices, bi-stable alternations involve higher level, distributed cortical networks that are common to different ambiguous stimuli.

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26.517

Even in continuous displays, multistable perception depends on history

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One of the hallmarks of multistable perception is that durations of successive dominance periods are statistically independent ("sequential independence"). This independence is surprising, because perceptual dominance is susceptible to adaptation and therefore should depend on history, at least to some extent. To investigate this puzzling contradiction we assessed the predictive power of cumulative history for future dominance periods. We found a significant influence of cumulative history on dominance durations, transition times, and transition direction.

Ten subjects viewed three types of multistable displays (binocular rivalry, kinetic-depth effect, and Necker cube) continuously for 300 seconds while reporting their perception (Tdom - mean dominance time). Our measure of cumulative history integrated - with exponential time constant τdecay - over all periods with a clear percept.

For 0.3<τdecay/Tdom<1, we observed a significant correlation between cumulative history and the next dominance time (correlation coefficient 0.2-0.5). This correlation was negative for dominance of the same and positive for dominance of the other percept, consistent with adaptation. When the respective cumulative histories of both percepts were balanced, transition durations and the likelihood of return transitions peaked, revealing the noise driven nature of these perceptual reversals.

In summary, multistable perception depends significantly on history, even for continuous displays. This dependence was hitherto overlooked, as it is evident only with an integral measure of history. The modest degree of this dependence, coupled with extended transitions in the event of balanced histories, underlines the importance of noise as a principal driver of perceptual transitions.

26.518

Effects of inter-ocular contrast difference and decorrelation noise on disparity discrimination

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Thresholds for the discrimination of disparity-defined structure in random-dot stereograms (RDS) are elevated when the images presented to each eye are of different contrasts, or when a proportion of the signal dots in a stimulus are replaced with uncorrelated noise dots. Such threshold elevations reveal limiting factors in the visual system's computation of binocular disparity. In the present study, we examine how these factors of inter-ocular contrast difference and decorrelation noise combine to elevate thresholds in a disparity discrimination task. Observers were presented with a series of RDS containing disparity modulated gratings, oriented at ±20 degrees, and asked to decide whether each grating was clockwise, or counter-clockwise rotated. Grating amplitude was varied to obtain thresholds at which disparity-defined orientation could be reliably discriminated. Thresholds were obtained across a range of grating spatial frequencies, for different inter-ocular contrast differences, and different proportions of decorrelation noise. As expected, discrimination thresholds were elevated by an increase in inter-ocular contrast difference, and by an increase in the proportion of uncorrelated dots present in the stimulus. However, the effect of these factors in combination was not simply additive. Instead, increased decorrelation noise led to proportionally greater threshold elevations when inter-ocular contrast differences were also high. This suggests that inter-ocular contrast differences affect disparity computation in a manner that exacerbates the correspondence noise problem produced by decorrelation. We compare the observed effects of inter-ocular contrast difference and decorrelation to other forms of noise in stereoscopic stimuli.

26.519

Perceptual Memory influences both continuous and intermittent Ambiguous Perception, but in opposite ways

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When observers view an ambiguous stimulus that is continuously presented their percept changes without any change in the stimulus itself. These perceptual alternations appear to occur in a stochastic, i.e. memoryless, manner. However, when short presentations of an ambiguous stimulus are interleaved with blank periods observers tend to see the same percept for many consecutive presentations. This suggests that perceptual memory influences intermittent ambiguous perception but not continuous ambiguous perception. We investigated this apparent inconsistency. We tested whether perceptual memory, built up during intermittent viewing of ambiguous stimuli, influences subsequent continuous viewing of those stimuli. Interestingly, we find that during continuous viewing the durations of the memorized percept are much shorter than the durations of the opposite percept. This reveals a direct link between continuous and inter-

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mittent ambiguous perception: the percept that dominated during intermittent viewing is inhibited during continuous viewing. We conclude that continuous viewing of ambiguous stimuli is not a memory-less process.

URL: http://www.phys.uu.nl/~wwwpm/PercMot/

26.520

Unconscious numerical priming despite interocular suppression

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Whether high-level properties of stimuli rendered invisible by interocular competition can influence perception and behaviour remains controversial. Here, we studied whether suppressed and invisible symbolic and non-symbolic numerical stimuli can elicit priming. First, we established that participants were objectively unable to discriminate numerical prime stimuli when interocular suppression rendered them invisible. Participants then enumerated a visible "target set" of items after being exposed to this suppressed, invisible (non-symbolic or symbolic) "prime set". Both symbolic and non-symbolic unconscious numerical primes induced robust priming effects specific to the target-prime distance. Relative to a no prime condition, primes larger than targets interfered with target enumeration and primes same as or smaller than targets facilitated target enumeration. Taken together, our findings present clear evidence for high level processing of stimuli rendered invisible through interocular suppression.

26.521

Size of vertical disparity pooling and the induced effect

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The fact that vertical disparities can influence perception is demonstrated in the induced effect (Ogle, 1938, Archives of Ophthalmology, 20), in which magnifying one eye's image vertically produces an illusion of slant about a vertical axis. The direction of the slant depends on the "sign" of the vertical magnification, i.e. which eye's image is made larger. Kaneko & Howard (1997, Vision Research, 37, 20) demonstrated that an illusion of a corrugated surface can be produced by alternating the sign of the magnification as a function of horizontal position across the stimulus. They found that illusory corrugations could be detected up to a maximum spatial frequency of 0.04 c/deg, and deduced that vertical disparities are averaged over about 20 deg-wide area. However, their experiments used very large, sparse dot stimuli (dotsize=2 deg), and included only 2 subjects. They also used long presentations (1 sec), in principle allowing subjects to build up a map of vertical disparity across the stimulus in successive saccades. We therefore performed experiments using short presentation times (200 ms), small dots (0.12 deg), and higher dot density, with the sign of vertical magnification alternating as a square-wave across the stimulus. The task was to discriminate the sign of the illusory slant for the central strip of the magnification grating. Despite the considerable experimental differences, our results are compatible with those of Kaneko & Howard, but reveal a wide variability between subjects. The estimated area over which vertical disparities are averaged, ranged over an order of magnitude from 3 deg to 30 deg in diameter, calling into question the conclusion of a uniformly broad spatial limitation for the area over which vertical disparities are pooled.

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26.522

Identifying discontinuities in depth: A role for monocular occlusions

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It is well established that monocular regions arising from occlusion of one object by another contribute to stereoscopic depth perception. However, the exact role of monocular occlusions in 3D scene perception remains unclear. One possibility is that monocular occlusions define object boundaries or discontinuities in depth. This is an attractive possibility, but to date it has not been tested empirically. Here we describe a series of experiments that directly test this hypothesis. Our novel stereoscopic stimulus consists of a foreground rectangular region set against a random-dot background positioned at zero disparity. One side of the foreground region is filled with a random-dot texture shifted towards the observer in apparent depth. The remaining area of the foreground is blank and carries no disparity information. In several experiments, we vary the presence or absence and the width of occluded areas at the border of the central blank area and the background texture. Our data show that the presence of occluded elements on the boundary of the blank area dramatically influences the perceived shape of the foreground region. If there are no occluded elements, the foreground appears to contain a depth step, as the blank area lies at the depth of the zero disparity border. When occluded elements are added, the blank region is seen vividly at the same depth as the texture, so that the foreground is perceived as a single opaque planar surface. We show that the depth perceived via occlusion is not due to the presence of binocular disparity at the boundary, and that it is qualitative, not quantitative in nature. Taken together, our experiments provide strong support for the hypothesis that monocular occlusion zones are important signals for the presence and location of depth discontinuities.

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26.523

Binocular Combination in Amblyopic Vision

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Amblyopia is a consequence of compromised binocular visual experience early in life. Here we investigate suprathreshold binocular combination in the amblyopic visual system, using a sensitive psychophysical paradigm adapted from Ding and Sperling (2006, 2007). On each trial, horizontal sine-wave gratings were presented independently to the two eyes using a mirror stereoscope. The two eyes' sine waves have identical spatial frequency of 0.68 cpd, but differ in contrast and have a 90 deg phase shift. The observer's task is to indicate the apparent location (phase) of the dark trough in the perceived cyclopean sine wave relative to a black horizontal reference line. The phase of the perceived cyclopean sine wave is used to compute the relative contribution of each eye to the cyclopean image. The relative contribution was measured as a function of interocular contrast ratios and base contrasts. Typically, for normal observers, the two eyes contribute equally when the two images have equal contrast. However, for amblyopic observers, we found that, to attain equal contribution, the non-dominant eye (NDE) needs to be presented with a higher contrast image (higher than one would predict from contrast sensitivities of the two eyes). The equal-contribution contrast ratios (NDE/DE, ECC ratios) were dependent on base contrast. At low base contrast, the binocular combination was almost a linear summation and the ECC ratios had lower values (near to 1 for some observers). When the base contrast increased, the binocular summation became more and more nonlinear and the ECC ratios became much larger (above 8) (interocular contrast gain control became more and more effective). The above results could be well predicted by Ding-Sperling gain control model if asymmetric gain control parameters are introduced. Conclusion. Interocular contrast gain control plays an important role in the dominant-eye suppression of the non-dominant eye in amblyopic binocular vision.

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26.524

Oculomotor endurance therapy for convergence insufficiency increases duration of near task performance

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In a majority of patients with convergence insufficiency, the ability to attain appropriate fusion ranges has been successfully restored by vision therapy. Clinically, though, a portion of these patients complain that they still cannot perform near vision tasks for an adequate/acceptable amount of time without suffering eye strain/fatigue.

Standard vision therapy protocols used to treat convergence insufficiency include training tasks that increase extraocular muscle strength and neuromuscular coordination. Interestingly, they do not, however, suggest tasks with the purpose of decreasing the fatigability of the extraocular muscles, and therefore, increasing endurance in these muscles. The purpose of this n-of-1 study was to determine if adding endurance-type training to a standard vision therapy protocol used by a subject with convergence insufficiency could lengthen the time that a near vision task (reading) could be performed before eye strain occurred. The subject of this study had already successfully undergone standard vision therapy for a convergence insufficiency, such that appropriate fusion ranges could be obtained. Unfortunately, the subject could still perform a near vision task (read) for only about 10 minutes before eye strain occurred. In this study, endurance-type training was incorporated into a standard vision therapy protocol by progressively lengthening the amount of time that an appropriate fusion range was held during exercise sessions over twelve weeks. After twelve weeks, the subject could hold an appropriate fusion range in the vision therapy exercises for 35 seconds with no discomfort. Also, the subject could perform a reading task for 60 minutes with no eye strain/fatigue. The results of this study support the idea that endurance-type training could be added to standard vision therapy protocols for patients with convergence insufficiency that, even after gaining the ability to attain appropriate fusion ranges, still cannot perform near visions tasks for an adequate/acceptable amount of time.

26.525

Amodal spatial facilitation resolves local ambiguities of kinetic depth

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On a local scale, visual information is massively ambiguous. Fortunately the brain is well equipped to integrate spatially and temporally separated visual information into a consistent more global conscious percept. Bistable kinetic depth cylinders are ambiguous with respect to their rotation direction causing conscious perception to alternate between possible perceptual interpretation in the absence of any physical changes in the stimulus composition. If two of these cylinders are presented coaxially their rotation directions couple as if the visual system shares spatially separated information in order to minimize the existing visual conflict stemming from the perceptual ambiguities. Here we present a neural network model of kinetic depth that explains this perceptual coupling with lateral facilitative connections between pools of neurons tuned for similar stimulus properties at different spatial locations. Based on the principle of amodal completion we suggest that these lateral connection are predominantly effective in the far field, connecting the 'back' sides of kinetic depth cylinders. A series of experiments further demonstrates that information sharing indeed occurs in the far and not the near depth field. It also makes clear that the spatial facilitation is based on a combination of depth and motion direction information and that the influence of the information sharing decreases as a function of the distance between stimuli. Our findings suggest that perceptual coupling of bistable stimuli reflects a more common mechanism related to occlusion processing. Facilitative connections may exist between similarly tuned far-field neurons, establishing an information sharing mechanism that resolves local ambiguities by relying on more global information.

26.526

Comparison of local and global stereopsis in children with microstrabismus

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Introduction: Convergent strabismus is a common condition in children which has been divided into several categories including microstrabismus. The main features of microstrabismus are small unilateral deviation of the eye (between 0˚ and 5˚), strabismic and/or refractive amblyopia, foveal suppression, and an abnormal retinal correspondence. It is generally accepted that stereopsis is present in patients with microstrabismus, although it is reduced. However, this concept relies primarily on the evaluation of local stereopsis, which contains visible local indices and monocular cues. Global stereopsis lacks monocular cues and is therefore crucial to precisely determine the ability of a patient to perceive depth.

Methods: A sample of 17 children (6 to 14 years of age) with microstrabismus was selected at the Clinique Universitaire de la Vision of University of Montreal. All 17 children were diagnosed with microstrabismus. Their local and global stereoscopic thresholds were obtained using the Randot® test.

Results : Ten children with microstrabismus (10/17, 59%) had local stereopsis of 50 seconds of arc or worst (standard being 20 seconds). A complete lack of stereopsis was observed in 7 (41%) children. Interestingly, none of the children tested was able to perceive global stereopsis with the exception of one child during only one of the follow up visits.

Conclusion: This study shows the relevance of testing both local and global stereopsis to assess the integrity of binocular vision. Many patients with microstrabismus show some degree of depth perception but only when measured with local stereopsis. Normal stereoscopic vision implies also the ability to discriminate random dot stereograms. A measurement of global stereoscopic threshold should therefore be performed with all patients in order to acquire a much more reliable estimate of their level of stereoscopic vision.

26.527

Stereopsis and Aging

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Two experiments investigated aging and stereopsis. The observers' ages ranged from 18 to 83 years. The overall goal was to challenge the older stereoscopic visual system by utilizing high magnitudes of binocular disparity and by making binocular matching more difficult. Experiment 1 evaluated observers' abilities to discriminate ordinal depth differences away from the horopter using standing disparities of 6.5 to 46 minutes arc. Experiment 2 assessed observers' abilities to discriminate stereoscopic shape using line-element stereograms. The direction (crossed vs. uncrossed) and magnitude of the binocular disparity (13.7 & 51.5 min arc) were manipulated. Binocular matching was made more difficult by varying the orientations of corresponding line elements across the two eyes' views. The results of both experiments revealed that older observers' stereoscopic vision is functionally comparable to that of younger observers in many respects. For example, both age groups exhibited a similar ability to discriminate depth and surface shape. The results also showed, however, that age-related differences in stereopsis do exist, and they become most noticeable when the older stereoscopic system is challenged by multiple simultaneous factors.

26.528

A display with multiple focal planes can stimulate continuous variations in accommodation

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Conventional stereoscopic displays have one focal distance, at the plane of the screen. This is problematic because it frequently results in a mismatch between the stimulus to vergence and the stimulus to accommodation, leading to discomfort, fatigue, reduced stereoacuity and distortions in perceived depth. This problem could be eliminated if the stimulus to accommodation also varied continuously with portrayed depth. A proposed method to achieve this is to use multiple image planes to present images at different focal depths. Continuous variations in focal depth are achieved by distributing image intensity across planes - a technique referred to as depth-filtering (Akeley et al., 2004, ACM T Graphic). Here we evaluate this method and show that depth-filtered stimuli do produce a continuous accommodation response between discrete focal planes. We measured accommodation responses to monocularly-viewed, spatially broadband, stimuli at two "real" and five intermediate "simulated" focal distances. The real distances were presented by displaying 100% image intensity at one of two image planes, positioned 2/3 Dioptre apart. Simulated intermediate distances (~0.1D steps) were presented by weighting image intensity across the two planes according to the ratio of the simulated object's dioptric distance from each plane. The accommodative state of the eye was monitored continuously using a Grand-Seiko WV-500 autorefractor. For all of our observers, mean accommodation responses to the depth-filtered stimuli were highly consistent with the simulated focal distance. Furthermore, variability in accommodation responses was equivalent for "simulated" and "real" stimuli. These findings are well predicted by a model of the changes in retinal image contrast that result from changes in accommodative state when viewing depth-filtered stimuli. We conclude that multiple focal plane displays, in conjunction with depth-filtering, can effectively simulate the continuous range of focal distances that occur in the real world, and therefore offer a promising solution for improving stereoscopic displays.

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26.529

Ability to use stereo predicts recruitment of a correlated artificial cue

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In previous cue recruitment experiments, subjects learned to use a novel cue to disambiguate the direction of rotation of a bistable Necker cube (Haijiang et al. 2006, Backus and Haijiang 2007). In these studies, trusted cues (occlusion and retinal disparity) were paired with a new position cue. We asked whether subjects with different levels of stereo acuity- thus presumably with different capacities for using our binocular disparity cue- would learn the new cue equally well. All subjects (n= 42) were tested on four different stereo acuity measures: the TNO test, the Paul Harris Randot test, the TODES test, and an in-house anaglyph display. Subjects also self-reported their ability to see Magic Eye (R) stereograms. During the experiment, subjects indicated which way a wireframe Necker cube was rotating on 400 trials, with alternating training and test (ambiguous) trials. Stereo ability correlated across subjects with proportion of training trials seen as specified by disparity ($r = -0.72$, $p < .001$). Performance on test trials was also well correlated with stereo ability ($r = -0.41$, $p = .01$). Better performance on test trials seems to result from the ability to see more training trials correctly: training trial and test trial performance was highly correlated ($r = 0.59$, $p < .001$). Three subjects were removed from the analysis as outliers. These subjects had poor stereo ability (ave = 550 sec arc), but were able to learn the new correlation as well as those with stereo acuities as low as 30 sec arc. We speculated that these subjects were using the occlusion cue to learn the correlation even in the absence of stereo information. However with a modified version of the first experiment, we found that these subjects were using the disparity information to make their perceptual decisions. For these participants, static stereo ability may not indicate stereo ability when a stimulus is moving.

Attention: Spatial Selection and Modulation

Saturday, May 9, 2:45 – 6:45 pm
Poster Session, Vista Ballroom

26.530

Quantifying Attention: Attention Filtering in Centroid Estimations

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Substantial evidence suggests that observers can accurately estimate the centroid of a spatially extended target. We investigated the top-down attentional control of these mechanisms. Observers estimated (with mouse-clicks) the centroids of briefly flashed, sparse clouds of either 8 or 16 dots of various intensities under three different attentional instructions: give equal weight (i) to just those dots brighter than the background, (ii) to just those dots darker than the background, and (iii) to all dots. Under all conditions participants did well at achieving the required attentional filter. We then required observers to repeat centroid estimations based on the same three attentional instructions, but to weight pertinent dots in proportion to their contrast amplitudes, assigning more weight to dots with extreme contrasts. Results: Observers were able to impose slightly different intensity-selective filters for Proportionally Weighted centroids compared to Equally Weighted ones. In both the Equal Weighting and Proportional Weighting conditions, a decrease in attentional efficiency was observed as target size was increased from 8 to 16 dots. A separate analysis of the centroid computation itself showed high variability across participants in the relative weights attributed to centrally versus peripherally located dots. Some observers down-weighted the peripheral dots relative to more central dots, other did the opposite. Our model-based analysis of centroid judgments yields a quantitative description of the multiple attention filters that subjects use to select certain dot intensities or centroid processing and of the subjects' distance-weighting functions used to compute the centroid.

26.531

Attention to hierarchical level influences attentional selection of spatial scale

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The extent to which spatial frequency (SF) is used to guide attention in hierarchical (Navon) displays is disputed, but ample evidence suggests that global perception may involve low spatial frequency (LSF) processing and that local perception may involve high spatial frequency (HSF) processing (Shulman et al., 1986; Shulman & Wilson, 1987; Robertson, 1996). It is debated whether SF selection is a low-level mechanism associating global and local information with absolute LSF and HSF content, or whether it is a higher level mechanism involving a selective process that defines the SF range in which global and local can then be relatively defined. We provided evidence supporting the latter claim in an earlier study (Flevaris et al., 2008) where we demonstrated that selection of LSFs or HSFs in a compound grating was influenced by the hierarchical level (global or local) attended. In the present study we extended our previous findings by demonstrating that attention to hierarchical level influenced SF selectivity despite a change in retinal location of the hierarchical stimuli and the grating stimulus. Participants viewed pairs of peripheral Navon displays and were asked to make same/different judgments on the global or local levels in separate blocks. Following the hierarchical displays, a single compound SF grating appeared at fixation and participants made orientation judgments about either the "thick lines" (LSFs) or the "thin lines" (HSFs). Importantly, the same compound SF gratings were presented in each block and what differed across blocks was the particular SF that was task relevant. Despite the change in task and retinal location between the Navon displays and the SF gratings, participants were faster at selecting lower than higher SFs following attention to the global level of the Navon displays, and they were faster at selecting higher than lower SFs following attention to the local level.

26.532

Attentional Color Hierarchy for Pursuit Target Selection

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We performed 2 experiments to investigate the effect of color on object selection. In Experiment 1, subjects fixated on a central dot and an aperture with a single surface of colored dots, either red, green, blue or yellow, moving left or right at a constant speed of 6.0 deg/sec 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. Saccading to the surface resulted in an automatic pursuit of that surface. Experiment 1 showed that color modulates motion processing as measured in smooth pursuit velocity for single surfaces.

Next, we investigated whether this color modulation was equivalent to a modulation of salience, by seeing whether target selection would be biased towards the color that produced a higher pursuit speed over a color that produced less pursuit speed. In Experiment 2, a second surface was placed in the aperture, moving at the same speed in the opposite direction and differing in color, and pursuit was again measured. If task-irrelevant color has no effect on salience and target selection, then pursuit would not be biased towards either surface of equal speed and contrast. In contrast, we found evidence of a selection hierarchy determining which surface was pursued: red > green > yellow > blue. Furthermore, the strength of selection (pursuit speed) was strongly correlated with the distance in color space between the two colors. These results suggest a bottom-up attentional hierarchy based on color processing, similar to the bottom-up salience effects of contrast. This attentional color hierarchy intrinsically modulated other features of the object; more specifically the motion processing that drives smooth pursuit. Thus, color and motion are likely bound at or below the level of areas MT and MST, and color modulates bottom-up salience.

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26.533

Central fixation task activates ventral LOC and dorsal hMT in human visual cortex

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Engaging attention at fixation with a task is widely used in brain imaging (fMRI) to control for the powerful effects of spatial attention . While the difficulty of a fixation task can modulate the processing of peripheral stimuli (Lavie, 1995;Rees, et al.,1997), little is known about cortical responses caused by attentive fixation tasks. We found that presenting a simple letter counting task at fixation strongly activated ventral and dorsal mid-level cortical areas , including spatial locations assigned to the periphery with retinotopic mapping.

Our intention was to control spatial attention with a baseline fixation task, while measuring responses to moving stimuli in the periphery. While peripheral stimuli were presented (16s ON-16s OFF), subjects counted the occurrence of a target (upright 'T's, 0.8 deg in size) amongst non-targets (inverted 'T's), and reported by button press whether target count was 'odd' or 'even'. Surprisingly, the presentation of moving stimuli in the periphery generated only weak BOLD responses. To test whether the fixation task may have caused this, we contrasted the attentive fixation task with passive fixation of a small dot in the centre of a blank screen. As expected, we found foveal activation in early visual areas. However, we also found extra-foveal responses in ventral lateral occipital area (LOC) and dorsal area hMT/V5. This pattern was consistent across subjects, and significantly correlated to the task period as identified by both modelled (GLM) and model-free (MELODIC) analysis.

These results lend support to a role for ventral area LOC in shape perception, (Kourtzi, et al.,2001) and hMT/V5 in letter reading (Demb et al.,1997). We conclude that the choice to employ an active fixation task that locks attention on certain visual features may have important consequences. Among these are the induction of a trade-off in cortical activity between regions-of-interest that serve central and peripheral vision.

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26.534

Diluting the burden of load: Perceptual load effects are simply dilution effects

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The substantial distractor interference obtained for small displays when the target appears alone is eliminated in large displays when the target is embedded among neutral letters. This finding has been interpreted as reflecting low load and high load target processing respectively, thereby supporting the theory of perceptual load. However, a possible alternative interpretation of this effect is that the distractor is similarly processed in small displays and large displays, yet its interference in the latter is diluted by the presence of the neutral letters. We separated the possible effects of load and dilution by adding high dilution displays. These displays contained as many letters as the high load displays, but their neutral letters were clearly distinguished from the target, thereby allowing for a low load processing mode. In five different experiments distractor interference completely disappeared for the high dilution displays. Thus, the different results for small and large displays reported in the literature are due to dilution, not perceptual load. Furthermore, when dilution is properly controlled for, there is no indication that distractors produce greater interference under low load than under high load conditions. Instead, there is a tendency for a reversed load effect, namely, greater distractor interference under high load than under low load conditions.

26.535

Exploring the causes of object effects on location-based inhibition of return when using spatial frequency specific cues and targets

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Purpose: By manipulating lower-level sensory (e.g., spatial frequency (SF), abrupt vs. ramped onsets) and higher-level perceptual (e.g., presence or absence of 3-D objects) stimulus variables we have previously found greater location-based IOR under P/ventral biased conditions and less IOR under M/dorsal biased conditions (Guenther & Brown, VSS 2007; 2008). The presence/perception of 3-D objects increased IOR overall and interacted with stimulus SF influencing IOR in the Guenther & Brown (2007) study. The present experiments were designed to test two alternative explanations for these object effects. First, the object effects were due to the increased high SF content associated with the objects edges/contours. Second, the object effects were due to the SF targets appearing as texture on the front surface of the objects. Method: Experiment 1 tested the first alternative account using blurry objects (i.e., with their high spatial frequency components removed but retaining their appearance as objects). Experiment 2 tested the second alternative account by presenting the 3-D objects displaced from the locations of the cues and targets. Cues and targets were Gabor patches presented in the upper/lower visual fields, in blurry 3-D objects (Exp. 1) or next to 3-D objects (Exp 2), using cue-to-target timing known to produce location-based IOR. Simple RT to target onset was measured. Different SF pairings were tested (1+12cpd; 1+4cpd; 4+12cpd). Results: Location-based IOR was influenced by target SF in both experiments replicating Guenther & Brown (2007). Conclusions: The object effects observed previously can be attributed to the increased P/ventral activity associated with the presence and perception of the 3-D objects and not due to low-level sensory influences due to their edges or the perception of the targets as texture on their front surface.

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Attentional Filtering Modulates the Induced Roelofs Effect, but Shifts of Attention Do Not Cause It

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When a visible frame is offset left or right from an observer's objective midline, the subjective midline is pulled toward the frame's center. Targets presented within this frame are then misperceived as being shifted in the opposite direction – an illusion known as the induced Roelofs effect (Bridgeman et al. 1997; Dassonville & Bala 2004). However, a large frame is not necessary to generate the effect – even a small peripheral square is sufficient, raising the possibility that the effect is driven by a shift of attention toward the center of the frame. As a first test of this hypothesis, we set out to determine whether the illusion would be affected by a manipulation known to affect attention; namely, the color-contingency effect. In Experiment 1, a target (defined by its color) was presented with 3 variously-colored distractors, along with a Roelofs-inducing frame that was either the same color as the target, or a distractor color. We found that the attentional filtering that was required to isolate the target from the distractors also modulated the magnitude of the Roelofs effect, with a larger effect when the frame and target were the same color. To more directly assess the relationship between shifts of attention and distortions of the apparent midline, Experiment 2 adopted a dual-task design that first drew the participant's attention to the left or right, then presented a near-midline target whose location was to be reported. If shifts of attention cause the midline distortion associated with the Roelofs effect, the participant's perception of target location should vary as a function of the location of the earlier attentional cue. Results indicate that this was not the case, suggesting that while attention can modulate the magnitude of the Roelofs effect, the effect is not directly caused by shifts of attention.

26.537

Spatial Attention in Conscious and Nonconscious Visual Processing

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We used a modification of Eriksen and Eriksen's (1974) flanker interference task, to assess the effects of spatial attention on choice reaction time (RT) to one of two probe stimuli that followed two flanking stimuli by 53 ms. Separate response keys were assigned to each probe. The probes and flankers consisted of outlined squares or diamonds. In the response-compatible condition, flankers' shapes were identical to that of the probe; in the response-icompatible condition, they were different from that of the probe. In Experiment 1 we established, as expected, that RTs are higher in the response-incompatible than in the response-compatible case. In Experiment 2 revealed two additional findings. 1) The differences between probe RTs when preceded by response-incompatible and response-compatible flankers decreased as the center-to-center spatial separation between the probe and flankers increased from 2o to 12o, indicating, in line with Erisksen and Eriksen's (1974) findings, that the effect is limited by the spread of spatial attention. 2) This trend occurred even when the flankers were rendered invisible by a metacontrast mask, indicating that spatial attention effects are expressed at the nonconscious level of flanker processing.

Eriksen, B.A., & Eriksen, C.W. (1974). Effects of noise letters on the identification of a target letter in a nonsearch task. Perception & Psychophysics, 16, 143-149.

26.538

Attention to the location of an invisible face can induce adaptation

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Moradi et al. (2005) showed that the face adaptation did not occur when the adaptor was invisible. However, Bahrami et al. (2008) found that spatial attention to the location of invisible adaptor could increase the amount of orientation adaptation. In this study, we investigated whether spatial attention could boost even the amount of adaptation from invisible face. We used the same method as in Moradi et al. (2005) except using a different suppressor. The stimuli were morphed faces in which certain percentage of a female face was intermixed with certain percentage of a male face. Participants' task was to judge whether these morphed faces looked like a female or a male against 5 different levels of femaleness. We first measured PSE of male/female discrimination before adaptation. We then had participants adapt to the female faces. 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 (suppressors) presented in a dominant eye and participants had to report their percept during adaptation. To modulate attention during adaptation, participants performed the contrast-decrement detection task on the attended suppressor. Contrast decrements were independently occurred in each visual field regardless of participants' locus of attention. For the unattended faces, we found that the PSE before adaptation did not differ from that after adaptation in the invisible condition, whereas the PSE after adaptation shifted towards more femaleness in the partially visible condition, replicating Moradi et al. (2005)'s findings. For the attended faces, however, the PSE after adaptation significantly shifted towards more femaleness even in the invisible condition. These results suggest that attention can modulate the effect of face adaptation even when the adaptor is invisible.

References: Bahrami, B., Carmel, D., Walsh, V., Rees, G., & Lavie, N. (2008). Spatial attention can modulate unconscious orientation processing. Perception, 37, 1520-1528. Moradi, F., Koch, C., & Shimojo, S. (2005). Face Adaptation Depends on Seeing the Face. Neuron, 45, 169-175.

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26.539

Beware the Watcher: The effects of direct gaze on attention to human faces

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Viewers tend to pay attention to faces more than to other objects in some circumstances. But what characteristics affect this preferential treatment? While eye contact is established as an important factor in social interactions, little research has examined its effect on attention capture. In the present study, we compared performance for pictures of faces that looked directly at the camera and therefore at the participant (direct gaze), faces that looked down (averted gaze), and household objects. Viewers were asked to fixate a central image, which depicted either a "direct-gaze" face, an "averted-gaze" face, or an object. Then two pictures appeared, one to the right the other to the left. All possible combinations of the three types of stimuli where used. On 2/3 of the trials one of these pictures had an asterisk on it. Viewers needed to report the location of the asterisk, if present, as quickly as possible. The results showed significant faster reaction times when the target asterisk appeared on a "direct gaze" face compared to an "averted gaze" one. A preferential treatment of faces in general was also observed; viewers responded faster when the asterisk appeared on a face compared to on an object. There was no overall effect of the fixation image, indicating no special difficulty in disengaging attention from a direct-gaze face. It appears that when exploring our environment we will attend a "watcher" faster than other stimuli, but we can easily ignore a "watcher" when we need to.

Visual Search: Attentional Mechanisms

Saturday, May 9, 2:45 – 6:45 pm
Poster Session, Vista Ballroom

26.540

The effect of context on rapid animal detection

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Human observers are capable of detecting animals within novel natural scenes with remarkable speed and accuracy. Recent studies found human response times to be as fast as 120ms in a dual-presentation (2-AFC) setup (Kirchner, Thorpe 2006). In most previous experiments, pairs of randomly chosen images were presented, frequently from very different contexts (e.g. a zebra in Africa vs. the New York Skyline). Here, we tested the effect of context on performance by using a new, contiguous-context image set.

Individual images contained a single animal surrounded by a large, animal-free image area. The image could be positioned and cropped in such a manner that the animal could occur in one of eight evenly spaced positions on an imaginary circle (radius 10 deg visual angle). In the first (8-way) experiment, all eight positions were used, whereas in the second (2-way) and third (2-afc) experiment the animals were only presented on the two positions to the left and right of the screen center. In the third experiment, additional rectangular frames were used to mimick the conditions of earlier studies.

Absolute hit ratios were on average slightly lower on the 8-way than in both other conditions (8-way:81%, 2-way:88%, 2-afc:87%), yet the range-normalized results show a slight advantage in performance for the 8-way condition (8-way:78%, 2-way:75%, 2-afc:73%). Average latencies on successful trials were similar in all three conditions (8-way:207ms, 2-way:198ms, 2-afc:203ms), indicating that the number of possible animal locations within the display does not affect decision latency.

These results illustrate that animal detection is fast and efficient even when the animals are embedded in their natural backgrounds and could occur in arbitrary locations in an image.

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26.541

Non-retinotopic visual search

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At the heart of feature integration theory there is a master map that operates on the various features maps. Explicitly or implicitly, it is assumed that these feature maps are organized retinotopically. If in conjunction search, for example, a horizontal green line must be found, the master map would look at the retinotopic position (x,y) in both the colour and the orientation maps to determine whether there is a "green" and a "horizontal" entry, respectively. Here, using a Ternus-Pikler display, we provide evidence that the master map operates on non retinotopic feature maps. We presented a typical Ternus-Pikler display where three squares appeared to move back and forth (group motion). Each square contained a different conjunction search display. The task of the observers was to search for a green horizontal line in the central square only. Retinotopically organized feature maps predict poor search performance because the central display changed position from frame to frame. In contrast to this expectation, we found a remarkably strong performance. Perceptually, only one central square with one search display was perceived for which search is easy. This indicates that efficient search results from the ability to integrate non-retinotopically across the two positions of the central square.

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26.542

Amodal completion does not require attention

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When one object occludes another, occluded objects appear to continue invisibly behind the occluder. Does this "amodal completion" require attention? Hulleman (VSS07) showed that efficient search for vertical bars among horizontal bars was disrupted by occluding diagonal bars. This suggests that the amodal completion that created oriented occluded items did not occur prior to search. However, Hulleman's oriented occluders might have disrupted orientation search. Here, four experiments manipulated orientation information in the occluder. Participants searched for a vertical bar among horizontal bars or vice versa. Bars were either unoccluded, occluded or "gapped" (i.e., occluded by an object of the same color as the background). In all experiments, search for unoccluded objects was efficient (0 – 2 ms/item), while search for gapped objects was inefficient (12 – 49 ms/item; except for one condition). In the first two experiments occluders were 45° tilted bars as in Hulleman's experiment. In Experiment 1, each bar had its own occluder, whereas in Experiment 2 the occluder covered three bars at once. Both experiments replicated Hulleman's finding that search for occluded bars was inefficient (> 19 ms/item). In Experiment 3 we used an unoriented square occluder. Here we found efficient search for occluded bars (0 – 3 ms/item). However, this may have been due either to the oriented convex hull of each item or to simple connectedness, rather than amodal completion. Experiment 4 controlled for this by adding a condition where the "gapped" objects were connected and had the same convex hull as the occluded object. Search for occluded objects was again efficient (1 ms/item), but search for the connected control objects was not (29 ms/item). These experiments suggest that the orientation signals created by amodal completion are weak, easily masked by orientation noise in the display. However, amodal completion appears to be a preattentive process.

26.543

Order effects determine whether irrelevant stimuli are scrutinized in preview and conjunction search

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Visual search is facilitated when half of the distractors are previewed before presentation of the full search display. Watson & Humphreys (2005) investigated whether the onset of irrelevant stimuli would disrupt this preview benefit. They found that presenting irrelevant dots between the preview and final displays affected the preview benefit only when the dots shared the same color with the new items. They proposed that this result reflected an anticipatory feature-based set for new stimuli such that stimuli matching this set would be attended. Our study investigated whether attention to irrelevant stimuli that match your attentional set for color is automatic. We found that the answer to this question strongly depended on the order in which participants experience the different search conditions in the experiment. When participants first complete a block of preview trials with irrelevant dots that never match the target color, they learn to ignore these dots and continue to do so throughout the experiment, irrespective of search condition (preview or conjunction search). However, when participants first experience a block of preview trials with irrelevant dots that always match the target color, they learn to attend to these dots and appear to inspect them even in later conjunction search blocks in the experiment. We replicated this result in two experiments. Further, in a third experiment, we found that participants learn to ignore irrelevant dots when the dots color is

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totally uncorrelated with the color of the target. Congruent with the results of Leber & Egeth (2006), these results suggest that early experience with a set of stimuli determines the attentional fate of these stimuli.

26.544

Expected value of stimuli enhances visual search but does not affect rapid resumption

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Rapid resumption refers to unusually fast visual search that occurs when a search display has been pre-exposed. To measure this, observers are presented with repeated search displays, each 100 ms ("look" episode) that are interrupted by blank displays, each 900 ms ("blank" episode). Look and blank displays are presented successively until the observer responds. Search times of less than 400 ms (rapid resumption) occur with some frequency following the second or subsequent looks but never after the first look. This ability to rapidly resume a search may reflect use of a perceptual prediction mechanism. Here, we asked observers' perceptual predictions would be enhanced if targets had been previously associated with rewards or losses. Previous research has shown that learned reward and loss value of stimuli can yield a selection advantage even in tasks where these contingencies are contextually absent. To test this, we combined an instrumental learning task with an interrupted visual search task. In Phase I, participants learned to associate faces with gain, loss, and no outcome. In phase II, learned faces were presented as targets in multi-item arrays. During the task, all stimuli had equal task relevance but differed in their expected value. In the search task, participants searched for a face defined by gender and reported whether a line of dots (present on each face) was on the left or right. The results indicate that compared to search for familiar targets with no expected value, search for targets previously associated with rewards or losses was faster. However, the benefits of expected value did not affect the frequency of rapid resumption responses. This dissociation suggests that value codes for stimuli do not affect the mechanisms underlying rapid resumption.

Acknowledgement: ESRC support for J. Gomez-Cuerva

26.545

Cortical What and Where Streams Interact to Regulate Contextual Cueing during Visual Search

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How do humans use predictive contextual information to facilitate visual search? A neural model explains challenging psychophysical data on positive vs. negative, spatial vs. object, and local vs. global cueing effects during visual search. The model also clarifies data from neuroanatomy, neurophysiology, and neuroimaging concerning the role of subregions in prefrontal cortex, medial temporal lobe, and visual cortices during visual search. In particular, model cells in dorsolateral prefrontal cortex prime possible target locations in posterior parietal cortex based on bottom-up activation of a representation of scene gist in parahippocampal cortex. Model ventral prefrontal cortex cells prime possible target identities on inferior temporal cortex based on the history of viewed objects represented in perirhinal cortex. Through simulations, the proposed model illustrates the dynamic processes of evidence accumulation in visual search, which incrementally integrates available spatial and object constraints to limit the search space, and offers new insights on the complex interplay among What and Where cortical areas orchestrating scene perception and scene memory.

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26.546

Visual marking survives graphical change without semantic change

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In an inefficient visual search task, when some distractors (old items) temporally precede some others (new items), the old items are excluded from the search, a phenomenon termed visual marking. Past studies have shown that this effect is unaffected by luminance change of old items but is eliminated by their shape change, suggesting that the shape identity has to be maintained for successful visual marking. It was unclear either the chance in meaning or shape was critical, because the shape changes accompanied meaning changes in the previous studies. The present study examined whether the consistency in the semantic or only graphical identity of old items was critical for visual marking. Under the meaning-change condition, on every trial each of the old items (pictures of butterflies) was replaced with a Japanese Kanji character representing "cow", creating both semantic and graphical changes. Upon these changes, new items (Kanji characters representing "dog") appeared at blank locations. Under the meaning-change condition, the old items (pictures of cows) turned into Kanji characters of "cow", creating graphical changes. Participants searched for a tilted character of "dog". The results indicated that the search under the meaning-unchanged condition was more efficient than that under the control condition in which all items appeared simultaneously. Under the meaning-change condition, however, the search efficiency did not improve relative to the control condition. These results indicated that visual marking survived the graphical change of old items as long as their meaning was maintained. A follow-up experiment replicated the preserved visual marking over graphical change and excluded an alternative that the results of the main experiment were due to an artifact of used pictures. These results suggested that consistent semantic identity during the preview period is sufficient to reveal visual marking even when graphical identity discontinued.

26.547

Learning in an attentionally-demanding triple-conjunction task

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Several studies have shown improvement in perceptual discrimination over the course of training sessions with spatial or feature range specificity. This type of specific learning does not address the question of whether and how general visual task expertise can be gained. We designed a conjunction search task in which a different target was previewed on each trial and was then randomly positioned in a search array, thus eliminating both feature and spatial specificity of learning. 5 subjects performed 10 sessions of 100 trials each over the course of 10 days. In each trial subjects had to find a color gabor patch target uniquely identified by its hue, orientation and spatial frequency among an array of 32 patches.

All subjects showed marked improvement over the course of training. A highly significant ($p < 0.005$) change in performance was observed from session 1 (44% correct) to session 5 (73% correct), beyond which performance plateaued. In order to isolate changes in visual behavior resulting from learning we construct feature similarity maps that define the similarity between items in a search array and a target, in individual feature dimensions. High values in the similarity maps indicate large differences between the target and an item, and vice-versa. We find small but negative correlations between saccade endpoint distributions (SED) and feature similarity maps, indicating that subjects were preferentially looking at distractor items more similar to the target. Moreover, the negative correlations grow stronger over the course of the sessions, for the hue and frequency features but not for orientation. We then correlate SED with linear combinations of

individual feature maps as well as a map derived from a simple minimum distance rule. The results indicate that subjects had an increased tendency to look toward items similar to the target in the hue and frequency dimensions.

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26.548

A calm eye is associated with the passive advantage in visual search

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Visual search can be more efficient when one views a display passively, allowing the target to pop into view, than when one actively directs attention around a display in a deliberate effort to locate a target (Smilek et al., 2006). However, little is known about why these different cognitive strategies lead to differences in performance. One possibility is that patterns of eye movements also differ with strategy, such that eye movements associated with the passive strategy allow search items to be registered in a more efficient way. Alternatively, the advantage of a passive strategy may accrue from processes that occur only after the search items have been registered, in which case one would not expect any differences in eye movements between the two strategies. In the experiments reported here, we monitored participants' gaze while they performed visual search tasks of varying difficulty after having been instructed to use either an active or a passive strategy. The passive strategy led to greater search efficiency (speed and accuracy) at all difficulty levels, which suggests that cognitive strategy may have even more influence on search performance than previously observed (Smilek et al., 2006). Furthermore, eye movement data showed that this passive advantage is correlated with fewer saccades per second and longer fixation durations. More detailed analyses examined differences in fixation location in the two conditions, and individual differences in eye movements independent of strategy. These findings are consistent with the hypothesis that the passive advantage in visual search is associated with a calmer eye.

26.549

The prevlanece effect is imbalanced: it is stronger for high target presentation rates, than for low

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Low frequency of target appearance in visual search increases the chance that an observer will respond 'absent', resulting in an increase in correct rejection rates, but also a decrease in hit rates (the 'prevalence effect'). Additionally, searching for more than one target at a time reduces the chance that a target will be detected (the 'dual-target cost'). Both the prevalence effect (Wolfe et al., 2007) and the dual-target cost (Menneer et al., 2007) have recently been cited as a cause for concern for those working in airport X-ray screening, where screeners search for multiple threat items that appear infrequently. Here, we present two experiments in which target prevalence was varied across a full range of presentation rates (across two experiments, prevalence levels of 2%, 20%, 24%, 50%, 76%, 80% and 98% were examined), finding that, although the dual-target cost did not interact with the prevalence effect, there was a surprising imbalance between the low and high prevalence conditions. In very high prevalence conditions (80%, 98% prevalence), participants were exceedingly biased towards responding 'present'. Although the opposite effect was observed in the very low prevalence conditions (2%, 20%), with a bias towards responding 'absent', the effect was considerably weaker. Thus, there appears to be some intrinsic imbalance in the manner in which 'present' and 'absent' responses are made as prevalence varies.

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26.550

Conjunction search following progressive feature disclosure

Elizabeth Olds[1] (eolds@wlu.ca), Timothy Graham[1], Jeffery Jones[1], Wafa Saoud[1]; [1]Department of Psychology and Centre for Cognitive Neuroscience, Wilfrid Laurier University

When a colour/orientation conjunction search display is immediately preceded by a display that shows the colour of each upcoming search item (in the location where each search item will appear), search is faster after this colour-preview than after an orientation-preview (Olds & Fockler, 2004). One explanation for this feature asymmetry is that colour has priority access to attentional selection relative to features such as orientation and size. In support of this hypothesis, we show that this asymmetry persists even after colour and orientation feature search performance is equated.

However, in further experiments we show that the explanation is not so simple: for colour/size conjunction search, colour-previews were less helpful than size-previews (even though colour-feature search was easier than size-feature search). Finally, for size/orientation conjunction search, orientation-previews produced much slower search than size-previews (even though orientation-feature search was easier than size-feature search).

We conclude: (1) The ease of feature search does not predict the amount of facilitation (or disruption) by the feature-preview. (2) Overall, size-previews produced the fastest RTs relative to no-preview baseline (for both colour-size and size-orientation conjunctions), followed by colour-previews (for colour-orientation conjunction but not for colour-size conjunction); orientation-previews often produced slower-than-baseline RTs.

While each feature-preview may potentially facilitate search, the transition from feature-preview display to search display may also disrupt search processes, because of luminance and/or colour changes. An explanation of this set of results must focus on both facilitation and disruption: neither suffices alone, since conjunction search performance after feature-preview can be significantly better or significantly worse than baseline.

REFERENCES: Olds, E. S. & Fockler, K. A. (2004). Perception, 33, 195-216.

Acknowledgement: NSERC

Sunday Sessions

Perception and Action: Decision and Action

Sunday, May 10, 8:30 – 10:00 am
Talk Session, Royal Palm Ballroom 1-3
Moderator: John Wann

31.11, *8:30 am*

Awareness and decision in monkey with blindsight

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Macaque monkeys with a unilateral lesion in V1 have been used as an animal model of blindsight. Here we sought for the neural mechanisms responsible for their visual awareness and residual vision. 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, in addition to the above condition, the monkeys have to maintain fixation when the saccadic target is absent, requires detection of the target. The d' for the FC task was significantly higher than that for the YN task, consistent with the studies of human blindsight patients. Next, we recorded neural activities from the superior colliculus (SC) of the monkeys performing the FC and YN tasks. We found that the transient response of the ipsilateral SC to the visual target was larger in the hit trials than the miss trials in the YN task. Such modulation was not found in the normal, contralateral SC. This suggests that the activity in SC comprises a part of neural correlates of reduced visual awareness specific to blindsight. Finally, we examined decision process of these monkeys using the FC task. We modeled the distribution of saccadic reaction times by a modified diffusion model and obtained evidence that the decision threshold in the affected hemifield was lower than that in the normal hemifield (Yoshida et al. 2008). These results suggest that the geniculostriate pathway is crucial for decision processes. We propose that these results reflect deficits in deliberate control of visual-oculomotor processing after V1 lesions, which may parallel loss of visual awareness in human blindsight patients.

31.12, *8:45 am*

Decisions on "when" and "what" are biased by different temporal spans of past incidences

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It has been proposed that decision making consists of two stages, integrating sensory evidence and choosing the alternative that is best supported by the evidence. The choice is thought to be made based not only on sensory evidence but also on statistical knowledge about past incidences (Gold and Shadlen, 2007). Here we show that decision regarding when an item is detected and decision regarding what item is identified are biased by different accumulation time spans of past incidences. Two experiments were conducted in which different groups of 5 subjects were asked to perform a "when" task and a "what" task, respectively. In the "when" task, subjects were asked to report in which one of two alternative events a stimulus with an orientation structure was presented. In the "what" task, subjects were asked to report which one of two alternative orientations was presented. The spatial and temporal configuration of the visual presentations in the experiments was identical. However, the task instructions differed. The incidence probability for each alternative was manipulated to examine how the observers' choice is influenced by the probability change. While observers' choices were biased toward the alternative with higher past incidence probability in both tasks, the time span of past incidences biasing a present choice is significantly narrower for the "when" than the "what" task. These differential results suggest that while a decision regarding when an event happens is partially determined by immediate past events, a decision regarding what feature is presented is determined by a longer accumulation of past experiences.

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31.13, *9:00 am*

Structure Learning in sequential decision making

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Human behavior in binary choice tasks can strongly deviate from normative predictions, even in simple repeated tasks with independent trials. Rather than reflecting decision-making errors (as most previous accounts have assumed), we propose that people try to learn causal models of both environment and task that explain how the outcome statistics are generated, or in other words, to reduce unexplained variability in outcome. We show that optimal decision making models that try to learn the structure of the environment show the same kinds of suboptimality. In particular, models that try to learn environmental dynamics (non-stationarity) and reward outcome generation capture many aspects of choice behavior deemed suboptimal, like limited memory, probability matching, and under and over-exploration. We show how probabilistic coupling between rewarding options can be learned, and how models that learn better capture human behavior in choice tasks. We also show how models that learn dynamics can benefit from making strong prior assumptions about the stochasticity of the environment.

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31.14, *9:15 am*

Optic Flow and Steering: Beyond MT+

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Field, Wilkie & Wann (2007) identified an area bordering, but distinct from the Parietal Eye-Fields (PEF) that was responsive to future path information during forward locomotion. We tested the function of this area using stimuli related to Land & Horwood (1995). Participants travelled on a sinusoidal trajectory at 8m/s across a textured ground plane, either forwards or backwards. In some conditions a distal roadway was presented 12m ahead, that indicated their direction of travel in 1.5s time, but not their current direction of travel. The task was to move a joystick to match their instantaneous direction of travel using the flow field information (passive_steering). The joystick motion was open-loop and did not change their actual direction of travel. We localized MT, MST and PEF in each participant and recorded eye-movements for each condition. Forwards and backwards locomotion produced equivalent activation MT+ (both with and without road). When travelling forwards or backwards without a road, there was lag of up to 1.16s in passive_steering but this lag was reduced to 0.5s when the road was present for forward motion, but not for backwards motion. This supports the idea that p' were able to buffer the information from a distant section of the road and use that in their steering response some 1.5s later. Forward road produced focal activation in the superior parietal lobule (SPL) equivalent to our previous findings. There were no systematic

differences in eye-movements that would explain the differential activations. Visual area MT+ is differentially responsive to flow patterns (Morrone et al, 2000) , the homologue of VIP is responsive to global egomotion signals (Wall & Smith, 2008), but this egocentric heading information only becomes useful when it is related to external goals for locomotor steering and focal areas of SPL appear to be processing those components.

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URL: http://www.rdg.ac.uk/ARL

31.15, *9:30 am*

Exposure to displaced optic flow results in adaptation of visual straight ahead

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When an error is introduced into the mapping between visual direction and the movement of the feet, an observer will initially take a curved path when walking to a stationary visual target. After a period of walking, remapping, or adaptation, will occur resulting in a straighter walking trajectory. Held and Freedman (1963) were the first to report remapping and hypothesised that the discrepancy between the anticipated and actual patterns of optic flow that result from self-movement is used to drive an adaptation in perceived direction. Recently, Bruggerman, Zosh and Warren (2007) concluded that their data provided evidence against the suggestion that optic flow is involved in the recalibration of perceived visual direction, instead suggesting that flow is involved in the regulation of visuo-motor mappings. Here we revisit the issue. We introduce an error by standard means with prisms, and manipulate the availability of optic flow. We measure perceived visual straight-ahead and proprioceptive straight-ahead before and after a short period of walking. In a repeated measures design, optic flow was (i) continuously available during normal walking; (ii) intermittently available in a "stop & go" stepping condition, and (iii) removed in a condition in which observers have vision only during the stationary part of each step. The sum of visual and proprioceptive shift was approximately equal in each condition (over 50% of the induced error). However, proprioceptive and visual components varied. The ratios were approximately 85:15 (visual/proprioceptive shift), 45:55 and 30:70 for the continuous, intermittent and no flow conditions respectively. This pattern of data contrasts with the conclusion of Bruggeman et al. We find that the shift in perceived visual direction increases as the exposure to optic flow (broadly defined as change in the structure in the retinal array) increases. This raises questions about what factors influence the locus of adaptation.

31.16, *9:45 am*

Stepping in the Right Direction: Control and Adaptation of Walking from Optic Flow

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Previous research indicates that optic flow is used to adapt the direction of walking, when the heading specified by flow is displaced from the locomotor axis specified by proprioception (Bruggeman, Zosh, & Warren, Current Biology, 2007). This adaptation does not affect the perceived straight ahead (no transfer to throwing or kicking—Bruggeman & Warren, VSS 2008), but it might recalibrate the direction of thrust. Here we investigate the degree of adaptation as the displacement of optic flow is progressively increased up to 22.5°.

Participants repeatedly walked to a target in a richly textured virtual environment while wearing a head-mounted display (63° H x 53° V), and head position was recorded with a sonic/inertial tracker (70 ms latency). The heading direction specified by optic flow was displaced to the right of the actual walking direction by 2.5° at the beginning of the experiment, and increased by 2.5° every ten trials to a maximum of 22.5° at the end of the experiment. Every tenth trial was a "catch trial" with a normal alignment (0° displacement), to measure the negative aftereffect of adaptation. If there is a limit to the recalibration of thrust direction (e.g. due to biomechanical constraints), adaptation and its aftereffect should saturate at some point; otherwise, they may increase monotonically.

Surprisingly, both the degree of adaptation and the negative aftereffect increased linearly with the flow displacement at a ratio of 1:2. In addition, detailed analysis of on-line steering showed a consistent pattern of adjustment based on optic flow across adaptation trials. These findings imply that optic flow adapts the walking direction by about 50% of the displacement, while the remaining discrepancy is reduced via on-line steering control. Thus, the visual control of steering from optic flow cannot be explained by adaptation.

Acknowledgement: NIH EY10923 & Center for Vision Research, Brain Science Program at Brown University

URL: hugobruggeman.com

Attention: Divided

Sunday, May 10, 8:30 – 10:00 am
Talk Session, Royal Palm Ballroom 4-5
Moderator: David Carmel

31.21, *8:30 am*

Afterimage duration and its modulation by attention and consciousness

Jeroen J.A. van Boxtel[1] (j.j.a.vanboxtel@gmail.com), Christof Koch[1]; [1]Division of Biology, California Institute of Technology, Pasadena, CA, USA

In recent years the study of the link between attention and conscious perception has intensified. Some reports claim that attention and conscious perception are intrinsically linked, while others claim that they are two independent processes. Strong evidence for the second proposal could be gained from a finding that paying attention to a stimulus and the conscious perception of that stimulus have opposing influences on the stimulus' processing. Here we report such evidence. We measured the influence of attention and conscious perception (i.e. visibility) on processing of a visual stimulus, by measuring the afterimage duration of that stimulus. The visual stimuli were gratings, presented monocularly, and peripherally during a 4-sec adaptation phase. A uniform average-luminance field followed this phase, and observers used button presses to indicate how long an afterimage was visible. During the adaptation phase attention and visibility were independently modulated. Attention was modulated by having the observers perform (or not perform) an attention-absorbing Rapid Serial Visual Presentation (RSVP) letter counting task at fixation during the adaptation. Visibility was modulated by presenting (or not presenting) a strong variant of binocular rivalry, continuous flash suppression (Tsuchiya & Koch 2005), in the eye contra-lateral to the adaptor. We found that increased attention to the stimulus reduced afterimage duration (Wilcoxon signed-rank test $p<0.01$; see also Suzuki & Grabowecky 2003; Lou 2001), while increased visibility (i.e. the absence of CFS) of the stimulus increased afterimage duration (Wilcoxon signed-rank test $p<0.026$). These findings show that attention and conscious perception are dissociable processes with potentially opposing effect on the stimulus' processing.

Acknowledgement: This research is supported by a Rubicon grant from the Netherlands Organisation for Scientific Research (NWO)

31.22, *8:45 am*

A distinction between perceptual blindness and attentional blindness (I): low-contrast versus attentional distraction

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Conscious perception of a visual stimulus can be impaired both by decreasing the signal strength in the stimulus as well as by distracting attention from the stimulus. In the present study, we report a method that allows us to classify different types of psychophysical techniques for rendering visual stimuli invisible.

Sunday Sessions

In experiment 1, we varied the visibility for a luminance blob by varying its contrast. Subjects were asked to report the presence or absence of the luminance blob together with their confidence rating: high/mid/low. In experiment 2, we maintain the contrast of luminance blob well above threshold but varied its visibility by manipulating the difficulty of a concurrent central visual search task. Observers detect the presence of blob with confidence rating (high/mid/low) as in experiment 1 in addition to their search result.

In both experiments, the target blob was presented only half of the trials. Between the two experiments, we identified conditions yielding a comparable d' and analyzed the confidence in "miss" trials in which subjects reported absence when the target was present. We found that subjects reported absence with high confidence when they missed a target due to low contrast, whereas they reported absence with little confidence when their attention was distracted. In the case of low-contrast stimuli, the confidence in reporting absence was as high as reporting absence in "correct rejection" trials in which no stimulus was presented. The distinct patterns in the confidence rating between the two types of blindness implies that blindness at a perceptual stage and attentional stage can be distinguished by objective measures based on a second-level signal detection framework..

31.23, *9:00 am*

Bright and dark attention: Distinct effect of divided attention at attended and unattended locations

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How does dividing attention affect visual sensitivity? Cueing a location improves contrast sensitivity (compared to uncued locations); but in life, a pertinent stimulus may appear in more than one place. If attention draws on limited processing resources, the straightforward prediction is that as the number of attended locations increases, contrast sensitivity should decline. However, spatial attention is known to be remarkably flexible, and manipulations of the number of cued locations have led to inconsistent results. Here we investigated the relation between contrast sensitivity and the number of attended locations.

In Experiment 1, participants reported the orientation (vertical/horizontal) of a target grating on each trial. Targets had varying contrasts, could appear in one of four locations arranged in a square around fixation, and were preceded by one to four briefly-presented peripheral cues directing attention to possible target locations. Cues were always valid (targets appeared only at one of the cued locations). Results showed that sensitivity decreased steadily as number of cues increased. This reduced sensitivity demonstrates the limits of divided attention at attended locations ('bright' attention).

To investigate the effect of attention at uncued locations ('dark' attention) in Experiment 2, either one or three locations were cued but cues had no predictive validity for target location. If dividing attention reduces sensitivity overall, sensitivity should decline with the number of cues at both attended and unattended locations. But if it is the efficiency of resource distribution that is impaired by divided attention, this leads to a counter-intuitive prediction: sensitivity at unattended locations should improve as the number of attended locations increases. Indeed, more cues again led to reduced sensitivity at attended locations, but to a symmetrical improvement at unattended ones. This finding demonstrates the existence of 'dark' attention (attentional operations at unattended locations) and resolves previous inconsistencies regarding divided attention.

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31.24, *9:15 am*

Both exogenous and endogenous target salience manipulations support resource depletion accounts of the attentional blink

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Traditionally, theoretical accounts of the attentional blink (AB) have postulated that the deficit occurs due to limited attentional resources being devoted to the first target (T1) at the expense of the second (T2; e.g., Chun & Potter, 1995). Recent theories have challenged this model (e.g., Di Lollo et al., 2005; Olivers et al., 2007), proposing instead that the AB occurs because subjects fail to maintain appropriate levels of attentional control when presented with distractors. Accordingly, it has been shown that there is no T1 and T3 performance difference (no AB) when three targets from the same attentional set are presented sequentially in an RSVP stream (Uniform trials). However, Dux et al. (2008) have argued that this finding rather reflects a performance trade-off between T1 and T3. In support of their hypothesis, Dux et al. (2008) found an AB (T1>T3 performance) under three-target Uniform conditions when subjects increased the resources they exogenously allocated to T1. Here, we investigated whether an endogenous manipulation of the attentional resources subjects devote to targets also effects the AB. Subjects viewed RSVP streams where three letter targets appeared sequentially amongst digit distractors. The attentional resources devoted to the targets were manipulated by varying each target's relevance to the task. In T1-relevant blocks, T1 required report on all trials whereas T2 and T3 required report on only 50% of the trials (subjects were instructed at the end of each trial whether to report just T1 or all three targets). Conversely, in T3-relevant blocks, T3 required report on all trials and T1 and T2 on only 50% of the trials. T1 performance was superior to T3 performance in T1-relevant blocks (an AB), and T3 performance was greater than T1-performance in T3-relevant blocks (a reversed AB!). These findings provide strong support for resource depletion accounts of the AB.

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31.25, *9:30 am*

Temporal dynamics of dividing spatial attention

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Mutually-exclusive theories posit that spatial attention is deployed either as a single focus or as divided foci. In fact, we have previously shown that whether the focus is unitary or divided depends on the observer's mental set. We now report that a unitary focus is the default mode and that it takes approximately 100 milliseconds to morph between unitary and divided modes. We employed an attentional-blink paradigm with two RSVP streams of distractors, one on either side of fixation, separated by a blank region. Two pairs of letter-targets (T1-pair/T2-pair) could appear either within the streams or in the central blank region. For one group, the T1-pair occurred predictably within the streams (encouraging a divided focus to optimize T1-pair identification); for the other group, it occurred unpredictably either within the streams or in the central region (encouraging a unitary focus). For both groups, the T2-pair appeared unpredictably either within the streams or in the central region. To assess the rate of morphing between unitary and divided modes, we varied the stimulus-onset-asynchrony (SOA) between successive items in the RSVP streams (70 or 100 ms). When the T1-pair location was unpredictable, T2-pairs in the central region were processed accurately at both SOAs, indicating a unitary focus. When the T1-pair location was predictable, however, T2-pair accuracy depended on the SOA: at an SOA of 70 ms, accuracy for a central T2-pair was relatively high, suggesting that there had been insufficient time to morph from the default (unitary) setting to the divided setting. At an SOA of 100 ms, however, accuracy for a central T2-pair was lower, indicating that there had been sufficient time for the focus to divide, leaving the central region unattended. We conclude the default mode is unitary, and that it takes a finite time period to morph to a divided focus.

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31.26, *9:45 am*

Neural decoding of semantic processing during the attentional blink

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When two masked targets are presented in rapid succession, correct identification of the first (T1) leads to impaired identification of the second (T2). Behavioral and event-related potential (ERP) studies have demonstrated that semantic information about T2 can survive this 'attentional blink' (AB) even though discrimination accuracy is impaired. Here we use neural decoding methods applied to ERP data to investigate whether T2 information inherent in neural activity recorded during the AB can be used to discriminate the T2 stimulus independent of behavior. Twelve observers performed an AB task in which T1 required the discrimination of the direction of a central arrow that was flanked by arrows pointing in the same direction (easy) or in a different direction (hard). The second task involved discriminating whether T2 was related or unrelated to a context word presented at the very beginning of the trial. Each subjects' electroencephalogram was recorded using 32 electrodes and the ERP time-locked to the T2 word was extracted. Consistent with previous studies (Giesbrecht et al., 2007), ERP indices of semantic processing were robust during the AB when T1 was easy, but not when T1 was hard. We applied a linear pattern classifier to the T2-evoked ERP data and evaluated performance of the classifier for separate post-T2 time points using a k-fold cross-validation scheme. This analysis revealed that outside the AB the classifier accuracy was above chance from 400-600 ms post-T2 regardless of T1-difficulty; during the AB, however, classifier accuracy was greater than chance only when T1 was easy. These results indicate that there is information inherent in the neural activity evoked during this task that can be used to discriminate T2 independent of behavior, but that the utility of this information is constrained by task demands.

Motion: Perception and Depth

Sunday, May 10, 11:00 am – 12:45 pm
Talk Session, Royal Palm Ballroom 1-3
Moderator: Sergei Gepshtein

32.11, *11:00 am*

Motion adaptation as a redistribution of visual sensitivity

Sergei Gepshtein[1,2], Luis Lesmes[1], Thomas Albright[1]; [1]The Salk Institute for Biological Studies, USA, [2]Brain Science Istitute, RIKEN, Japan

Motion adaptation is a robust perceptual phenomenon known from antiquity, yet understanding its principles has been elusive. Recent theories proposed that adaptation optimizes visual sensitivity to properties of the variable environment, thus improving the ability to perceive motion at the adapting conditions (Sakitt and Barlow, 1982; Wainwright, 1999; Stocker and Simoncelli, 2005). Previous efforts to support this premise produced controversial results. In speed adaptation, for example, sensitivity to adapting speeds either increased or decreased; it also changed for speeds very different from the adapting speed (Krekelberg, van Wezel, and Albright, 2006).

According to a new normative-economic theory of motion perception (Gepshtein, Tyukin, and Kubovy, 2007) spatiotemporal sensitivity manifests an optimal allocation of scarce computational resources in the visual system, driven by two factors: Gabor's uncertainty principle of measurement and statistics of stimulation. The theory predicts that speed adaptation should induce a characteristic pattern of sensitivity changes, forming foci of increased and decreased sensitivity across the spatiotemporal sensitivity function (Gepshtein, Tyukin, and Albright, 2008, www.journalofvision.org/8/6/1037/).

We measured human contrast sensitivity over a large range of spatial and temporal frequencies (0.25-8 c/deg and 0.5-32 Hz). The observers viewed drifting luminance gratings of variable contrast and discriminated the direction of motion. We varied the statistics of motion speed: In some blocks of trials low speeds were more common than high speeds, and in other blocks high speeds were more common than low speeds. We compared the spatiotemporal contrast sensitivity functions obtained in the different statistical contexts and found changes of sensitivity that formed foci of increased and decreased sensitivity similar to our predictions. These findings support the normative-economic theory and the view that motion adaptation amounts to reallocation of computational resources in the visual system.

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32.12, *11:15 am*

The coordinate system of the motion aftereffect is retinotopic

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Although eye-, head- and body-movements can produce large-scale translations of the visual input on the retina, perception is notable for its spatiotemporal continuity. The visual system might achieve this by the creation of a detailed map in world coordinates—a spatiotopic representation. We tested the coordinate system of the motion aftereffect by adapting observers to translational motion and then tested (1) at the same retinal and spatial location (full aftereffect condition), (2) at the same retinal location, but at a different spatial location (retinotopic condition), (3) at the same spatial, but at a different retinal location (spatiotopic condition), or (4) at a different spatial and retinal location (general transfer condition). We used large stimuli moving at high speed to maximize the likelihood of motion integration across space. In a second experiment, we added a contrast-decrement detection task to the motion stimulus to ensure attention was directed at the adapting location. Strong motion aftereffects were found when observers were tested in the full and retinotopic aftereffect conditions. We also found a smaller aftereffect at the spatiotopic location but it did not differ from that at the location that was neither spatiotopic nor retinotopic (general transfer location). This pattern of results did not alter when attention was explicitly directed at the adapting stimulus. We conclude that motion adaptation took place at low, retinotopic levels of visual cortex and that no spatiotopic interaction of the motion adaptation and the test occurred across saccades.

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32.13, *11:30 am*

Asymmetric interaction between motion and stereopsis revealed by concurrent adaptation

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Although joint processing of motion and stereopsis has been suggested by contingent aftereffects, the reciprocal nature of encoding these two features has not been systematically studied. To investigate mutual influences between motion and stereopsis, we measured the processing of these features in parallel under 'concurrent' adaptation. In experiment 1, the adapting stimulus consisted of 110 random dots moving coherently in a single direction (left or right) at a single disparity (crossed or uncrossed 0.2°). Before and after adaptation, observers reported which one of the two sequentially presented intervals contained coherent motion or stereo signal. For motion detection, one of the intervals contained only 'noise' dots that were moving in random directions and the other contained both 'noise' and 'signal' dots that coherently moved either in leftward or rightward direction. All dots were at crossed or uncrossed disparity of 0.2°. For stereo detection, 'noise' dots were randomly dispersed over ±0.3° and 'signal' dots were at either crossed or uncrossed 0.2°. All dots were moving either leftward or rightward. We found a strong asymmetry between motion and stereopsis. The detection of disparity signal after adaptation was more impaired when the tester was moving in the adapted direction than in the non-adapted direction. In contrast, the test disparity hardly affected the detection of coherent motion, which is in contrary with the findings reported in contingent aftereffects. In experiment 2, we employed an adaptor that contained two groups of dots that were moving oppositely at crossed and uncrossed disparities, respectively, as in the previous studies of contingent aftereffects. Using the same testers as those in experiment 1, we observed considerable disparity dependency in motion detection. The results urge the reinterpretation of previously reported contingent aftereffects and imply an asymmetry between neural mechanisms devoted to processing motion and stereopsis in human visual cortex.

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32.14, *11:45 am*

3D motion perception depends on eye-specific signals outside V1

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Perception of 3D motion relies on two dissociable binocular cues: changes in disparity, and interocular velocity differences (IOVDs). The IOVD cue requires that the visual system extracts monocular velocities from corresponding retinal regions. We performed psychophysical experiments in which a plaid (the sum of 2 sinusoidal component gratings) drifted in opposite directions in the two eyes. If IOVDs are extracted early in the motion processing stream, 3D motion percepts should be strongest when one of the components drifts horizontally. If IOVDs are extracted later, percepts should be strongest when the pattern motion is horizontal.

For all stimuli, we measured the strength of the 3D motion percept as a function of the overall stimulus orientation/direction. For 'Type I' plaids, the resulting tuning curve was narrowly centered on the pattern motion prediction, and very different than one obtained with a comparable stimulus in which the monocular half-images yielded percepts of transparent components rather than coherent pattern motion. For 'Type II' plaids, which yield very different component- and pattern- motion signals, perceived 3D motion was strongly affected by the plaid direction, confirming a distinct contribution of pattern motion signals.

Finally, we presented a novel 'microcomponent' dichoptic stimulus that effectively bypassed binocular processing in early visual cortex. The stimulus consisted of small (0.5 deg diameter) randomly- oriented and -positioned drifting Gabors. All Gabor component velocities were compatible with a single global pattern motion. Gabors were spaced so that only one fell within any V1-sized receptive field. Moreover, they were dichoptically spaced such that no binocular overlap existed at the scale of V1 processing. This stimulus nonetheless produced compelling 3D motion percepts.

These results demonstrate that eye-specific circuitry exists outside V1, and must play a key role in 3D motion perception.

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URL: http://web.austin.utexas.edu/rokers/demo/vss09/

32.15, *12:00 pm*

Cortical regions for the processing of stereoscopic motion in depth as revealed by fMRI in the alert rhesus monkey

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Introduction. Although a high proportion of the motion selective cells in non-human primate motion areas are disparity-selective, there is no convincing evidence for cells specific to stereomotion-in-depth, and the neural basis of stereomotion processing remains obscure. However, recent fMRI studies in humans (Likova and Tyler, 2007) have revealed activity related to cyclopean stereomotion-in-depth (csMID; based entirely on temporal changes-in-disparity), with the earliest activation site in an occipito-temporal region anterior to hMT+ (the CSM region). To determine if there is an analogous area for csMID in the non-human primate, the present investigation used fMRI in the alert rhesus monkey combined with the same visual stimuli as used in the human study to search for cortical regions activated by csMID.

Methods. Data were acquired on a Varian/Magnex 4.7T scanner with a 60cm vertical bore. Stereoscopic visual stimuli were presented using an Avotec visual display system fitted with IR cameras for monitoring eye position. Using the same csMID stimulus paradigm as in the human study, we acquired BOLD functional images at a spatial resolution of 1.5x1.5x1.5 mm.

Results. The statistical maps generated from our fMRI experiments identified focal activation in two posterior regions: the fundus of the superior temporal sulcus (STS) and the IPS. The activation in the fundus of the STS appeared to be contiguous with MSTv, while that in the IPS appeared to coincide with VIP.

Conclusions. These results extend the analysis of motion in humans and macaques to cortical regions involved in the processing of motion-in-depth. The results strongly suggest that rhesus monkeys possess a cortical region in the STS specialized for the processing of csMID, comparable to the CSM region of humans. Furthermore, this study identifies potential targets for fMRI-guided neurophysiological studies of the cortical mechanisms of stereomotion processing in the rhesus monkey.

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32.16, *12:15 pm*

Vestibular input to human MST but not MT

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In macaques, cortical area MST receives vestibular as well as visual input. The vestibular tuning of MST neurons can be either (i) congruent with their tuning for optic flow, suggesting combination of cues to specify self-motion more accurately, or (ii) opposite, perhaps allowing head motion to be discounted in order to facilitate detection of object motion. In contrast, it is thought that macaque MT does not have vestibular afferents.

We have examined whether human MT and MST have vestibular inputs by applying galvanic vestibular stimulation (GVS) in combination with fMRI. GVS involves passing a controlled current between two electrodes attached to the mastoid processes, to stimulate the cranial nerves that connect the vestibular organs to the brainstem. We applied a 1Hz sinusoidal alternating current of ±1 mA during conventional fMRI acquisition at 3Tesla. All participants reliably experienced vestibular sensations during stimulation intervals (roll and/or yaw that alternated in direction at 1Hz). Scanning was performed in total darkness and also while continuously observing a static visual scene. In separate scans, MT and MST were identified conventionally with unilateral visual motion stimulation, exploiting the fact that MST but not MT responds to ipsilateral visual stimuli.

During GVS, significant time-locked activation was seen in the MT+ complex. It occurred in darkness as well as during vision so cannot be attributed to image motion caused by cyclotorsional eye movements. In every case, it occurred only in the anterior portion of MT+ and the active region corresponded well to MST as defined visually. Activity was also seen in parieto-insular vestibular cortex (PIVC). Suppression was often seen in occipital cortex and in somatosensory cortex, consistent with known inhibitory interactions.

We conclude that human MST receives vestibular afferents but human MT does not. In addition, GVS provides an alternative localizer for MST.

Acknowledgement: Funded by The Wellcome Trust

32.17, *12:30 pm*

'Directionality' as an especially powerful cue to perceived animacy: Evidence from 'wolfpack' manipulations

Tao Gao[1] (tao.gao@yale.edu), Gregory McCarthy[1], Brian J. Scholl[1]; [1]Yale University

The currency of visual experience consists not only of features such as color and shape, but also higher-level properties such as animacy. We explored one cue that appears to automatically trigger the perception of animacy in an especially powerful manner: directionality, wherein an object (1) appears to have a particular orientation based on its shape (as a wolf's head tells you which way it is facing), and (2) varies this heading systematically with respect to the environment (as a wolf consistently faces its prey during a hunt). Previous studies of perceived animacy have relied on problematic perceptual reports, but we used several new performance measures to demonstrate the power of directionality in some surprising new ways. In all experiments, subjects viewed oriented 'darts' that appeared to face in particular directions as they moved. First, in the Don't-Get-Caught! task, subjects controlled the trajectory of a 'sheep' on the screen to avoid getting caught by a 'wolf' dart that pursued them. Subjects escaped much more readily when the darts (including the wolf) consistently faced 'ahead' as they moved. Second, in the Search-For-Chasing task, subjects had to detect the presence of a chase between two darts. Performance suffered dramatically when all darts (including the wolf) acted as a 'wolfpack' — consistently all pointing toward the same irrelevant object. The shapes coordinated orientations masked actual chasing, while simultaneously making each object seem to 'stalk' the irrelevant object. Third, in the Leave-Me-Alone! task, subjects had to avoid touching darts that moved on random trajectories, and tended to steer clear of display regions where the darts were oriented as a 'wolfpack' facing the subject's shape — demonstrating that subjects find such behavior to be aversive. These results demonstrate a new cue to perceived animacy, and show how it can be measured with rigor using new paradigms.

URL: http://www.yale.edu/perception/

Object Recognition: From Features to Objects

Sunday, May 10, 11:00 am – 12:45 pm
Talk Session, Royal Palm Ballroom 4-5
Moderator: Anya Hurlbert

32.21, *11:00 am*

Features used or features available?

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Reading speed decreases with eccentricity, even when the stimulus size and spacing are scaled. This is puzzling given that the periphery is faster by most measures. This discrepancy has been attributed to slower feature integration in the periphery. In the periphery, the rate of feature integration depends on both the number of features and eccentricity (Cantone, Tillman, & Pelli, VSS 2008). Here, we ask which features matter: the number available or only those actually used. We measure reading speed for four-letter words in the fovea and the periphery. We vary the set size from which the words are chosen: either the 26 most frequent words or all 2200 four-letter words. Less information and hence fewer features would be needed to identify words selected from the smaller set (Shannon & Weaver, 1948). Hick's law (1952) states that reaction time is proportional to the logarithm of set size and hence to the amount of information. However, the number of features available in any given word is the same in both sets. We find that set size has a large effect on reading speed, indicating that what matters is the number of features used. When words are selected from the larger set, reading speed is slower in the fovea and falls much faster (twice as fast) with eccentricity than when they are selected from the smaller set. We also find that changing the font to change the perimetric complexity (perimeter2/area, a measure of how many features are available) has no effect on reading speed. Thus we conclude that the slowing of feature integration with eccentricity depends on the number of features used, not the number available.

32.22, *11:15 am*

Material Perception: What can you see in a brief glance?

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People can recognize natural objects and natural scenes with remarkable speed, even when they have never seen the pictures before (Biederman et al., 1974; Potter 1975, 1976; Thorpe et al., 1996; Greene & Oliva 2008). But how quickly can people recognize natural materials? We built an image database containing 1000 images of 9 material categories (e.g., paper, fabric, glass, etc). To prevent subjects from simply doing object recognition, we used cropped images in which overall object shape was not a useful cue. To prevent subjects from simply using color, texture, or other low level cues, we chose images with highly diverse appearances. For example, "plastic" includes close-ups of red trash bags, transparent CD cases, and multi-colored toys. Images were obtained from websites like flickr.com. We found that humans can correctly categorize images with very short durations and in challenging conditions (e.g., 40 msec followed by a noise mask, or presented in the middle of an RSVP stream at 40msec per image). When we degraded the images by simple manipulations like removing color, or blurring, or inverting contrast, performance was reduced but was still surprisingly good. We also measured recognition speed with reaction time. To measure baseline RT, we gave subjects very simple visual tasks (e.g., Is this disc red or blue? Is this diagonal line tilted left or right?). We then asked them to make a 3-way material category judgment (e.g., paper or plastic or fabric?). Material categorization was nearly as fast as baseline. Beyond judgments of material category, observers can judge dimensions of material appearance like matte/glossy, opaque/translucent, rigid/non-rigid, soft/rough, warm/cool reliably even in 40 ms presentations. In conclusion, material perception is fast and flexible, and can have the same rapidity as object recognition and scene perception.

Acknowledgement: NTT Communication Science Laboratories, Japan National Science Foundation

32.23, *11:30 am*

The interaction of colour and texture in an object classification task

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Many natural objects are characterised not only by shape and mean colour, but also by their particular chromatic textures: the speckled red of a strawberry is distinctively different from the streaky red of an apple. While the roles of colour and shape have been well explored in object recognition, chromatic texture has not. Here we study the roles of mean colour and texture – and their interaction -- in an object classification task using familiar objects.

Images of natural objects were captured using a tristimulus-calibrated digital camera under controlled illumination. Reference surface patches were taken from different locations on single objects, then manipulated by changing either their original texture or colour (e.g. combining banana texture with carrot colour). Stimuli were presented on a calibrated CRT monitor.

Observers performed a three-way speeded classification task for 3 stimulus sets: uniform colour patches (red, green or blue), whole natural object images (shape cue intact) and natural surface patches ('congruent', i.e., reference patches, and 'incongruent', i.e., manipulated patches). For the latter two sets, 3 groups were formed from combinations of 7 objects (example classification: potato, lime, or carrot). The task was performed at 2 different presentation times (40 ms and 250 ms).

Observers were able to perform the task, even for incongruent patches. Classification performance (reaction time and accuracy) for whole object images was effectively the same as for uniform colour, at both presentation times. Classifications for incongruent patches were slower than for congruent patches, most pronouncedly at 40ms. Incongruent textures slowed down classification by colour more than incongruent colours impeded classification by texture, only at the shortest presentation.

The results strongly suggest that texture and colour interact in object recognition and, at least for this task, texture plays a more dominant role than mean colour in object classification.

Acknowledgement: This work was funded by the Engineering & Physical Sciences Research Council (UK) (grant EP/D0687381/1).

Sunday Sessions

32.24, *11:45 am*

Evidence for autocorrelation and symmetry detection in primary visual cortex

David Berry[1,2] (dlb40@cam.ac.uk), Horace Barlow[1]; [1]Physiology, Development & Neuroscience, University of Cambridge, UK, [2]Department of Physics, University of Évora, Portugal

The detectability of patterns in random dot arrays was measured as a function of dot density and compared with the statistical limit set by different methods of detecting the pattern. For filtering, cross-correlation, convolution, or template matching, the limit is expected to be inversely proportional to the square root of dot density. But for auto-correlation, which can detect symmetries of various types, the limit is unaffected by dot density under many conditions. Confirming previous results, we found that the coherence-threshold is often constant for Glass patterns, but the range of constancy depends on details of the display procedure. Coherence-thresholds were found to increase when the average number of dots expected at each location rose towards or exceeded a value of one; we therefore think it results from the non-linear effects of occlusion that occur when a later-programmed dot falls in the same location as an earlier one. To test this, these non-linear effects were prevented by arranging the luminance of each location to be directly proportional to the number of times that location was covered by a dot. Millions of dots can be used for these images, and they retain the streakiness of Glass patterns, while discrete dots disappear. The constant coherence threshold for detecting this streakiness is maintained over a huge range of dot densities, extending right down to the range where discrete dots become visible and up to patterns that are essentially full-tone images with no discrete dots. At threshold, all these patterns have similar auto-correlation functions, as we can see from the way both low dot-number Glass-patterns and these mega-dot, multi-tone, Glass-like images are formed. This startling fact raises the question whether primary visual cortex computes auto-correlations as well as, or even instead of, the local, Fourier-type, wavelet analysis of the currently popular paradigm.

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32.25, *12:00 pm*

Cue dynamics underlying rapid detection of animals in natural scenes

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Humans are good at rapidly detecting animals in natural scenes, and evoked potential studies indicate that the corresponding neural signals emerge in the brain within 100 msec of stimulus onset (Kirchner & Thorpe, 2006). Given this speed, it has been suggested that the cues underling animal detection must be relatively primitive. Here we report on the role and dynamics of four potential cues: luminance, colour, texture and contour shape.

We employed a set of natural images drawn from the Berkeley Segmentation Dataset (BSD, Martin et al, 2001), comprised of 180 test images (90 animal, 90 non-animal) and 45 masking images containing humans. In each trial a randomly-selected test stimulus was briefly displayed, followed by a randomly-selected and block-scrambled masking stimulus. Stimulus duration ranged from 30-120 msec.

Hand-segmentations provided by the BSD allow for relatively independent manipulation of cues. Contour cues can be isolated using line drawings representing segment boundaries. Texture cues can be removed by painting all pixels within each segment with the mean colour of the segment. Shape cues can also be removed by replacing segmented images with Voronoi tessellations based on the centres of mass of the BSD segments.

In this manner, we created nine different stimulus classes involving different combinations of cues, and used these to estimate the dynamics of the mechanisms underlying animal detection in natural scenes. Results suggest that the fastest mechanisms use contour shape as a principal discriminative cue, while slower mechanisms integrate texture cues. Interestingly, dynamics based on machine-generated edge maps are similar to dynamics for hand-drawn contours, suggesting that rapid detection can be based upon contours extracted in bottom-up fashion. Consistent with prior studies, we find little role for luminance and colour cues throughout the time course of visual processing, even though information relevant to the task is available in these signals.

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32.26, *12:15 pm*

What mechanism underlies object priming effects under Continuous Flash Suppression?

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Recently, Almeida and Colleagues used Continuous Flash Suppression (CFS) to study the involvement of the dorsal visual stream in object categorization (Almeida, Mahon, Nakayama, & Caramazza, 2008. PNAS). They found that categorically related primes rendered invisible by CFS facilitated the categorization of tool targets, but not animal targets or non-living non-manipulable targets (e.g., vehicles). Those data indicate that that action-relevant information computed by the dorsal visual stream processes influenced object categorization processes.

Those data raise the question of the nature of the mechanism through which knowledge about object manipulation influences object categorization. One possibility is that knowledge about object manipulation becomes relevant only at the level at which objects are categorized as tools or animals. An alternative possibility is that information about object manipulation is used during object recognition.

To study these two possibilities, we developed a picture naming experiment in the context of CFS suppressed, categorically congruent and incongruent, primes. If the information suppressed under CFS influences semantic categorization decisions, a priming effect would not be expected in the naming responses. However, if CFS suppressed information influences object recognition processes, then a category-specific priming effect for tools should be expected in the picture naming task.

We found that participants were faster to name tool target pictures in the context of tool primes than in the context of animal primes ($t(15) = 2.44$ and $p = 0.028$; priming effects ranged from -23 to 76 ms; 12 out of 16 participants showed positive priming effects; mean = 18 ms; SEM = 7 ms). This was not true for animal target pictures ($t(15) = 1.62$ and $p = .125$; priming effects ranged from -75 to 38; 7 out of 16 showed positive priming effects; mean = -13 ms; SEM = 8 ms). These findings suggest that that information about object manipulation/ graspability influences object recognition.

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32.27, *12:30 pm*

At 130 ms you “know” where the animal is but you don’t yet “know” it’s a dog

Michèle Fabre-Thorpe[1,2] (michele.Fabre-Thorpe@cerco.ups-tlse.fr), Sébastien M. Crouzet[1,2], Chien-Te Wu[1,2], Simon J. Thorpe[1,2]; [1]Université de Toulouse, UPS, Centre de Recherche Cerveau et Cognition, France, [2]CNRS, CerCo, Toulouse, France

Since the influential studies by Rosch and colleagues in the 70s, it is generally agreed that the visual system can access information at the basic level (e.g., dogs) faster than at the subordinate (e.g., Chihuahua) or superordinate levels (e.g., animals). However, the advantage of the basic category over the superordinate category in object recognition has been challenged recently, and the hierarchical nature of visual categorization is now a matter of debate. In a series of psychophysical studies, we addressed this issue using a forced-choice saccadic task in which two images were displayed simultaneously on each trial and participants had to saccade as fast as possible towards the image containing the designated target category. Kirchner and Thorpe (Vision Research, 2006) previously demonstrated that successful saccades towards animal targets could be initiated with minimum latencies as short as ~130ms". This protocol allows us to compare the temporal dynamics of visual recognition at the basic and superordinate level within very short delays after stimulus onset. There were two major findings. First, with such very short processing time, participants' performance was impaired in categorizing an object at the basic level when compared to its superordinate level. Second, when categorizing an object among different basic levels, saccades started at the same mean latency but with a low performance accuracy that was influenced by the degree of morphological similarity between targets and non-targets (dog/bird: 61% correct; dog/cat: 46% correct). Follow-up computational modeling further confirmed that these behavioral results cannot be predicted by pure bottom-up saliency differences between the images used. Therefore, our results support a coarse-to-fine model of visual recognition. The visual system first gains access to relatively coarse visual representations which provide information at the superordinate level of an object, but additional visual analysis is required to allow more detailed categorization at the basic-level.

Scene Perception: Categorization and Memory

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

33.301

Rapid scene understanding: evidence of global property processing before basic-level categorization

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What information is available from a brief glance at a scene? While previous efforts to answer this question have focused on scene categorization or object detection, real-world scenes contain a wealth of information whose perceptual availability has yet to be explored. Here we used image exposure thresholds to compare several basic-level categorizations with global-property categorizations: tasks that reflect ecological properties describing spatial and functional aspects of a scene space. In separate experimental blocks, observers performed yes-no forced-choice tasks on either global properties (e.g. openness, naturalness) or basic-level categories (forest, desert, etc). All target images were masked with an RSVP sequence of textures to fully mask visual features. Thresholds on all tasks were remarkably short: observers achieved 75% correct performance with presentations ranging from 19ms to 67ms, reaching maximum performance after 100ms. Global-property tasks had significantly shorter thresholds than basic-level tasks, suggesting that there exists a time during early visual processing where a scene may be classified as open or navigable, but not yet as a mountain or lake. We explored this possibility in a second experiment: observers were shown a briefly presented scene (30ms masked) and then given four image alternatives. In addition to the target, the three distractors were chosen from a 2x2 in which images could share a global property, a category or neither with the target. We compared the error distributions made in this task, and found that observers were significantly more likely to choose the distractor sharing a global property with the target category than alternatives that shared the category, providing evidence that global properties were more completely processed than basic-level categories in this short presentation time. Comparing the relative availability of visual information reveals bottlenecks in the accumulation of meaning. Understanding these bottlenecks provides critical insight into the computations underlying rapid visual understanding.

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33.302

Searchlight analysis reveals brain areas involved in scene categorization

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Our ability to categorize natural scenes is essential for visual tasks such as navigation or the recognition of objects in their natural environment. Although different classes of natural scenes often share similar image statistics, human subjects are extremely efficient at categorizing natural scenes. In order to map out the brain regions involved in scene categorization, we use multivariate pattern recognition to analyze the fMRI activation within a small spherical region (the searchlight, Kriegeskorte et al. 2006) that is positioned at every possible location in the brain. From local activity patterns in each searchlight, we attempt to predict the scene category that the subject viewed during the experiment. Such an analysis allows us to generate a spatial map of those brain regions producing the highest classification accuracy. Furthermore, we can generate similar maps of the correlation of the pattern of errors made by the classification algorithm at each searchlight location with the pattern of errors made by human subjects in an accompanying behavioral experiment. Lastly, we ask which searchlight locations show a decrement in prediction accuracy for up-down inverted images relative to upright images, to reveal brain regions that may participate in the inversion effect that we found in the behavioral experiment. Together, these maps implicate large regions of the ventral visual cortex in the categorization of natural scenes, including area V1, the parahippocampal place area (PPA), retrosplenial cortex (RSC), and lateral occipital complex (LOC), previously shown to be involved in natural scene categorization (Caddigan et al., VSS 2007 & VSS 2008; Walther et al. HBM 2007 & SfN 2008) as well as other intermediate-level visual areas. We further explore the functions of these regions with respect to natural scene categorization and attempt to find their specific contributions to the scene categorization process.

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33.303

Categorization of good and bad examples of natural scene categories

Ana Torralbo[1] (atorralb@uiuc.edu), Barry Chai[2], Eamon Caddigan[3, 1], Dirk Walther[1], Diane Beck[3, 1], Li Fei-Fei[2, 4]; [1]Beckman Institute, University of Illinois, [2]Department of Computer Science, Princeton University, [3]Psychology Department, University of Illinois, [4]Psychology Department, Princeton University

Despite the vast range of images that we might categorize as an example of a particular natural scene category (e.g., beach), human observers are able to quickly and efficiently categorize even briefly presented images of these scenes. However, within the range of images that we might categorize as a "beach", for example, some will be more representative of that category than others. We asked whether participants' ability to categorize briefly presented scenes differed depending on whether the images were good or bad examples of the scene. 3000 images from six categories (beaches, city streets, forests, highways, mountains and offices) were first rated by naïve subjects as good or bad examples of those categories. On the basis of these ratings, 50 good and 50 bad images were chosen from each category to be used in a categorization experiment, in which a separate set of participants were asked to categorize the scenes by pressing one of six buttons. The images in this experiment were presented very briefly (<100 ms), followed by a perceptual mask. Good and bad examples of all the categories were intermixed randomly. As predicted, participants categorized good examples of a category significantly faster and more accurately than bad examples, suggesting that part of what makes an image a good example of a category can be gleaned in very brief presentations. To further understand the neural basis of this categorization ability, in a follow-up fMRI experiment, we will ask whether a statistical pattern recognition algorithm trained to discriminate the distributed patterns of neural activity associated

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with our six scene categories might also show a decrement in classification accuracy for good versus bad examples of the category. By comparing classification accuracy within different brain regions (e.g., V1, PPA) we can ask which brain regions are most sensitive to this good/bad distinction.

33.304

Basic Level Scene Categorization Is Affected By Unrecognizable Category-Specific Image Features

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Computational models can effectively categorize scene images based solely on their Fourier amplitude spectra "signature profiles" (Oliva & Torralba, 2001). However, recent behavioral studies have shown that amplitude spectra signatures are insufficient for scene category recognition, suggesting instead that characteristic phase spectra signatures are necessary. Using a scene categorization masking paradigm, Loschky et al. (2007) demonstrated that phase-randomized scenes-as-masks produce weaker masking than normal-scenes-as-masks, and that phase-randomized masks do not produce category-specific masking effects. Nevertheless, because phase randomization renders a scene-as-mask unrecognizable, the loss of masking could reflect a reduction in conceptual masking rather than a loss of local phase structure. Here, we tested the hypothesis that local, unrecognizable, category-specific features in the phase spectrum of a mask are sufficient to produce category-specific masking effects. Composite phase spectrum masks (CPSMs) were created by sampling different portions of the phase spectra of images within a single scene category (beach, forest, home interior, store interior, street, or tall building), thus CPSMs were naturally structured, but were not recognizable as members of their categories. Using a "go no-go" paradigm, images from pairs of categories were masked by CPSMs from each category. The results showed that when the basic-level category of the target and mask matched, masking was weaker than when they differed, thereby supporting the hypothesis that low-level category-specific features do mask specific image categories. Interestingly, regardless of CPSM category, there was a separate effect of whether the target-distracter image pairs were from the same or different superordinate categories (natural vs. man-made, or indoor vs. outdoor). Scene categorization at the basic level was easier when the pair of basic level categories came from different superordinate categories, consistent with the claim that scene category distinctions are first made at the superordinate level, and only later at the basic level (Loschky & Larson, 2008).

33.305

Superordinate category advantage in scene categorization depends on within- and between-category similarity structure

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What category level is processed fastest when classifying a scene? This is still an open question. Recent studies have shown that Natural vs. Manmade superordinate category classification could be achieved before basic level category. One possibility is that superordinate categories are highly distinctive due to singly sufficient features (Loschky and Larson, 2008; Gosselin and Schyns, 2001). However, we need to take into account the specificity of membership of each category. Distances between basic level categories within a superordinate category are not constant. For instance, City Center scenes seem more similar to Street than Highway, possibly because Highway has strong contrasts to two others in terms of dominant edge orientations (horizontal vs. vertical). If a superordinate category is organized by widely dissimilar categories, the relationship between within-category similarity and between-category dissimilarity would not favor superordinate advantage (Rosch et al., 1976). To test this possibility, we investigated how fast superordinate and basic level categorization were achieved in a go/no-go categorization task. Stimuli were extracted from a database of Oliva and Torralba's (2001) 2 superordinate and 8 basic level categories. In Experiment 1, Natural category was defined as a set of Coast and Mountain, while Man-made as Highway and City Center. In Experiment 2, Highway images were replaced with Street images. Subjects were asked to press a key if briefly presented stimuli (40ms) were targets as quickly and as accurately as possible. In Experiment 1, reaction times of superordinate category classification were not faster than basic level category. Meanwhile, In Experiment 2, speed advantage for superordinate over basic level partially appeared. These results suggest that superordinate categorization is not faster than basic level categorization when membership within a superordinate category are widely distant, and that it is unlikely that scene classification is sequential processing in which either of category levels is processed "first".

33.306

Semantic guidance of eye movements during real-world scene inspection

Alex D. Hwang[1] (ahwang@cs.umb.edu), Hsueh-Cheng Wang[1], Marc Pomplun[1]; [1]Department of Computer Science, University of Massachusetts at Boston

Real-world scenes are filled with objects representing not only visual information, but also meanings and semantic relations with other objects in the scene. The guidance of eye movements based on visual appearance (low-level visual features) has been well studied in terms of both bottom-up and top-down aspects. However, effects on eye movements by object meaning and object relations have been studied comparably less because of a few hurdles that make such study more complicated: (1) Object segmentation is difficult, (2) Semantic relations among objects are hard to define, and (3) A quantitative measure of semantic guidance has to be developed.

This is the first study to measure semantic guidance, thanks to the efforts by two other research groups: the development of the LabelMe object-annotated image database (Russell et al., 2008) and the LSA@CU text/word latent semantic analysis tool, which computes the conceptual distance between two terms (Landauer et al., 1998). First, we generated a series of semantic salience maps for each eye fixation which approximated the transition probabilities for the following saccade to the other objects in the scene, assuming that eye movements were entirely guided by the semantic relations between objects. Subsequently, these semantic salience maps were combined and the final strength of guidance was measured by the Receiver Operator Characteristic (ROC), which computes the extent to which the actual eye fixations followed the ideal semantic salience map.

Our analysis confirms the existence of semantic guidance, that is, eye movements during scene inspection being guided by a semantic factor based on the conceptual relations between the currently fixated object and the target object of the following saccade. This guidance may facilitate memorization of the scene for later recall by viewing semantically related objects consecutively.

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33.307

Visual similarity does not systematically affect scene recognition

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Conceptual and perceptual similarity lead to recognition errors with verbal material, objects, faces, and scenes: the more similar the items, the more confusion in memory. Surprisingly, whether perceptual similarity between independent scenes alone affects scene representation and confusion in memory has never been investigated. Here, we used a continuous perceptual space to evaluate this range of similarity between independent pictures, and explored whether scene recognition is affected by perceptual similarity. In Experiment 1, we measured the degree of perceptual confusion between 200 targets and associated decoys, orthogonally matching the targets on visual layout and conceptual gist. In Experiments 2 and 3, we used the resulting confusability index to assess whether perceptual similarity affects observers' performance on a 2-AFC (Exp.2) and an old/new (Exp.3) tests. Results of Pearson correlation tests addressing the relationship between the false alarm rates and confusability index showed that the rate of false alarms was not correlated to the perceptual similarity for the 2-AFC test. Does the confusability index fail to capture perceptual similarity between scenes? It does not appear to be the case, as the false alarm rate of the single recognition test was significantly correlated to the confusability index. These results strikingly contrast with the well-known effect of conceptual similarity effect, namely recognition errors increase with increased conceptual similarity. Here, on the contrary, results suggest that scene representation actually seems detailed enough in memory to support accurate discrimination of the target scenes among distractors, whatever distractors are very similar to the target scenes or not.

33.308

The properties of incidental memory in change detection

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In normal scene-viewing, observers intentionally and incidentally retain details of the visual scene. Observers who focus attention on an object in a visual scene can maintain the visual representation of the object even when they do not intentionally memorize it. This study examined the properties of representation in incidental memory by using a memory and change detection task in a flicker paradigm (30 second trials with an image for 250 ms followed by a blank for 250 ms). In a half of the trials, the original image alternated with a modified image (change detection condition). In the other trials, only the original image was presented repeatedly (memory condition). These conditions were mixed in a block. Participants were instructed to find a change in a scene and not instructed to memorize the visual scene. When participants could not find a change within 30 seconds, they were instructed to guess where a change existed or judge whether a cued target object was an object which they had previously seen (recognition test). In the change detection trials, participants could accurately report a change. This result assures that participants concentrated on finding a change in the scene. In the memory trials, when a change did not exist in a scene and participants should answer a recognition test, their performances were above chance level (50%). This suggests that incidental visual representations were retained even in an unfamiliar scene-viewing situation such as the flickering presentation. Further analysis reveals that participants could accurately judge an image presented previously as an image they had seen, but could not accurately reject a new image as unfamiliar. This suggests that visual representations in incidental memory are not stable enough to judge a changed object as a change, which contributes to change blindness.

33.309

Negative Emotional Images Slow Down Initial Encoding Time

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We limited the exposure duration of emotional photographs to investigate whether the speed of encoding was influenced by the emotional valence of the pictures. Participants viewed slide shows in which scenes (1/3 negative, 1/3 neutral, 1/3 positive emotional images from the IAPS) were presented for 60ms and then masked. The slide show was followed by an old/new recognition memory test. Memory was best for positive, moderate for neutral, and worst for negative images. These results cannot be explained by the arousal level of the images (positive and negative scenes were matched for arousal) or response biases for different emotional images (there were equal numbers of false alarms for different emotional foils during the recognition test). Follow-up studies revealed that these emotional effects disappeared when the stimuli were inverted or the encoding time was increased to 1500ms. These data suggest that the effect is due to emotional valence rather than low-level visual differences between the images (e.g., color, brightness, spatial frequency distributions) and suggest that the time required for encoding is critical to the effect. We conclude that negatively valenced emotional pictures slow encoding time. A final study investigated whether negative images were slow to encode because of an attentional bias away from them or because they produced an overall interruption in processing. This experiment presented two images per slide, one neutral and one that was negative, neutral, or positive. An attentional bias away from negative objects predicts that low recognition rates for negative images will coincide with higher recognition rates for the neutral images that appear with them. A global interruption in ongoing processing predicts low recognition accuracy for both the negative images and their neutral pair. Preliminary data suggest that negative images produce an overall interruption in processing.

33.310

Implicit semantic features and aesthetic preference

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Studies on determinants of aesthetic preference usually focus on objective features of visual stimuli. However, in our previous research, we attempted to specify the basic implicit, subjective dimensions of a visual Gestalt. The studies on subjective dimensions implied that subjective features converged in three main factors: affective, conative (arousal) and cognitive dimensions (Markovic and Jankovic, 2001 Perception 30 Supplement, 30). The present study was aimed at examining relations between the subjective dimensions mentioned above and aesthetic preference of abstract visual patterns. Participants were asked to evaluate monochromatic abstract visual patterns on the aesthetic preference scale (the seven-step bipolar beautiful-ugly scale), and on the instrument involving 35 bipolar scales (the scales' poles were defined using adjectives with opposite meaning). The scales for the instrument were based on the previous research indicated above. Visual patterns differed on the following dimensions: "regular-irregular", "simple-complex", "sharp-oval" and "dark-light". The principal component analysis revealed the same triple factorial structure as indicated in the previous studies. High and significant positive correlation was found between aesthetic preference and three subjective dimensions. The regression analysis further revealed that affective dimension (pleasant, good, gentle, nice) explained the greatest amount of variance, followed by conative dimension (interesting, impressive, rich, complex) and finally cognitive dimension (familiar, clear, regular). In the conclusion, we proposed the model for prediction of aesthetic preference based on implicit, subjective semantic features of visual stimuli.

33.311

Don't look! Fixating occluded objects distorts scene memory

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Knowing what will be tested, and fixating the relevant areas of a scene, is expected to yield better memory. This expectation fails in the case of boundary extension (memory beyond the boundaries of a view). Eye-tracking revealed that, when forewarned about the nature of the memory test, compared to test-naïve observers, test-informed observers more frequently fixated markers for boundary placement -- in particular, the place where a boundary cropped the main object (Dickinson, Michod & Intraub, 2008). Yet, at test, boundary extension was at least as great for pictures in which the main object was cropped. Was memory unaffected by these fixations? Or, might memory for the cropped boundary have been accurate, but associated with an increase in boundary extension at the other boundaries, thus resulting in a similar rating? To test this, observers (N = 72) studied 12 single-object-photographs (6 with cropped objects) for 14s each, and were instructed to memorize the objects, layout and background. Half the observers were test-informed and half were test-naïve during presentation. At test, the same views were presented again and observers reported "same" or they adjusted the boundaries to recreate the remembered view (using the mouse). As before, boundary extension was greater in the test-naïve condition (13% area increase) than in the test-informed condition (4% area increase; $t(70) = 3.6$, $p<.01$), and occlusion did not reduce boundary extension. In fact, analysis of cropped scenes in the test-informed condition revealed that the cropped side was the only one that yielded significant boundary extension ($p <.01$). Results run counter to traditional models of eye movements and scene representation and will be discussed in terms of a new multi-source model of scene perception (Intraub & Dickinson, 2008) in which visually-derived information and amodally-derived information play equally important roles.

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Sunday Sessions

33.312

Neural art appraisal of painter; Dali or Picasso?

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Professional art appraisers identify painters from their artistic style based on their knowledge and experience. Even ordinary people with no professional training can distinguish some painters by their styles to a certain extent. Although recent neuroimaging studies have begun to investigate the brain activities elicited by viewing artworks, the neural basis of art style recognition remains elusive. In this study, we investigated the neural representations of art style recognition by constructing a "neural art appraiser" that predicted the identity of the painter based on the fMRI activity pattern measured while a person was viewing an artwork. We used paintings of Dali or Picasso as stimuli to examine the possibility of distinguishing artworks of the two painters based solely on brain activity. We also compared the prediction performance between two subject groups, one with artistic training and the other with no artistic training, to test the effect of artistic expertise. The neural art appraiser consisted of a statistical pattern classifier based on a linear Support Vector Machine. First, the classifier was trained using the fMRI activity patterns from whole brain elicited by Dali's and Picasso's paintings. Then, the trained classifier was tested for its ability in identifying the painter (Dali or Picasso) on the basis of the fMRI activity pattern elicited by a novel painting, which had not been used for the training of the classifier. We found that two artists were reliably distinguished based on fMRI signals in both subject groups. Furthermore, the prediction accuracy was significantly higher in the subject group with artistic training than in that with no artistic training. Our findings demonstrate that fMRI signals contain information about highly abstract and elusive visual categories such as artistic styles.

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33.313

This is Your Brain on Art

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The nature of aesthetic response to artwork has long been debated by scientists and philosophers alike, yet an understanding of aesthetic reactions remains elusive. Is an aesthetic reaction to visual art more than a simple preference to certain visual stimuli? And if so, in what way (e.g. additional emotional components, and/or larger range)? We combined fMRI with behavioral factor analysis to address this. Sixteen observers viewed 109 paintings while whole head BOLD fMRI was collected. After viewing each artwork for 6 sec., observers made a recommendation (1-4 score) indicating how aesthetically pleasing they found the artwork. Following scanning, observers viewed the artworks again and rated the degree to which each artwork evoked the following emotions: pleasure, fear, disgust, sadness, confusion, awe, joy, sublimity and beauty. Observers showed moderate agreement in their emotional reactions to the artwork, but almost no agreement in which stimuli they found aesthetically pleasing. Factor analysis was used to identify latent variables, revealing individual differences in how observers evaluated the paintings – the majority of observers (twelve) used two or more unipolar factors for emotional valence (a positive factor and a separate, uncorrelated negative factor), while the remaining four observers treated valence as a singular bipolar factor. Factors reflecting emotional intensity were also commonly observed. Correlation of scores with BOLD revealed brain areas related to aesthetic preferences, including several sites previously reported for art and non-art stimuli (striatum, ventromedial prefrontal cortex, anterior cingulate). In addition, we found several frontal (frontal operculum, ventromedial prefrontal cortex, superior frontal sulcus, precentral sulcus), posterior (intra-parietal sulcus, superior temporal sulcus), and subcortical sites (mediodorsal thalamus, substantia nigra) not previously reported. Both the behavioral and brain data suggest that an aesthetic reaction to visual artwork is more multidimensional than a simple preference, is highly individual, and involves the interaction of multiple emotional components.

33.314

Effects of scene inversion on boundary extension

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People apply previously learned contextual knowledge to facilitate the perception and encoding of scenes. When extrapolation following the employment of contextual information occurs, it sometimes leads to scene memory distortion: people report as if they saw more than they actually had seen. This phenomenon is called the "boundary extension" effect (Intraub & Richardson, 1989). The present study aimed to clarify the effects of contextual information on boundary extension in a more systematic way. Based on the assumption that it is harder to extract contextual information from inverted scenes compared to intact scenes (Kelley, Chun, & Chua, 2003), we presented inverted scenes either during encoding or retrieval to manipulate the level of contextual information and compared the magnitude of boundary extension effect for upright versus inverted scenes. In a series of experiments, we found that scene inversion during encoding, but not during retrieval, significantly reduced boundary extension. We further confirmed this finding in a recognition test for peripheral objects in scenes. Using objects which shared context with, but were absent in the original scene stimuli, we expected that scene inversion would reduce false recognition of those objects. The result showed that false recognition occurs significantly less often for inverted scenes compared to upright scenes. Showing reduced memory distortion for inverted scenes, the current study directly demonstrated that access to contextual information is a critical component of scene extrapolation process.

33.315

Experience-dependent psychological distance in a distance Stroop task

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Psychological distance refers to the perceived gap between a stimulus and a person's direct experience and its activation influences the decisions and actions that the person makes towards the stimulus. In a picture-word version of the Stroop task, when a word conveying close psychological distance (e.g., "friend") appeared geographically closer, its identity was judged faster relative to a word conveying far distance (e.g., "enemy"). It was suggested that the interference between social distance and spatial distance contributes to this effect (Bar-Anon et al., 2007). In the current study, we tested whether the level of familiarity might affect the construction of psychological distance. We hypothesized that a familiar stimulus, relative to an unfamiliar stimulus, is perceived to be psychologically closer to the observer and so its perception might be modulated by the perceived spatial distance. To test this hypothesis, we first trained participants for nonsense words in a lexical decision task. Three nonsense words were presented in nonword trials with pre-assigned exposure frequency (56, 16, and 8 times in total 160 trials). Participants then performed a distance Stroop task with the most familiar and the least familiar nonwords. Two nonsense words were presented equally often and each of them appeared in either proximal or distant spatial locations in 16 different scenes with clear depth cues. Participants were asked to make a speeded judgment on the identity of each word regardless of spatial location. The results showed a significant interaction between the word familiarity and the spatial distance: the familiar word was judged faster in proximal locations but slower in distant locations relative to the unfamiliar word. The current findings suggest that familiarity could be one of the critical factors that underlie the construction of psychological distance.

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33.316

General and Specific Effects of Expertise on Change Detection

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Expertise in a particular domain can bias visual attention and memory toward expertise relevant information. This bias is generally thought to be domain specific. That is, there are differences in the allocation of attention and memory for information relevant to the domain of expertise, but not for non-relevant information. In the current studies we examined biases in the allocation of attention for experts in radiology. Participants detected changes to real-world scenes and to radiographs. In Experiment 1, change detection performance on a one-shot change detection task was examined for undergraduates, 1st year veterinary medicine students and 4th year veterinary medicine students. There were no differences in performance on the real world scenes between groups, but 4th year veterinary students performed significantly better on the radiograph change detection task than the undergraduates. In Experiment 2, a flicker change detection task was used and the expert group consisted of veterinary doctors rather than veterinary students. Two novice groups were used in Experiment 2, psychology undergraduates and PhDs from the Psychology and Sociology departments. The accuracy data replicated Experiment 1; accuracy did not differ between novices and experts for the real-world scene change detection task and, experts were more accurate than novices on the radiograph change detection task. Interestingly, the reaction time data on the flicker task revealed an interaction between level of expertise and change detection task. That is, experts were faster at detecting changes in radiographs than in real world scenes and novices showed the opposite pattern. This interaction was caused not only by the experts detecting changes faster in the radiographs than the novices, but also by the experts detecting changes in the real-world scenes slower than the novices. This suggests a general effect of expertise that leads to a decrement in performance for non-domain specific information.

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Face Perception: Wholes, Parts, Configurations and Features

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

33.317

The use of shape and pigmentation information across the spectrum of face recognition ability

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Recent work has demonstrated that the range of face recognition ability is very large, with developmental prosopagnosics at the low end (who in severe cases have difficulty identifying nuclear family members) and super-recognizers at the high end (who report rarely forgetting a face). It is not known what underlies this variation. One possibility is that lower-level perceptual abilities predict face recognition ability. Shape and pigmentation (surface reflectance) information have been shown to be about equally useful for face recognition by normal observers. This study seeks to determine whether this is also the case for people with very good and very bad face recognition ability, in order to determine whether face recognition ability is selectively associated with ability to perceive face shape or face pigmentation. Here we report findings from prosopagnosics and super-recognizers as well as normal control subjects. Subjects performed a facial similarity task, in which they sorted a set of faces in order of similarity to a target face. In the pigmentation condition all the faces had the same shape but different pigmentation, so that use of pigmentation information was required to perform the task. In the shape condition all the faces to be sorted had the same pigmentation but different shape, so that use of shape information was required to perform the task. By comparing performance by developmental prosopagnosics, normal control subjects, and super-recognizers on the shape and pigmentation conditions, we can determine whether shape or pigmentation perception is associated with face recognition ability.

33.318

The Role of Eyebrows in Face Recognition: With, Without, and Different

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The primate visual system is exceptional, particularly when used for face recognition and discrimination. While it is generally accepted that facial features are processed holistically, eyes have long been considered the facial feature that is most important; however, most examinations of the salient features in face processing involving manipulations of the eyes have used only the eyes or a combination of the eyes and eyebrows. Recent evidence has suggested that the eyebrows alone may be an important feature for recognition, perhaps second in importance only to the eyes. There are several possible explanations for this importance: eyebrows sit on a convexity, are high contrast features that are relatively large, tend to be a stable facial feature, and appear to be important for conveying emotion and other nonverbal information. Even so, eyebrows have received little attention from face recognition researchers. The present study used the Brown face database, digitally manipulated using Adobe Photoshop, to explore the role of eyebrows in face recognition. Subjects were asked to identify whether two faces presented sequentially were the same or different. On same trials, subjects were presented with one of three possible face-pairs: two original faces; one original face and the same face with digitally removed eyebrows; or one original face and the same face with digitally exchanged eyebrows. Results suggested that eyebrows are an important feature in face processing, indicating that additional research is needed to further explore the role of eyebrows in face recognition.

33.319

Are Local Changes in Faces Really Local?

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In Anes, Short & Storer (VSS08), brief face presentations with an inverted eye (but not eyebrow) in the LVF resulted in greater bizarreness ratings than RVF inverted eye presentations. In Experiment 1 of the present study, participants (n=15) viewed an unaltered target face, then a 120 ms exposure of a probe face, and indicated whether the probe was the same as the target. Same judgment RTs increased for LVF eye inversions (648 ms) relative to unaltered faces (604 ms, $t[14]=3.49$, $p<.01$) and RVF eye inversions (608 ms, $t[14]=2.39$, $p<.05$). Local and/or global relational information disrupted by Thatcherizing an eye appears to be more efficiently encoded by the right hemisphere, resulting in both elevated bizarreness ratings and same judgment RTs.

We address recent work by Goffaux and colleagues in which independent manipulations of interocular distance and vertical eye position (Δ=15 pixels) were made. In these studies, the RH is quite sensitive to vertical displacement of the eyes and the LH is sensitive to horizontal displacement and feature changes. In Experiment 2 here, stimuli with one eye moved out or down (Δ = 3 or 6 pixels, with the eyebrow position fixed) were presented in the same/different task. We hypothesized that RVF horizontal manipulations and LVF vertical manipulations would increase same judgment RTs over those for unaltered faces, but observed no visual field by manipulation interaction. Same judgment RT increases after 3 pixel displacements tended to be higher in the RVF than LVF. Conversely, 6 pixel displacements in the LVF resulted in greater same judgment RT increases than in the RVF. Are small vertical or horizontal changes more local and LH-mediated while slightly larger changes are local and global and RH-mediated? In another planned experiment we will move the eye and eyebrow together to maintain local relations while disrupting global configuration.

Sunday Sessions

33.320

Social monitoring: The psychophysics of facial communication

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We often rely on the facial expressions of others to determine our response to events they can see, but we cannot (e.g., a dog barking behind you likely poses no threat if the person facing you is smiling). Recent advances in personal computing now make it convenient to study social monitoring in new ways. Specifically, the video camera atop the screen makes it possible to record the dynamic expressions of participants otherwise engaged in the tasks studied by cognitive scientists. The video clips of these facial expressions can then be used as stimuli in their own right to study social monitoring processes and abilities.

In our lab we began by selecting 80 photos from the IAP set (Lang et al., 2005) that varied in valence (negative vs. positive) and arousal (low vs. high). In Part 1 the 80 images were presented in a random order for 3 sec, with participants viewing the complete set three times. The first time no mention was made of facial expressions. Participants were told the camera would record where they were looking while they categorized images as negative or positive. The second time they were asked to deliberately make expressions that would convey the emotional tone of the picture to someone else. The third time they were asked to make expressions that would mislead someone regarding the picture.

In Part 2 the video clips from these three phases were used to answer several questions about social monitoring: Which IAP pictures result in reliable spontaneous expressions that convey emotions to viewers? Does reading someone's facial expression improve with training through feedback? How easy is it to discriminate genuine from faked expressions? Answers to these and other questions will be presented in discussing how to harness this new technology in the study of social-cognitive perception.

33.321

The discrimination of features, configuration and contour by patients with acquired prosopagnosia

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Studies of the face inversion effect suggest that the configuration of internal features may have special status for expert face-processing mechanisms. Experiments with prosopagnosic subjects have shown that lesions of the fusiform gyrus impair the discrimination of such configurations. However, whether this impairment is selective or part of a more pervasive difficulty with facial structure is unclear.

We studied five patients with acquired prosopagnosia. We used an oddity paradigm in which they had to determine which of three simultaneously viewed faces differed from two others under unlimited viewing duration. Faces could differ in one of six ways, in external contour (forehead or chin), feature configuration (horizontal eye position or vertical mouth position), or feature shape (eye or mouth width). Processing load and attentional requirements were varied by using blocks in which either all 6 changes were possible, only one change was possible, or two changes were possible.

Patients varied in their results. One patient with bilateral anterior temporal damage showed little perceptual deficit in any condition. A left-handed patient with right FFA/OFA damage had a selective deficit for eye position in the 1-change and 2-change conditions, but had general impairments in the 6-change condition. Another left-handed patient with bilateral anterior temporal damage and loss of the right FFA/OFA was impaired for eye shape and eye position in all conditions, with deficits for mouth shape under 2-change and 6-change conditions. A patient with bilateral occipito-temporal damage was impaired for all stimuli in all conditions. A similar pervasive deficit was surprisingly found in the last patient, with a small right amygdalohippocampectomy.

We conclude that eye position may be particularly vulnerable to perceptual deficits in prosopagnosia, but that more general difficulties in perceiving other aspects of facial structure can occur, particularly under conditions stressing attention to the whole face.

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33.322

Classification of fMRI activation patterns in face-sensitive cortex to the parts and location of faces

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The fusiform face area (FFA) and occipital face area (OFA) are known to respond more to faces than other objects, but the spatial structure of processing within these areas is not yet known. Previous physiological investigations in primates and neuroimaging studies in humans suggest that face-sensitive regions contain independent neural populations that are tuned to the internal features of the face, the shape of the head, or the full face, i.e., the conjunction of the features and the head outline. To test this hypothesis, we obtained fMRI data from eight participants while they viewed images of synthetic full faces, internal features, or head outlines. The FFA and OFA, defined as the regions with greater activation to photographs of faces compared to houses, were localized within individual subjects in a separate set of functional scans. We constructed linear pattern classifiers, based on all voxels in the regions of interest, using support vector machines, to test whether the FFA and OFA process the three different types of stimuli in a spatially distributed manner. Classification was significantly above chance for all types of stimuli according to a leave-one-out verification procedure. In an additional experiment, we found a dissociation in processing between the areas. Classification of the physical position of a face, in one of four visual quadrants, was better in OFA, than FFA, but classification of the type of stimulus, across position, was better in FFA than OFA. This suggests that the FFA and OFA are involved in different aspects of face processing, with OFA positioned earlier in the processing stream. The results are consistent with a columnar organization of faces and face parts, which in turn would support tasks such as viewpoint processing, gender classification, and identity discrimination.

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33.323

The fusiform face area is recruited more for sequential than holistic processing: an aperture viewing study

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Faces are particularly well suited to recruit holistic processing, whereas other classes of objects recruit more feature-based processing. Sequential presentation of features disrupts the perception of second-order relations and therefore disrupts holistic processing. One way of presenting features sequentially is with aperture viewing, where subjects view the object through a small, moveable aperture. Here, we compared BOLD fMRI measurements during aperture viewing and normal (whole) viewing of faces, Greebles, and buildings to test the effect of sequential feature-based presentation on activation in the FFA and other areas of visual cortex. Neuroimaging and neuropsychological studies have linked holistic processing with a face-selective region of cortex in the fusiform gyrus called the fusiform face area (FFA). However, contrary to our prediction based on this evidence, the FFA showed more activation with aperture viewing than whole viewing, suggesting that the FFA may not be recruited solely or specifically for holistic processing. The superior temporal sulcus (STS), which is another face-selective region, showed a different pattern of activation than the FFA, in which activation decreased while subjects were actively exploring the stimulus, then increased at the termination of the trial. Early visual cortex showed a third distinct pattern, which was sustained deactivation below fixation baseline. This pattern may be due to the influence of aperture view-

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ing on the spatial allocation of attentional resources. The results are discussed in terms of the spatial and temporal integration processes required to successfully recognize objects under aperture viewing conditions.

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33.324

Flexible Neural Tuning for Face Parts and Wholes in the Fusiform Face Area

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Visual perception is qualitatively modified by experience, changing from part-based to holistic with familiarity or expertise. Yet the neural correlates of such effects in higher-level visual areas remain relatively unexplored. Here we examined the neural basis of flexible changes in neural tuning to parts and wholes using a manipulation of perceptual similarity, which has previously been shown to affect visual processing. Unfamiliar faces were arranged along arbitrarily-defined eye and mouth dimensions either equidistantly ("Diamond" stimulus space) or asymmetrically ("Kite" space) to differentially engage holistic or part-based processing, respectively. Although subjects were never informed of the stimulus space arrangements, they nonetheless showed a significantly smaller face inversion effect for the Kite space, suggesting that this stimulus set is processed in a more part-based manner. Functional magnetic resonance imaging (fMRI) of the Diamond versus Kite stimulus space during an unrelated target detection task revealed a corresponding switch from holistic to part-based tuning in face-selective right fusiform gyrus (the Fusiform Face Area, or "FFA"). In contrast, the left FFA consistently showed part-based tuning for both Diamond and Kite spaces. Thus, the flexible tuning of the right FFA for wholes and parts cannot be explained as a general response property of ventral visual areas, but likely reflects this region's special importance for holistic processing of faces. These data indicate that, at least in some high-level visual areas, recruitment of holistic or part-based representations can be modulated by perceptual similarity. Together with previous data on familiarity (Harris & Aguirre, 2008), these results underscore the flexibility of neural tuning within higher visual areas, suggesting that factors such as familiarity and perceptual similarity may interact for increased efficiency of sensory coding.

33.325

Configural information in mother's face perception for infants

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The importance of configural information in face processing has been demonstrated widely on adults (e.g. Maurer et al, 2002). Additionally, infants' face studies indicated that 7- to 8-month-olds have an ability to be sensitive for the configural facial information (Thompson et al, 2001).

One paradigm for investigating the configural information on face perception is the composite face paradigm, which was created by Young et al (1987). The stimuli on the paradigm were combined the top part of a famous face with the bottom part of another. Chimeric face was created by aligning both parts, while the non-composite face was the misalignment of the top and the bottom parts of faces. The finding showed that recognition on the chimeric faces was more difficult than when the faces were non-composite faces.

In this study, we investigated what facial information is effective for 5- to 8-month-old infants to discriminate their own mother's face with unfamiliar faces by the composite face paradigm. We presented a pair of mother's face and unfamiliar face on three conditions; the normal condition (non-modified face images), the composite condition (chimeric face images), and the non-composite condition (misaligned face images). The stimuli were presented for 15 sec x 2trials on each condition.

Our results showed that 7- to 8- month-olds could show the preference for their mother's face on the non-composite condition, whereas they could not discriminate between mother's and unfamiliar faces on the composite condition. These results were consisted with adults' composite face studies. In contrast, there was no preference for their mother's faces on composite as well as non-composite conditions on 5- to 6-month-olds.

Those results suggest that 1) there is the developmental difference on configural face processing, and 2) infants aged over 7-month-old are sensitive to configural information on familiar face perception.

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33.326

Can Motion Cues Facilitate Configural Face Processing in Children?

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A classic developmental account of face recognition suggests that adults are proficient in processing both local featural cues and configural cues, with the latter ability emerging more gradually in development. Evidence supporting this qualitative view comes from studies demonstrating that children are impaired in configural processing, but not featural processing, compared to adults. However, findings have been inconsistent across studies. Proponents of the opposing (quantitative) view contend that various demonstrations of configural impairments in children may actually reflect factors related to general cognitive development, such as working memory capacity or selective attention.

In the current investigation, we attempted to identify one such potential confound. Motion cues are of particular importance to form perception earlier in life, so that static stimuli may offer an unfair advantage to adults in perceptual tasks. We investigated whether the addition of rotational motion to a typical face discrimination task, such as that used in Mondloch et al. (2004), would eliminate age effects for configural processing. Faces differed in either the spacing among local features or the appearance of the local features themselves. In an earlier version of this study, we found no evidence of a configural impairment in children with either static or moving stimuli, but we also were not able to demonstrate the motion benefit for the younger group that we had expected, (Shroff et al., 2008). Preliminary findings from the current study, which includes several stimulus refinements, indicate that access to motion cues may boost children's configural performance for those perceptual tasks that would be too difficult with only static cues available. This lends support to the quantitative view, as it suggests that configural processing may emerge early in development, but is simply more vulnerable to disruption due to other cognitive deficits.

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33.327

Does holistic processing predict face identification? The effect of aging

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Although most young observers exhibit holistic processing, the extent of holistic processing does not predict face identification (Konar et al., JOV 2008). Here we examined the effects of aging on holistic face processing, as indexed by the Composite Face Effect (CFE), and the role holistic processes play in face identification. The CFE was measured in two groups of younger (mean=22.0 and 19.3 years; n=24 and 52) and older (mean=69.9 and 68.1 years; n=26 and 24) adults. All groups had significant CFEs. There was an age difference in the CFE based on measures of response time in both experiments, with old adults showing higher CFEs (ts≥2.4, ps≤0.03). There was no age difference in the CFE based on accuracy (ts≤-0.5, ps≥0.63). Therefore there was no evidence that holistic processing, as indexed by the CFE, declines with age, consistent with previous suggestions that holistic processing is spared in aging (Boutet & Faubert, 2006).

We then correlated the CFE with face identification accuracy measured in a 10 AFC task that used an unlimited viewing time, and a 4 AFC task that used a short stimulus duration that was identical to the one used in the CFE task. Accuracy in the 10 AFC task did not differ between age groups, but accuracy was lower in older subjects in the 4 AFC task. As reported previously, CFE and face identification were not correlated in younger subjects. In older subjects, CFEs were not correlated with accuracy in the 10 AFC identification task, but CFEs based on response accuracy, not reaction time, approached a significant correlation with face identification accuracy in the 4 AFC task (rho=0.36). The results suggest that holistic processing is maintained throughout our adult lives, and suggest that such processing may place greater constraints on face identification as we age.

Acknowledgement: This research was supported by NSERC grants to PJB and ABS (42133 and 105494), and the Canada Research Chair programme.

33.328

Spatial structure and whole-object processing in acquired prosopagnosia: the meaning of configuration

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Facial configural processing may be preferentially vulnerable to face inversion, and there are reports that patients with an apperceptive variant of acquired prosopagnosia have impaired configural processing. However, configuration has several meanings, including the perception of spatial structure (particularly second-order relations) or holistic styles of processing. To distinguish between these two, we recruited ten patients with acquired prosopagnosia to test their processing of abstract objects, in which whole-object processing demands could be manipulated more systematically than faces.

First, we used an oddity paradigm in which subjects had to compare three dot patterns to detect the odd one out. This consisted of a series of blocks in which we manipulated stimulus complexity (number of dots = 2, 4 or 8), variations in size and orientation between the three patterns, or the regularity of global structure (octagons versus random structure in the 8-dot stimuli) generated effects that would suggest a failure to process at a whole-object level. Second, we used hierarchical letters, to determine if reaction times reflected perception of global structure.

With dot-patterns, patients were impaired even for simple 2-dot stimuli, but did better with more complex patterns, when size or orientation varied, or with a regular global structure. In experiment 2, they demonstrated normal latency effects of global-level processing.

We conclude that apperceptive prosopagnosia is associated with a configural deficit that impairs perception of spatial structure, not just for faces but also for non-facial patterns. While we cannot conclude that holistic processing is entirely normal in these subjects, their performance shows significant modulation by whole-object structure, indicating that some whole-object processing is occurring in these patients.

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33.329

Acquired prosopagnosia following right unilateral brain damage: Impairment specific to holistic processing of the individual face

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Acquired prosopagnosia – the inability to recognize individual faces despite preserved low-level visual and intellectual abilities – can inform normal face recognition theories. Here, we present the extensive investigation of a new case of prosopagnosia, GG (66 years old), who sustained a stroke to the right posterior cerebral artery, damaging the occipital lobe, lateral fusiform and parahippocampal gyri, unilaterally in the right hemisphere. GG presents a massive prosopagnosia, being unable to recognize from their face both famous and familiar people.

Our behavioural testing of GG (25 experiments) and age-matched controls aimed at addressing three major issues in the literature: (1) can the impairment be restricted to faces; (2) is it a matter of detection or individualization of faces; (3) what is the nature of the deficit. First, GG failed all experiments involving face retrograde/anterograde memory and perception. Contrariwise, he was normal at mnesic and perceptual tests with several other object categories (chairs, boats, cars, birds, dogs, famous places). Moreover, he showed normal basic visual integrative processes (Navon effect, 3D figures matching, dots configurations perception). Second, a set of face detection tasks (faces in visual scenes, Mooney and Arcimboldo faces) revealed preserved facial detection abilities, even when face detection is based on global information rather than detailed features. Third, we tested GG with classical paradigms measuring holistic face processing (face inversion effect, composite effect, whole-part advantage). Strikingly, GG did not show any of the three effects. Finally, two face matching experiments showed a reduced sensitivity to the eyes region, and a processing bias to the mouth.

Altogether, these observations are in line with different previous studies of prosopagnosia, indicating that lesions to different localizations in the right cortical face network can lead to an inability to extract a holistic representation of the individual face, a fundamental process for normal face recognition.

33.330

Detecting the Thatcher illusion in a case of prosopagnosia

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We explored configural face processing in a prosopagnosic patient (PHD, Eimer and McCarthy, 1999) who does not produce an N170 is response for faces. In two sets of studies he was presented with two versions of the Thatcher illusion. In the first set, he was asked to detect Thatcherized from matched typical faces from successive single presentations of faces. He also performed a simultaneous 2 alternative forced choice (2AFC) discrimination task with the same stimulus set to address the question of whether pairs of faces were the same or different. In the second set he was asked to detect Thatcherized from matched typical faces. He also performed in control conditions where orientation decisions were made to isolated eye and mouth features, as well as eye and mouth features presented alone but within face outlines. The results were analyzed using d-prime and C to facilitate cross condition comparisons. The data showed PHD unable to detect Thatcherized from matched typical faces in either study 1 or 2. However, he was as sensitive as controls in the 2AFC discrimination condition of Study 1. In study 2 he showed evidence of moderate sensitivity to the identification of orientation for isolated features; this sensitivity was much enhanced for eyes by face outlines but hindered for mouths. We interpret these findings as showing intact feature processing that should be sufficient to allow the detection of the Thatcher illusion, as well as some evidence of relational processing for eyes but not mouths. However, simultaneous presentation of features and face outline does not allow selective attention to eyes that would enable detection of Thatcherized from matched typical faces. The results suggest one aspect of successful face categorization is to determine face-specific configural routines that allocate attention within faces and that these are missing in PHD.

33.331

Squirrel monkey (Saimiri sciureus) can perceive Thatcher Illusion

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PORPOSE: Thatcher illusion is a phenomenon where it is hard to detect the change of local features in an inverted face, although we can easily recognize the change in an upright face (Thompson, 1980). This illusion is thought to be due to the face configural processing. There is no evidence that the squirrel monkey can perceive Thatcher illusion.

 See page 3 for Abstract Numbering System

METHOD: Subjects were two squirrel monkeys and human participants. The stimuli consisted of the target human face and three kinds of distractor human faces. In the training phase, the discrimination between the target face and two kinds of distractor face (e.g. the face with difference of the eyes from the target face) was trained until the subject obtained the given criteria. In the test phase, the subject was asked to discriminate between the target face and the new distractor face (the face with reversing the eyes from the target face). The faces were tilted at the angles of 45, 135, 225, 315 degrees, there was four conditions as below. A: both the target and the distractor faces were upright, B: the target was upright and the distractor was inverted, C: the target was inverted and the distractor was upright, and D: both the target and the distractor were inverted.

RESULTS AND DISCUSSION: In the training phases, the subject could reach the criteria at or less 5 sessions in all conditions. In the test phases, the condition A, B, and C could immediately reach the criteria. On the other hand, the condition D was needed to 19 sessions for reaching the criteria. These result shows that it is hard to detect the change in an inverted face by the monkey. Squirrel monkey can perceive Thatcher illusion. These results suggest that the squirrel monkey could utilize the configuration of the face like human do.

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33.332

Contrasting methods of model estimation for configural and holistic perception

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A central question in perceptual and cognitive psychology is the nature of the processes that combine the multiple sources of environmental information in order to support the subjective, unitary percepts of objects. One of the more promising extant approaches is known as general recognition theory (GRT). GRT provides formal, mathematically-specified definitions of the ways in which perceptual dimensions (e.g., the various elements of a face) can interact during perception and identification, and generalizes the signal-detection-based distinction between perceptual and decisional effects to multidimensional stimuli. Although the formalisms of GRT provide clear definitions and distinctions, there are only a limited set of quantitative and statistical methodologies available for relating theory to data, and there have been (to date) no attempts to comprehensively assess the relative strengths and weaknesses of these approaches. The work presented here is an initial attempt providing this comprehensive assessment. We consider three approaches to the question of model estimation and recovery. The first, based on work by Ashby, Kadlec, and Townsend, involves application of a set of measures applied to response frequencies drawn from signal detection theory. The second, based on work by Maddox, Ashby, and Thomas, involves the numerical estimation of model parameters under a variety of constraints. The third approach, based on work by De Carlo and Rouder, involves estimation in terms of novel extensions to standard statistical methods. The approaches are contrasted using data sets with known configurations, including violations of underlying model assumptions (including mean-shift integrality), and performance is characterized in terms of rates of inferential error, sign and magnitude of statistical bias, and consistency and efficiency. In addition, the models are contrasted using published data sets. The results of these efforts are used to highlight weaknesses in current approaches that require further work.

Attention: Brain Mechanisms

Sunday, May 10, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

33.401

CONUS masking reveals saliency representation in reach-related areas of the posterior parietal cortex

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The parietal reach region (PRR) and Area 5 of the posterior parietal cortex (PPC) have been shown to encode reach plans. However, there have not yet been studies examining the possible effects of attention on visual responses in these parts of the PPC. We used a new masking technique which highlights salient regions of an image, CONUS (Complementary NatUral Scene) masking (Wilimzig et al., 2008), to examine whether PRR and Area 5 represent salient features in natural scenes.

Presenting a brief flash of a natural scene (6.2 ms, e. g.) followed by an equally brief flash of the CONUS mask –the exact inverse of the natural scene which may simply be obtained by subtracting it from the maximum entry in each respective color channel - to human subjects results in a percept that closely resembles the saliency map of a natural scene by masking non-salient regions of the image while nonlinear temporal integration preserves some information within salient regions of the image. An advantage of this paradigm is that it can produce saliency maps rather automatically and without requiring the subject to perform a behavioral-attention task. A monkey (macaca mulatta) passively viewed natural scenes while PRR and Area 5 spiking activity was recorded from a microelectrode array implant. The activity for non-salient regions of the images decreases due to the presentation of the CONUS mask while activation for salient regions increased consistent with psychophysical results in human subjects.

The experimental phenomenon of CONUS masking and finding its neural basis provide important constraints on the current understanding of saliency processing in the brain and on computational approaches to saliency, specifically due to its relationship with temporal integration. In addition, our newly developed paradigm provides an important tool for investigating the neural basis of saliency representation for natural scenes in neurophysiological experiments.

33.402

Behaviorally-related variability of hemodynamic responses in macaque V4

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Identical stimuli can generate neuronal response with highly variable response amplitudes and timecourses. We ask whether variability in neuronal response (one measure of noise) depends on behavioral state. To address this question, we used intrinsic signal optical imaging to study the hemodynamic response area V4 in individual macaque monkeys in 4 behavioral states: Attention-In, Attention-Out, Passive Fixation, and Anesthetized (cf. Tanigawa et al NS abstract 2008). Between 70-100 trials were acquired for 4 sec at 4hz per condition. First-frame subtracted reflectance change (dR/R) timecourses from regions of interest overlying V4 color, luminance, and orientation domains were plotted. Using condition-specific amplitude-normalized response, the deviation between the dR/R and the mean dR/R for each time frame was calculated and averaged across all trials. Mean deviation values and associated standard error were compared across conditions.

Domain-specific comparisons showed that neuronal variability from hemodynamic responses were dependent on behavioral state. The timecourse of deviation values showed different temporal patterns of response variability for the different behavioral conditions. In the Anesthetized state, deviation values climbed monotonically over the 4 sec acquisition period. In contrast, in the awake states deviation magnitudes increased initially and then plateaued. Moreover, deviation values for Attention-In were initially greater than Attention-Out conditions but plateaued at smaller values in the latter part of the 4 sec acquisition period. Attention-Out and Fixation were indistinguishable. Behaviorally related effects appeared similar across color, luminance, and orientation domains in V4. These behavior-related differences in hemodynamic response variability in macaque V4 suggest a lower level of neuronal noise in the alert than anesthetized state and furthermore that, in the alert animal, attention has a predictable effect on neuronal noise over the timecourse of the task.

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URL: http://www.psy.vanderbilt.edu/faculty/roeaw/index.html

33.403

Attentional enhancement of orientation responses in human visual cortex depends on task

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When spatial attention is directed to a stimulus, are all of the features contained in that stimulus more strongly encoded in the visual system, or are feature-selective responses strengthened only for those features that are relevant to the task performed by the subject? We used functional MRI in combination with pattern-based analyses to address these questions. Subjects performed either an orientation discrimination task or a contrast discrimination task involving one of two laterally presented gratings. Attention was directed to one or the other grating by a central cue, and task difficulty was manipulated using an adaptive staircase procedure. With both tasks, much stronger BOLD responses were observed for attended stimulus locations than unattended locations in early visual areas. To test whether this also improved the strength of orientation-selective responses, we used a pattern-based analysis to decode the presented stimulus orientation from cortical activity in these regions. In the orientation discrimination task, we found significantly better decoding performance in the attended condition as compared to the unattended condition in areas V1, V2 and V3. However, this attentional enhancement of cortical responses to orientation was not found in the contrast discrimination task. We conclude that while the overall BOLD amplitude increases with attention regardless of task, attentional enhancement of feature-selective responses depends on the task performed.

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33.404

Attentional modulation in human visual cortex is constrained by the degree of competition among stimuli

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Natural scenes contain multiple objects that compete for neural representation in visual cortex by mutually suppressing their activity. These competitive interactions can be biased both by top-down and bottom-up factors. Here, we probe the idea that the local neural circuits mediating competitive interactions provide an interface for attentional mechanisms to operate on. If so, the magnitude of attention effects will directly correlate with the degree of neural competition. To investigate the interaction of attention and competition, 3 different types of stimulus arrays were created that varied in their degree of perceptual organization (noPO, weakPO, strongPO), inducing varying degrees of competition as shown previously. Each stimulus array was presented while subjects either attended to the array or attended away, performing a task at fixation. The stimulus consisted of four illusory contour inducers, which were displayed in the upper right visual quadrant. In the strongPO condition, inducers were rotated inward forming an illusory figure (i.e. a square). In the weakPO condition, the inducers were aligned to form a percept of a loosely defined figure. In the noPO condition, inducers were rotated outward, forming no figure. To measure the degree of competition, the stimuli were presented either sequentially (SEQ) or simultaneously (SIM). Sensory suppression indexes (SSI) were calculated for each visual area (V1-V4), for each level of PO and each attentional condition: (SEQ-SIM)/(SEQ+SIM), larger indexes represented a greater degree of competition. In the unattended conditions, SSIs were largest for the noPO condition and smallest for the strongPO condition. When the stimulus array was attended, attentional enhancement was largest for the SIM noPO condition, resulting in a larger reduction of the noPO SSIs compared to the strongPO SSIs throughout extrastriate cortex. This suggests that the amount of attentional enhancement observed is dependent upon the amount of competition left unresolved after bottom-up processes occur.

33.405

Active ignoring in early visual cortex

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The time taken to find a search target amongst distractors can be reduced if half the distractors are previewed before the remainder of the distractors (and target) are added to the display. Participants behave as if they are excluding the previewed items from their search. Previous studies suggest that this "preview benefit" results from active ignoring of search items presented in the preview display. These studies also reveal enhanced neural activation in posterior parietal cortex in response to preview trials. Here we investigated, using event-related fMRI, whether changes in neural activity during active ignoring can be found in early visual cortex.

Whilst maintaining central fixation, participants searched for a sideward T amongst a set of L-shaped distractors. In the Preview condition an initial display of distractors was previewed and remained on the screen when the new distractor items and target appeared. In the Full Set condition the initial distractor display was uninformative and disappeared upon arrival of the new distractors and target. The number of distractor items in the second display was identical in the two conditions. Crucially, on a minority of trials (Preview-display only and Full Set-first-display only trials) the second display was not presented. These trials were visually identical between conditions, only the expectation of the participant differed. This allowed us to measure preparatory activity associated with ignoring the previewed distractors.

We found higher activation in early visual cortex in the Preview-display only trials compared to the Full Set-first-display only trials during blocks of trials where participants benefited from the preview display. This is consistent with increased attention to the successfully previewed items. We also found that this activation was modulated by the amount of preview benefit. Our results suggest that active ignoring of previewed distractors leads to signal changes even in the earliest visual areas.

33.406

Up and down-regulation of visual cortex by posterior parietal cortex modulates selection-by-saliency: Evidence from combined TMS-fMRI

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Objective: Using TMS over the parietal cortex, we have recently shown (Mevorach et al., 2006) that selection and suppression of saliency are lateralised in the brain with the right pIPS critical for the selection of salient targets and left pIPS critical for the suppression of salient but irrelevant information. It is not known, however, whether TMS applied over the parietal cortex also results in changes of brain activity in other functionally related areas which are combined to bring about the change in behaviour. In the present study we combined offline TMS with functional brain imaging to assess the differences in brain activity induced by TMS that underlie the changes in behaviour.

Methods: In two sessions participants performed a Global/Local task where the relative saliency of target and distractor levels was manipulated. In each session participants performed the task twice while functional brain imaging data were collected. In between those scans 20 minutes of offline TMS was applied over either the left or right pIPS.

Results: The behavioural data indicated dissociable effects for left and right IPS stimulation in accordance with the left and right pIPS being critical for the suppression and the selection of saliency, respectively. In addition, the imaging data revealed differential effects of left and right pIPS stimulation on visual cortex, with increased activity following TMS over the left pIPS compared with TMS over right pIPS.

Conclusion: The data support the notion that TMS over a particular site can lead to activation change in other remote (but functionally related) brain regions. In particular it suggests that selection of salient information benefits from an increase in brain activity in visual cortex (which is modulated by the right pIPS), whereas suppression of saliency benefits from a reduction in brain activity in visual cortex (which is modulated by the left pIPS).

33.407

Disentangling selective attention from orienting of attention

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Selective attention and orienting of attention have sometimes been used interchangeably in the literature. However, there is some evidence suggesting that the two mechanisms may implicate distinct areas of the brain. The distinction between selective- and orienting of- attention is important for both theoretical and clinical reasons since it has implications for the diagnosis and treatment of ADHD as well as of other clinical populations. A special paradigm was designed (for use in the scanner) in order to investigate whether these two aspects of attention are dependent or distinct. The paradigm is a combination of the cost-benefit technique (Posner, Snyder, & Davidson, 1980) with an exogenous cue (Jonides, 1981) and a conjunctive visual search task (Triesman & Gelade, 1980). This new paradigm enabled us to compare low vs. high selective attention conditions as well as valid vs. invalid trials within a single task. As was expected, the behavioral data showed significant main effects of selectivity and validity whereas there was no interaction between these factors. Moreover, imaging data showed that selective and orienting attention were mediated by two rather distinct fronto-parietal networks. Both functions activated the cingulate gyrus but at different foci. Orienting-related activation was evident in the inferior frontal gyrus and precentral gyrus. Selecting-related activation was found in the medial frontal gyrus and at some parietal regions in the left hemisphere. These results support the hypothesis that these are two independent functions as assumed by the four-facet model of attention (Tsal, Shalev & Mevorach, 2005). Since in some cases ADHD is characterized by weak selective attention and/or deficient orienting of attention the present findings may help in the future to shed light on the etiology of ADHD.

33.408

Neural Mechanisms of Voluntary and Involuntary Attention

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In the present study, we used a spatial cueing task to investigate fMRI activity associated with voluntary and involuntary attention. A spatial cue appeared on either the left or the right side of fixation, above the horizontal meridian (HM). 250 milliseconds later, a target appeared below the HM, either on the cued- or on the uncued side. The target was one of two faces, and the participants' task was to indicate which face was presented. The spatial separation of cue and target allowed separate measurements of cue- and target-related fMRI responses in retinotopic visual areas. Attention type was manipulated by varying the proportion of targets appearing on the cued vs. the uncued side. For half of the blocks, the cue was non-predictive of target location, engaging only involuntary attention. In the remaining blocks, the cue was predictive of target location, engaging both voluntary and involuntary attention. All blocks included cue-only trials which allowed measurement of the responses to cue presentation alone in the different attention conditions. Blocks in which the cue preceded target presentation were paired with matched post-cue blocks in which the order of cue and target was reversed, rendering the cue temporally task-irrelevant. Behaviorally, participants were significantly faster when the target appeared in the cued side for both predictive and non-predictive blocks, and this difference was larger in the predictive condition. Importantly, post-cueing resulted in no difference between cued and uncued RTs. fMRI localizers were used to define cue- and target-related ROIs in occipital and parietal cortex as well as ventral face-selective areas and frontal regions implicated in spatial attention. Our experimental design allows a comparison of each trial type in predictive and non-predictive conditions under identical stimulus conditions. In addition, fMRI coherency analysis is being performed to examine the circuitry engaged in voluntary and involuntary attention.

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33.409

Attention gates spatial coding in the human pulvinar

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Due to its widespread connectivity with visual cortex, as well as with putative sources of attentional control in frontal and parietal cortex, the pulvinar is regarded as a likely hub for coordinating attentional modulation across visual areas. Despite the theoretical appeal of this idea, there is little direct evidence to support the role of the pulvinar in mediating spatial attention. Precisely representing object position would be critical to such a task, and we recently reported that the human pulvinar encodes position information with precision on the order of that found in early extrastriate areas. In the present study, we tested whether position coding in the pulvinar is modulated by the focus of spatial attention. In an fMRI experiment, we presented four Gabor patches situated in the four visual quadrants. While fixating, subjects attended to either the upper or lower pair of Gabors to detect slight changes in contrast, and ignored the remaining Gabors. We independently manipulated the positions of the attended and unattended stimuli so that we could test for position information about each separately in the BOLD response. Using a multivariate pattern analysis to track fine changes in the spatial pattern of the BOLD response, we found that activity in both the right and left pulvinar precisely reflected the positions of the attended stimuli, but contained no information about the positions of the ignored stimuli. Our results show that attention gates position coding in the pulvinar: when attended and ignored objects are present simultaneously, activity in the pulvinar selectively encodes the locations of the attended stimuli.

33.410

Priming and backward interference in the human brain: SOA manipulations reveal processing interactions during the Stroop and reverse Stroop tasks

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In the present study, we exploit the high temporal resolution of EEG to study processing interactions in the human brain using variants of the Stroop (color naming) and Reverse Stroop (word naming) tasks in which the task-relevant and -irrelevant features were presented with varying temporal separations. High-density event-related potentials (ERPs) and behavioral performance were measured while participants reported in separate experimental session, either the bar color or the color-word, as quickly as possible while ignoring the other dimension. The task-irrelevant component could appear at one of five stimulus onset asynchronies (SOAs) relative to the presentation of the task-relevant component: -200 or -100 ms

Sunday Sessions

before, +100 or +200 ms after, or simultaneously. ERP and behavioral markers of stimulus conflict (congruent vs. neutral vs. incongruent) and of target selection (word vs. color) are considered.

We observed for both tasks that incongruent relative to congruent presentations elicited slower reaction times, higher error rates, and characteristic ERP difference waves. Responses for the two tasks both contained early, negative-polarity, central-parietal deflections, and later positive components, though the distribution and latencies differed slightly with task. These congruency-related differences interacted with SOA, showing the greatest behavioral and electrophysiological effects when irrelevant stimulus information preceded task-relevant target occurrence and reduced effects when the irrelevant information followed the relevant target. We interpret these data as reflecting two separate processes: (1) a priming mechanism for the more efficient processing of a task-relevant target stimulus when preceded by a congruent, but irrelevant distractor; and (2) the diminishing effects of Stroop-related interference when irrelevant distractor information follows the task-relevant target. The high-degree of symmetry in the timing of these effects for these two tasks suggests that stimulus incongruency affects the strength, rather than the speed, of processing in the activated brain network.

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33.411

Neural Correlates of the Right-Brain Dominance for Spatial Processes

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The right brain is dominant for spatial and attentional functions, and right-brain damage often results in spatial deficits such as spatial neglect. However, to date there is no comprehensive understanding of the underlying neural mechanisms because right-dominant asymmetries in healthy individuals are subtle and often inconsistent. We have recently introduced a relatively sensitive test of asymmetries, called gratingscales task that requires perceptual comparisons between two stimuli containing high and low spatial frequencies. Interestingly, people are leftward-biased in their perceptions when instructed to compare high spatial frequencies but not when comparing the low spatial frequencies of the same stimuli. Here we used this effect to narrow down the temporal-spatial structure of neural systems underlying the perceptual bias. We recorded the electrical event-related potentials of participants while they compared high or low spatial frequencies of the gratingscales task, or while they performed a control task on the same stimuli. We found that both tasks differed in similar ways from the control task. Both showed a greater negativity 150 ms after stimulus onset that originated from bilateral occipital electrodes and then migrated to electrodes over right parietal and right latero-occipital regions. This was followed by bilateral positivity over occipital and parieto-occipital regions at ~200 ms. Importantly however, only for high spatial frequency judgments task differences traveled back to right latero-occipital electrodes, manifesting in a more pronounced N300 there. Our data offer novel insights into the interplay between perceptual, attentional, and potentially working memory functions involved in perceptual biases. Future research will specify locations and the functional role of these components in the right-brain dominance of spatial tasks.

33.412

The role of the ventrolateral frontoparietal attention network in social attention

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Spatial orienting is typically understood as being driven either by external events (reflexive attention) or by the current goals of an individual (voluntary attention). Functional neuroimaging studies indicate that the two modes of orienting are controlled by two interdependent networks, (i) the ventrolateral frontoparietal network, that is involved in processing of unexpected target events, and (ii) the dorsolateral frontoparietal network that is responsible for maintenance of task goals and coordination of the two networks. In the last 10 years, numerous studies have reported that spatial attention is obligatorily shifted in the direction of perceived eye gaze direction. While the behavioral profile of this social orienting effect is consistent with reflexive orienting, the neural networks that control it remain poorly understood. Here we examined the temporal sequence of brain activity associated with shifts of social attention elicited by eye direction using electroencephalography and Multiple Source Beamformer (MSBF) analyses. MSBF analyzes changes in EEG oscillatory activity in a specific frequency band and depicts the neural generators of the spectral density in 3D space. Participants were presented with spatially uninformative central eye direction cues and were asked to detect an onset of a peripheral target while their EEG was recorded from 64 channels. Replicating previous reports, behavioral data revealed that participants were faster to detect targets appearing at gazed-at relative to not gazed-at locations. Cue-related MSBF analyses focused on the theta band (4-8Hz), which is thought to be a carrier frequency for attentional control operations. This analysis revealed increased spectral density in the theta band during the post-cue interval in regions of the ventrolateral frontoparietal network, including the temporalparietal junction, middle frontal gyrus, and ventrolateral frontal cortex. These results suggest that, in addition to processing of unexpected events, ventrolateral attentional control network may play a significant role in directing social attention.

33.413

Localization contributes to feature binding: A transcranial magnetic stimulation study

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Feature binding refers to correctly associating one feature of an object (e.g., shape) to another feature of the object (e.g., color). In our previous study, we found that errors in feature binding increased with errors in localization of that feature (Jingling and Zhaoping, 2007, Journal of Vision, 7(9):644, 644a). In this study, we aim to test whether interfering neural activities at a brain region that relates to location process could also affect feature binding. In Experiment 1, we tested whether the chosen area, right intraparietal sulcus (IPS), responsible for localization. Observers performed two tasks before and after they received continuous theta burst stimulation (cTBS), an inhibitory paradigm, on their right IPS. They viewed a target cube (either red or green) presented among yellow cubes during experiment. In one task they were requested to localize the target, and in the other to discriminate its color. Results showed a reduced accuracy in localization after (80.9%) than before (88.0%) cTBS, but not significantly different in color discrimination. In Experiment 2, observers performed feature binding and localization tasks with the same stimuli before and after brain stimulations. They viewed a briefly presented string of different colored letters and either to report identity and color of the target (the feature binding task) or to locate target relative to nontargets (the localization task). Two brain stimulations, the continuous (cTBS) and intermittent theta burst stimulation (iTBS), were applied to the same observer in different day. Preliminary findings revealed that brain stimulations on right IPS modulated the error rates in feature binding and localization in the same direction. Our study thus provides evidence on that spatial localization of features contributes to feature binding.

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33.414

The role of a sustained left parietal-occipital component in the serial chaining of two cognitive operations

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A fundamental process in human cognition is to accomplish chained sequential operations in which a second task requires an input from the preceding one. In Experiment 1, we required participants in a novel spatial PRP-type task to respond as quickly as possible to two sequential visual tasks, which were either chained or independent. The results revealed RTs for the Chained condition were larger than RTs for the Independent condition across 5 levels of SOA. In Experiment 2, participants performed the same task (100ms SOA only) while magnetoencephalographic (MEG) signals were recorded simultaneously. Half of the trials contained only the first task (single-task trials) while the other half contained both tasks (dual-task trials). The independent condition also included two sub-conditions where the cue and target were either spatially congruent (same side) or incongruent (different side). The event-related field data suggest that a sustained posterior component (SPC) beginning 0.3s and lasting for 700 ms after Task 2 onset is linked with the chained processing of two cognitive operations. Multiple-channel comparisons reveal this component originated from occipito-parietal areas, primarily in the left hemisphere. The SPC did not appear in two other contrasts suggesting it is linked with chained processing rather than task difficulty or attention switching. Additional time-frequency analyses confirmed a larger event-related desynchronization (power decrease) for the Chained condition between 0.3s to 1.1s after Task 2 onset in the frequency band of 0 to 22Hz. We suggest the left SPC may be linked with the serial processing requirement involved in decision-making and response selection.

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33.415

Prism adaptation reverses the local processing bias in patients with right temporo-parietal junction lesions

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Lesions to the right temporo-parietal cortex commonly result in hemispatial neglect. Lesions to the same area are also associated with hyperattention to local details of a scene and difficulty perceiving the global structure. This local processing bias is an important factor contributing to neglect and may contribute to the higher prevalence of the disorder following right compared to left hemisphere strokes. In recent years visuomotor adaptation to rightward shifting prisms has been introduced as a promising treatment for hemispatial neglect. Explanations for these improvements have generally described a leftward realignment of attention, however we have obtained evidence that prism adaptation reduces the local processing bias. Five patients with right temporal-parietal junction lesions were asked to identify the global or local components of hierarchical figures before and after visuo-motor adaptation to rightward-shifting prisms. Prior to prism adaptation the patients had difficulties ignoring the local elements when identifying the global component. Following prism adaptation, however, this pattern was reversed, with greater global interference during local identification. The results suggest that prism adaptation may improve non-spatially lateralised deficits that contribute to the neglect syndrome.

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33.416

Magnocellular VEP delay in high Autism Quotient individuals: Absence of the Magnocellular Advantage may explain poor global identification of locally salient Navon figures

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Many individuals in normal life exhibit certain characteristics of Autism Spectrum Disorder. We were interested whether differences in early visual processing (grouping, motion) shown by autistic children (Dakin and Frith, 2005) would be demonstrated by adults of normal intelligence with high versus low AQ (autism quotient scale; Baron-Cohen, 2001), and whether such differences would be reflected in the electrophysiology of the magnocellular and parvocellular pathways.

129 participants completed an online questionnaire and 15 low AQ (<11) and 14 high AQ (> 20) were selected for further testing. Participants identified (reaction time/accuracy) the global or local form of locally or globally salient (and congruent or incongruent) Navon figures. In addition, infinite and limited (100 ms) dot lifetime motion coherence thresholds were measured. First and second order kernels of the visual evoked potential (VEP; VERIS multifocal system) using achromatic stimuli of low (24%) and high (96%) contrast, indicative of magno and parvocellular function (Klistorner et al 1997), were recorded.

A mixed design ANOVA with AQ score (high versus low), target identity (global versus local), congruency (congruent versus incongruent) and saliency (globally salient versus locally salient) demonstrated a significant Score*Target Identity*Saliency interaction ($F(1, 27) = 9.20$, $p=.005$) on the Navon figures task. Non-linear VEP grand mean average waves for first order and for the first slice of the second order kernel (K2.1) showed significant departures, with the magnocellular generated K2.1 showing manifest delay at high contrast in high AQ participants.

The delayed magnocellular VEP observed at high contrast for the high AQ group would negate the magnocellular advantage (Laycock et al 2007) seen in normals, preventing any assistance from retroinjection of dorsal stream grouping information to area V1 in the recognition of global forms.

33.417

Electrophysiological Evidence of Shifts in Spatial Attention Corresponding to a Synaesthetes' Mental Calendar

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For individuals with Time-Space Synaesthesia, months of the year occupy very specific and highly consistent spatial locations. For example, L experiences the months of the year in the form of a 'scoreboard 7", where January is experienced on her left side, July on her right side, with the rest of the months curving behind her. Using a spatial cueing paradigm, we were able to empirically confirm L's subjective reports of her mental calendar. Month names were centrally presented followed by a target square appearing on the left or right of the display. L was reliably faster at detecting targets in validly cued relative to invalidly cued locations, whereas controls showed no response time differences. Furthermore, L demonstrated cueing effects even at short stimulus onset asynchronies (150 ms SOAs) between cue and target, suggesting her attention was automatically shifted to the cued location. Here, we used event-related brain potentials (ERP's) to provide converging evidence for these rapid shifts of attention. Compared to non-synaesthetes, at approximately 100 ms following the onset of the targets, L's brain potentials were more positive in frontal sites for valid than invalid targets, reflecting an early enhancement in attention to validly cued locations. Moreover, L exhibited a later posterior positivity occurring about 300 ms to 600 ms in response to invalidly cued targets, possibly reflecting a re-directing of attention to the uncued location. Importantly, non-synaesthetes showed neither the early or later deflections in response to validly and invalidly cued targets. Overall, we were able to substantiate L's behavioural cueing effects at short SOAs with electrophysiological evidence revealing the emergence of early evoked potentials to validly cued locations. These findings further strengthen our claim that for some synaesthetes months automatically trigger shifts in spatial attention.

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Perceptual Organization: Segmentation

Sunday, May 10, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

33.418

What determines the degree of transparency of a visual surface?

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Achromatic perceptual transparency has been studied extensively over the past 40 years. Recent models proposed by Robilotto and Zaidi (2002; 2004) and Anderson et al (2006; 2008) suggest that perceived image contrasts determine the degree of perceived achromatic transparency (or opacity) of a visual surface. However, Robilotto and Zaidi suggested that perceived transparency is determined by the perceived contrast of the image region occupied by the perceived transparent surface alone, whereas Anderson et al proposed that it is determined by the ratio of the perceived contrasts in the transparent and 'plain-view' regions.

Anderson et al (2008) argued that observers equate perceived-contrast ratios when asked to match opacity, but that whether or not observers are also able to explicitly match perceived-contrast ratios (when asked to match contrast ratios, rather than opacities) is irrelevant to their opacity theory. In fact, if observers are unable to match ratios of perceived contrasts, then Anderson et al's theory would be logically incoherent, since no unique ratio structure for perceived contrast would exist (two patterns could have equal contrast ratios according to one measure and unequal contrast ratios according to another). In my experiments, observers' matches of perceived-contrast ratios (to the extent that observers were able to make them) were very different from their opacity matches using the identical experimental setup (Albert, 2008).

Recent evidence suggests that both perceived filter contrasts and filter-to-background relative properties (contrast ratios, filter boundary contrast, and mean luminance ratios) influence opacity matching (Albert, 2008). Observers tend to equate perceived filter contrasts in matching opacity so long as filter-to-background relative properties remain qualitatively similar in the target and match patterns. Otherwise, making filter-to-background relative properties qualitatively similar will be more important than equating perceived filter contrasts. I propose a new model that is consistent with the existing data.

33.419

Curvature-based segregation for multi-oriented textures

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Texture perception and texture segregation are traditionally linked to the notion of feature gradient (e.g., Nothdurft, 1985,1991; Landy&Bergen, 1991; Mussap&Levi ,1999). Previously, we argued (Ben-Shahar, 2006) that at least for Orientation-Defined Textures (ODTs) this link is lacking since smoothly-varying ODTs exhibit salient perceptual singularities despite having no outstanding orientation contrast. Instead, these perceptual singularities can be predicted by a perceptual measure that depends upon two orientation curvatures, one tangential and one normal, that come about naturally from considering the intrinsic differential geometry of the ODT. This measure can be computed in a biologically plausible fashion using known mechanisms in the primary visual cortex (Ben-Yosef&Ben-Shahar, 2008), thus providing additional evidence for the computation of curvatures very early in the visual process.

In this work we begin to generalize our previous results by presenting multi-oriented textures -- orientation-defined textures with more than one dominant orientation at each point. Since in the limit any texture or natural image can be represented as a superposition of oriented components, possibly at different frequencies, these multi-oriented patterns constitute a critical first step towards generalizing curvature-based segregation to general textures. We therefore propose that a curvature-based model for segregation of multi-oriented textures must decompose the texture into a set of smoothly-varying orientation maps, each of which gives rise to its own perceptual singularities defined by the perceptual singularly measure discussed above. We present biologically plausible models for achieving this task and discuss further implications to general texture segregation.

33.420

Perception of average orientation

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When attention is spread diffusely across multiple objects, observers can create statistical summaries of object features, such as average size (Ariely, 2001; Chong & Treisman, 2003) or the average location of a group (Alvarez & Oliva, 2008). We tested whether such summary representations are available for another primary visual feature, orientation. Participants judged the average orientation of either a set of six lines or six Gabor gratings, with either homogenous or heterogeneous orientations, presented for 800ms. Participants then chose between the correct average and a foil alternative that was rotated by 7-42 degrees. In all conditions, accuracy became significantly higher than chance at various foil distances, suggesting that, at minimum, coarse averaging was possible in each condition. However, accuracy in the heterogeneous condition was lower than that in the homogeneous condition, suggesting that orientation averaging is not as precise as orientation perception in a display containing redundant orientation information. We also found that participants were more accurate at averaging lines than gratings, despite a control study showing that 800ms was ample time to extract equally precise orientation from a single line or grating. Furthermore, using heterogeneous instead of homogenous displays caused a larger averaging impairment for gratings, compared to lines. This suggests that average orientation is more accessible when boundary features convey the orientation information rather than when only the surface features carry the orientation information, despite the fact that early visual areas often favor gratings over lines and that gratings contain redundant orientation information. Our study suggests that the estimation of the average orientation is possible, though imprecise, and that the boundary information may play a critical role in the processing of average orientation.

33.421

Figure-Ground Segmentation determines Contextual Learning in Visual Search

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In visual search, invariant contextual information can provide an important cue for efficient target detection. For example, in the contextual cueing paradigm, repetitions of the spatial layout of a search display can implicitly guide attention to the target location, facilitating the detection of the target among nontargets. Here, we explored how contextual cueing is influenced by figure-ground segmentation. We conducted a series of experiments using search displays that contained a cluster of four nontarget items forming the corners of an imginary square. The results showed no contextual facilitation even though the group was predictive of the target location, whereas the baseline condition (without nontarget grouping) showed the typical contextual cueing effect. Subsequent experiments revealed that contextual cueing was preserved when targets appeared within the boundaries of the square, but not when they were outside the square boundaries. Taken together, our results suggest that figure-ground segmentation provides a framework within which the search context is acquired.

33.422

Competition-induced Suppression in Figure-Ground Perception Spans Multiple Levels

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Peterson & Skow (2008) showed that a familiar configuration that loses the competition for figural status is not perceived consciously and is suppressed, at least at the level of categorical shape. Here we used a target discrimination task to investigate whether the location of the familiar configuration is suppressed. Targets (left- or right-oriented bars) were located on the inside or outside of small, enclosed, symmetric novel silhouettes, near their borders. In high-competition silhouettes a portion of a familiar object was suggested along the outside of the silhouette borders, but lost the competition for figural status to the ensemble of cues that favored perceiving the inside as figure. In low-competition silhouettes there was nothing familiar on the outside. If the location of the losing familiar configuration is suppressed, then discrimination response times (RTs) for outside targets will be longer for high-competition than low-competition silhouettes. In Experiment 1, black (white) silhouettes were exposed for 80-ms on white (black) grounds. Targets (100 ms) followed silhouette disappearance. RTs were longer for both inside and outside targets following high-competition than low-competition silhouettes, $p<0.05$. Such an effect could arise if suppression mediated by feedback intended for the outside of the high-competition silhouettes was coarse and spread beyond the outside location when silhouettes offset. In Experiment 2 silhouettes remained on with targets. High-competition RTs were longer than low-competition RTs for outside, but not inside, targets, $p <0.05$. We take these data to indicate that 1) the location of the losing familiar configuration in the high-competition silhouette is suppressed, 2) suppression is mediated by coarse feedback and 3) the borders of the silhouette prevented suppression from spreading to the inside in Experiment 2. Thus, suppression of the losing familiar configuration spans multiple hierarchical levels.

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33.423

On the relationship between attention and figure-ground perception

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Nelson and Palmer (2007) claimed that attention is automatically drawn to figures based on faster detection and discrimination responses for targets shown on the familiar side of a small set of bipartite, equal-area displays, each shown multiple times. We tested this "figural advantage" hypothesis using 8-region equal-area black and white alternating convex and concave displays, in which convex regions are highly likely (~89%) to be seen as figure (Peterson & Salvagio, 2008). In Experiment 1 we used 40 displays, each repeated 16 times. Participants reported whether a masked target shown at variable SOA (0, 150,250, 500) for 80 ms on one of the regions adjacent to fixation was an "X" or a "Y". At all SOAs discrimination tended to be better for targets on concave than convex regions, $p <0.02$, indicating a perceptual advantage for the groundside rather than the figure side. In Experiment 2, we presented 24 displays, each once only, and included a set of 8 control stimuli with black and white equal-area regions delimited by straight edges. Participants reported whether an unmasked 100-ms target on one of the regions adjacent to fixation was a square or circle. Different groups saw targets appearing at 80-ms or 120-ms SOA. In both groups, subjects' reaction times were approximately the same for targets appearing on convex versus concave regions, although participants in the 80-ms SOA group were faster at reporting targets on concave regions than straight-edge regions in control displays, $p <.03$, again suggesting a ground advantage rather than a figure advantage. In an additional experiment, observers' discrimination responses were faster for targets on concave regions (grounds) rather than convex regions (figures). Thus, we obtained no evidence that attention is drawn to a convex figure near fixation. We suggest that Nelson and Palmer's results depend upon familiarity.

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33.424

Scale of attention influences figure-ground assignment

Lauren Hecht[1] (lauren-hecht@uiowa.edu), Shaun Vecera[1]; [1]University of Iowa

Figure-ground organization can be influenced by spatial attention: cuing exogenous attention to a region of an ambiguous figure-ground display prompts that region's designation as figure (Vecera et al., 2004). But can the width of the attentional scope also affect figure-ground organization? The spatial window of attention influences the interpretation of an entire visual scene (e.g., Navon, 1977; Pan & Eriksen, 1993), such as allowing one to focus on a global shape versus focusing on local elements of that global shape. Because cues giving rise to figural assignment vary along the shared contour, the window of spatial attention may also influence their use for figure-ground segmentation. For example, a figure with a contour shaped like the right side of a 'B' contains two convexities, but also contains a single concavity on the ground side (the point at which the loops of the B intersect). If attention is constricted around this single ground convexity, then this convexity cue may demand the opposite figural assignment from what is anticipated when considering the entire contour (i.e., the B shape as figure). To examine this possibility, observers attended to a figure-ground display either globally or locally. When attention was set broadly, figural assignment aligned with the global interpretation. However, when attention was set locally, the local convexity dictated which region was seen as figure, even though this local convexity opposed the global interpretation of the display. These results suggest that the width of the attentional window can impact what image-based cues may be used to complete figure-ground assignment.

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33.425

Statistical learning in everyday perception: The case of variable segment lengths

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Statistical learning is a mechanism of perception that helps to parse continuous input into discrete segments on the basis of distributed temporal and spatial regularities. Nearly all previous studies of temporal statistical learning have used fixed segment lengths, e.g. composing a continuous stream of input out of three-item 'triplets'. In natural environments, however, the units of perceptual experience — e.g. events and words — rarely come in fixed lengths. As such, we explored the operation of statistical learning in temporal streams containing segments of variable lengths. Observers passively viewed a continuous stream of novel shapes appearing one at a time. These streams had no overt segmentation, but they were constructed from segments of either a fixed length (all triplets) or variable lengths (combining one-, two-, and three-shape subsequences) — controlling for both overall stream duration and segment frequency. Statistical learning was then assessed with a two-alternative forced-choice familiarity test pitting subsequences from the stream against recombinations of those same shapes into novel subsequences. The resulting learning was equally robust for observers who had viewed fixed-length segments and observers who had viewed variable-length segments, demonstrating that statistical learning does not assume that "one-size-fits-all". This sort of variability is not only characteristic of the visual environment, but is also a basic property of language. Accordingly, we also replicated these studies (with similar results) in auditory statistical learning of pseudowords. In other studies, we have explored the ability of both visual and auditory statistical learning to cope with other forms of variability, such as when individual elements are 'recycled' into multiple subsequences in the same stream — since the same objects are present in multiple events and the same syllables are used in multiple words. These results contribute to a growing body of research demonstrating the usefulness of statistical learning for everyday perception.

URL: http://www.yale.edu/perception/

33.426

Temporal grouping in figure-ground segregation and the influence of spatial structure

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Sunday Sessions

Figure-ground processing requires the grouping of visual elements and their segregation from background elements. The time course of this process and its dependency on fast spatio-temporal modulations however is unclear. In two experiments, we examined these effects using stimuli in which visual elements flicker with various frequencies and temporal phase relations. In the first experiment, detection of a figure (defined purely by spatial properties) was measured under conditions of different temporal structure (the phase between figure and ground, as well as between figural elements was varied). In the second experiment, a task of pure temporal grouping was created by presenting out of phase figure and ground components, which also lacked the spatial properties required for grouping. The results of both experiments show that temporal modulations (on the time-scale of 20ms per frame and faster) have an effect on perceptual organization. In addition, there were important differences in the role of temporal structure across stimuli: when temporal properties were irrelevant, figure detection was impaired by the separation of figure elements into different phases. The task of purely temporal figure-ground grouping revealed that phase relations (with surprisingly small asynchronies ~14ms) could be used, but depended on the smoothness of the figure elements. These findings are discussed in relation to the neural representation of visual objects, and the time course of their formation.

33.427

Psychophysical Evidence for Object Segregation Through Endogenous Asynchrony

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Introduction: Decomposing the retinal image into its constituent objects involves grouping the neural outputs responding to common objects and segregating these from the outputs responding to separate objects. Prior research has suggested that perceptual groups are represented cortically through synchronous oscillatory firing. Modeling studies have further suggested that separate perceptual groups be represented by asynchronously firing neural populations. We provide evidence corroborating this hypothesis, showing both that elements lying on a common object are endogenously synchronized and that elements lying on separate objects are endogenously desynchronized.

Methods: We adopted a similar paradigm to that of Cheadle et al., (2008) where subjects judged the synchrony of two flickering Gabors embedded in a static background pattern. We constructed the background patterns around the Gabors such that it placed them either a) on a common object, b) on separate objects, or c) on no objects. We found that the static background pattern significantly affected subjects' ability to judge the target Gabors' synchrony. Comparing synchrony judgments within and between background patterns allowed us to estimate the endogenous neural coherence imposed on the neural populations responding to the patterns.

Results: We replicated Cheadle et al.'s finding that Gabors on a common object are endogenously synchronized relative to Gabors in the no object pattern. We extended this result by showing that Gabors on separate objects are actively desynchronized relative to both the no object condition and to the one object condition.

Conclusions: More than just synchronizing neural responses to common objects, our evidence implies that there is also an active desynchronization process that segregates responses stemming from separate objects. This finding suggests a mechanism by which objects are segregated from each other – different objects are tagged with different phase labels that are actively repelled from one another.

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33.428

Persistence of border ownership signals does not reflect capture of attention

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A remarkable feature of our brains is that they provide us with a perceptually continuous visual scene despite the constantly changing retinal images due to eye and object movements. Neurons in early visual cortex play an important role in interpreting scene structure by encoding border ownership of edges. Border ownership signals arise for attended as well as unattended objects (Qiu et al., Nature Neuroscience 2007). We have previously found a short-term memory for border ownership in the responses of V2 neurons (O'Herron and von der Heydt, Journal of Vision 2007): When a figure display switches to a split field that is ambiguous with regard to border ownership, neurons continue to signal border ownership according to the initial display for more than one second. The circumstances suggest that this persistence is independent of attention because we found it in monkeys that were trained to fixate a dot on the display and ignore any other visual stimulus. However, because the onset of a stimulus can capture attention, it is conceivable that border ownership signals are maintained by persistent attention. We examined this possibility by presenting two figures sequentially with the reasoning that each figure onset should capture attention, and so, after the second figure's appearance, attention should change to that location. After brief presentation, each figure was replaced by an ambiguous edge as described above. We found that the border ownership signal at the first figure did not drop when the second figure was presented and showed normal persistence. Reversing the order of presentation showed that border ownership signals persisted simultaneously at the two ambiguous edges. We conclude that the persistence of border ownership signals is not driven by persistent attention.

33.429

Perceptual learning differs for detection and discrimination: evidence from contrast, texture, motion, stereo and colour thresholds

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A permanent change of perception as a result of experience is defined as perceptual learning. It is known that the improvement is very specific, e.g. for the precise stimulus orientation and position, indicating that the underlying plastic changes are at least partly on the level of primary visual cortex (Fahle, J Vis. 2004).

Here we examined the role of task (binocular detection vs. discrimination) in different visual modalities (contrast, texture, motion, stereo, colour; see also Grimsen et al., this conference), using the same stimulus position and stimulus type. Nine healthy subjects (mean age 24.6 years) were measured on five separate days in intervals of no more than four days. At each day a four-alternative-forced-choice detection and discrimination task were utilized to identify detection and discrimination thresholds (62.5% correct responses) within each modality for each visual field quadrant using an adaptive staircase procedure.

Differences between visual field quadrants were not evident in either modality for both, detection and discrimination thresholds. Perceptual learning could be obtained for contrast, motion and colour detection but not for texture and stereo detection. In contradistinction, perceptual learning was only evident in stereo discrimination while thresholds of all other modalities were stable across the five testing days. The correlations between detection and discrimination within each modality were small but significant across subjects and days.

The results indicate that perceptual learning is highly specific across different visual modalities, as well as across different tasks within the same visual modality. The dependence of perceptual learning on early versus late selection, as well as attention mechanisms are discussed (Fahle, Philos Trans R Soc Lond B Biol Sci. 2008).

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33.430

Effects of healthy aging on visual detection and discrimination: evidence from contrast, texture, motion, stereo and colour thresholds

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During normal aging both the optics and the retina of the eye changes, primarily deteriorating visual acuity. Relatively little is known about other visual abilities and the effects of aging on the primary visual pathway. Improving the knowledge about perceptual abilities in the elderly is essential for understanding impaired visual functions after brain damage (such as stroke), particularly because of the required differentiation between age-based and damage-specific perceptual decline.

Here we examined the influence of age on the performance in both visual detection and discrimination using various visual submodalities (contrast, texture, motion, stereo, colour; see also Kraft et al., this conference), with the same stimulus position and stimulus type in both tasks. Perceptual thresholds were obtained for each submodality and for each visual field quadrant using a spatial four-alternative-forced-choice method controlled by an adaptive staircase procedure (converging to 62.5% correct responses). Fifty-two healthy subjects between 21 and 75 years were tested and subdivided into five groups according to their age. Perceptual thresholds significantly increased with age for all submodalities and for both tasks (detection and discrimination). These results indicate that visual perception generally declines across different visual submodalities during healthy aging. The relation between psychophysically measured decrease of different visual functions and optical, retinal and neuronal changes as well as how these methods can evaluate visual perception after brain damage are discussed.

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33.431

Is segmentation from motion parallax influenced by perceived depth ?

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A powerful cue for parsing occlusion boundaries arises from relative image motion produced by an observer's self-motion ("motion parallax"), which may also utilize vestibular cues. In this situation, segmentation of adjacent surfaces is intimately associated with their perceived difference in depth. Here we investigate to what extent a depth difference generated from self-motion might aid in segmentation performance.

Stimuli appeared within a circular aperature containing a near-horizontal boundary between half-discs that were filled with 1/f (fractal) noise textures. On each trial the observer freely executed lateral head movements, which were measured using a 6-DOF electromagnetic tracking system. The textures' movements were linked to the head movement with no perceptible lag. Three relative motion conditions were compared: the two halves could move in opposite directions, in the same direction at different speeds, in sync with the head movement, or they could both move against the head movement (simulating a pair of surfaces on opposite sides of, farther than, or closer to the fixation point, respectively).

On each trial the observer reported whether the moving boundary was slightly oriented left- or right-oblique. A method of constant stimuli was used to measure a boundary orientation threshold. To examine the effect of self-motion, using comparable texture motions, we kept the head fixed with the image regions moving according to trajectories recorded during previous head-moving trials.

Orientation thresholds were smaller when the textures were moving oppositely than when moving in the same direction, and similar for the same-direction cases. Overall there was little or no difference in segmentation performance between head-free and head-fixed conditions, even though observers often reported seeing a depth difference. These results suggest that segmentation is a low level mechanism that preceeds depth perception, and that it may not benefit from vestibular input.

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Memory: Visual Learning and Memory

Sunday, May 10, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

33.432

Effects of Training to Perform a Working Memory Task on Regular Spiking and Fast Spiking Neurons in the Lateral Prefrontal Cortex

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The prefrontal cortex (PFC) plays an important role in working memory. In order to understand how it mediates this function, we tested how training to perform a working memory task modifies the properties of different types of neurons. We performed neurophysiological recordings, collecting data from all neurons isolated from our electrodes. We evaluated spatial selectivity of neuronal responses to visual stimuli appearing on a 10-degree, 3x3 grid, and feature selectivity to eight geometric shapes. We used a Selectivity Index defined as (max-min)/(max+min) to quantify neurons' selectivity. Then we classified neurons as Regular Spiking (putative pyramidal neurons) and Fast Spiking (putative interneurons) based on the characteristics of the action-potential waveform and baseline firing rate (Constantinidis and Goldman-Rakic, 2002). Prior to training, we found 191 RS neurons and 9 FS neurons that responded to the visual stimuli. After training in a working memory task that required monkeys to remember the locations and features of stimuli, we recorded from 150 RS and 10 FS neurons. Approximately equal number of neurons exhibited delay period activity, before and after training (26% of RS and 33% of FS neurons had delay period activity prior to training and 22% of RS and 40% of FS neurons after training). Fast Spiking neurons had broader selectivity for the stimuli than RS neurons, indicated by lower Selectivity Index values (0.65 vs 0.75 for spatial, 0.30 vs. 0.52 for feature stimuli, which was significantly different, t-test, $p<0.01$). Average Selectivity Index values did not change appreciably after training for either the FS or the RS neurons. Our results suggest that both pyramidal neurons and interneurons in the prefrontal cortex respond to visual stimuli and exhibit delay-period activity before and after training and training appears to have the same effect on both types of neurons.

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33.434

Memory for visual items of central or marginal interest: Impact of eye movements and subject's expertise

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In complex scene, memory for central interest items is better than memory for marginal interest items and this difference remains stable independently of the scene presentation duration (Melcher, 2006). However, without eye movement recording, it is not possible to know whether central interest items are better remembered because they are more fixated or because they are more meaningful. To answer this question, we analysed the memory of complex scenes (paintings) according to the eye movements and subjects' expertise. 15 novice subjects and 15 art historians (experts) were asked to look at 6 paintings that were separately and randomly presented for 10 seconds. After each painting presentation, subjects were asked questions about pictorial details of 3 categories: details of central or marginal interest and background information. Although experts had prior knowledge about the

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paintings, the accuracy of answers about the pictorial details did not differ between both groups. We obtained a significant difference between the types of details without any effect of expertise: all subjects showed best memory for central information while they failed to remember background information and marginal details. Eye movement recordings showed subjects spent the longest time in the background zone, followed by the time spent on central target and finally by the time spent on the target of marginal interest. Despite the longest time spent in the background zone, memory for these details was poorer than for central interest items, suggesting the importance of the meaning over the fixation duration. Eye movement recordings also showed novice's answers concerning background and central information were more accurate when they looked longer at the asked detail and when this detail was watched early on in the presentation while in the expert group, the accuracy of the answer was not influenced by the duration and moment they watched the asked detail.

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33.435

Auditory recognition memory is inferior to visual recognition memory

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For several decades we have known that visual memory for scenes is surprisingly robust. In the most dramatic demonstration, Standing showed observers up to 10,000 images for a few seconds each, and reported that they could subsequently identify which images they had seen before with 83% accuracy. We wished to examine whether an analogous ability exists in the auditory domain. In every experiment, participants listened to a variety of sound clips during a study phase. During the testing phase, participants listened to another set of clips and had to indicate whether each clip was old or new. In Experiments 1-3, stimuli ranged from complex auditory scenes (talking in a pool hall) to isolated auditory objects (a dog barking) to music. In some conditions, the sound clips were paired with pictures or their verbal descriptions during the study phase to help with encoding. Participants were then tested for recognition of the sound clips alone. We also measured memory for the verbal descriptions alone and the matching pictures alone using the same experimental paradigm. In every situation, auditory memory proved to be systematically inferior to visual memory. Two explanations suggest themselves. Auditory objects might be fundamentally different from visual objects. In their physics or psychophysics, they may actually be less memorable than their visual counterparts. Alternatively, auditory memory might be fundamentally different/smaller than visual memory. We might simply lack the capacity to remember more than a few auditory objects, however memorable, when they are presented one after another in rapid succession. In either case, it is unlikely that anyone will find 1,000 sounds that can be remembered with anything like the accuracy of their visual counterparts.

33.436

Memory for natural images: The role of visual and conceptual features

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Human long-term memory for visual stimuli is substantial; however, it is still not entirely clear whether images are remembered on an image-based, perceptual level or on a more abstract, conceptual level. To disentangle the contribution of both components, we used a memory test paradigm in which we varied the similarity between target image and distractor. For each target image, three distractors were chosen. One (called "similar") was conceptually and visually similar, one (called "gist") only had the same gist, and one distractor (called "rand) neither shared the gist nor visual details. The image sets were validated by showing participants three images at a time and having them pick the one they considered as most dissimilar to the other two. 45 item sets were kept in which the random image was consistently chosen as least similar to the target, followed by the image sharing the gist. In the main study, 21 participants viewed a sequence of 184 images, each for one second. In the following test phase, participants performed a recognition task on 45 item pairs, each consisting of a target image and one of the three distractors. We analyzed recognition performance across the distractor classes. It was highest when a target image had been paired with a random distractor and lowest when paired with the distractor from the category "similar". Significantly more errors were committed when the distractor image was most similar to the target image. After two weeks, six participants were tested again but on different target – distractor pairings. Performance remained virtually the same, both in overall performance and distribution across distractor classes. Our results show that long-term memory for natural stimuli is extensive and that visual features play an important role in recognition.

33.437

A role for color in memory for known and unknown faces?

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Color information can improve performance in categorizing and naming (natural) scenes, yet impairs recognition performance in memorizing and detecting changes in images. Color has thus been proposed to specifically facilitate the detection of the gist of scene images, at a cost of details (Nijboer et al., 2008. Recognising the forest, but not the trees: An effect of colour on scene perception and recognition. Consciousness and Cognition, 17, 741-752). Here we ask whether this shift towards processing of the gist also occurs for images of (famous or unknown) faces, as faces are generally thought to be processed in a more 'holistic' fashion (i.e. with less focus on the parts, or details).

Participants viewed a set of 80 face images (40 in color, 40 in grayscale, half of which of famous persons) during a study phase. Each image was presented for 1s, (500ms ISI). After the study phase and a 3-minute interval, each of these images was presented in the test phase as well, randomly interleaved with 80 new images. Half of the new images were different images of the same face, the others were images of completely new faces. Participants indicated for each image in the test phase whether it had been included in the study phase as well.

Hit Rate and False Alarm Rate for images of faces shown in color and grayscale were comparable, irrespective of whether they belonged to famous or unknown persons. Although Hit Rate was relatively low (possibly obscuring some of the effects), these results suggest that color information does not modulate the balance between processing gist or details of these images. Apparently, unlike scene images, images of both famous and unknown faces are processed in a similar manner at this level, irrespective of color information being present or not.

33.438

How fast is the search for a change in change detection?

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We recently proposed a model of change detection in which observers search for the presence of a change between the test array and a visual working memory (VWM) representation of the sample array (Hyun, Woodman, Vogel, Hollingworth & Luck, in press). We found that the change detection occurs immediately after presentation of the test items regardless of set sizes, suggesting the search for a change occurs just like simple feature pop-out search. However, it has been unclear whether the search for a change can be completed as fast as a pop-out target is found in visual search. In the present study, we tested this idea by interfering with the search for a change. In the change detection task, with a fixed set size of four, we presented pattern masks 17ms after the test items with 100ms exposure duration (SOA 117ms). We recorded ERPs (N2pc) evoked by the test items. The masks are known to disrupt the process during which sample items in change detection are consolidated (Vogel, Woodman & Luck, 2006). The presence of N2pc indicates how good visual attention is focused to the location of a visual change. We compared the mean amplitude of N2pc from the trials with masks against those without masks, and found the N2pc amplitude was larger when without masks. The results indicate that the masks interfered with the pop-out of a change, and therefore focused attention was less evident. The search for a visual change appears very rapid but requires a certain amount of time at least longer than 117ms. The results support for the idea that the minimum amount of time needed for the search for a change is longer than pop-out visual search.

33.439

Does item familiarity influence change detection performance?

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Evidence that people often fail to detect substantial visual changes to objects and scenes (i.e., change blindness) has been used to infer an overall lack of detailed internal visual representations of the visual world (e.g., O'Regan & Noë, 2002). However, people can retain detailed visual information for extended periods of time and recall details of both pre- and post-change objects even when they fail to notice changes (e.g., Mitroff et al, 2004; Hollingworth, 2005). Such recognition in the face of change blindness implies either (a) that change blindness results from a failure to compare representations of the pre- and post-change objects or (b) that longer-term representations are inaccessible to shorter-term change detection processes. In this experiment, participants studied individual objects for a subsequent memory test and, after this study phase, performed a change detection task with arrays of objects that either did or did not include these familiar objects. Change detection was better for "old" than for "new" objects even though object familiarity was not predictive of the change or its location. The pattern held for both short and long initial viewing of the pre-change array, with somewhat better detection for the longer initial viewing. This finding suggests that long-term representations of objects can contribute to the short-term processes involved in change detection tasks (at least in a 1-shot task), and that change blindness in the face of persisting representations can better be attributed to a comparison failure.

33.440

Memory for motion is optimally represented in spatiotopic coordinates

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The direction of stimulus motion is encoded by directionally selective neurons in intermediate visual areas, such as area MT. In studying the storage of this information, Zaksas et al (2001) demonstrated a sharp drop in performance of a memory for motion task as the spatial separation of the 2 stimuli to be compared reached a critical distance. This critical separation increased with retinal eccentricity in a way consistent with the receptive field sizes of neurons in cortical areas MT, V4 and LIP. To differentiate between these areas, we asked whether this critical separation is in retinotopic or spatiotopic coordinates. We measured the ability of human subjects to discriminate the directions of two coherently moving random-dot stimuli (sample and test) separated by a 1350 ms delay. The subjects first fixated on a spot and the sample stimulus appeared in the right or left upper hemifield for 500 ms. The subjects were then required to make a rightward or leftward saccade of 10 degrees and the test stimulus would then appear in the same spatiotopic or retinotopic location as the sample. The subjects then indicated if they thought the sample and test stimuli were moving in the same direction or different directions via a button press. The sample stimulus could move in any of the 8 cardinal directions, and the test stimulus differed from the sample by 3.8 to 90 degrees. We found that the direction difference thresholds were lower when the test stimulus appeared in the same spatiotopic location as the sample stimulus compared to when it appeared in the same retinotopic location. This suggests that memory for motion is likely stored in a region that spatially updates remembered information across saccades, such as area LIP, as opposed to a retinotopic area, such as MT or V4.

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33.441

A biologically inspired psychometric function for accuracy of visual identification as a function of exposure duration

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The psychometric function of letter identification is typically described as a function of stimulus intensity. However, the effect of stimulus exposure duration on letter identification remains poorly described. This is surprising because the effect of exposure duration has played a central role in modelling human performance in whole and partial report tasks in which multiple simultaneously presented letters are to be reported (Shibuya & Bundesen, 1988). Therefore, we investigated visual letter identification as a function of exposure duration. On each trial, a single randomly chosen letter (A-Z) was presented at the centre of the screen. Exposure duration was varied from 5 to 210 milliseconds. The letter was followed by a pattern mask. Three subjects each completed 54,080 trials in a 26-Alternative Forced Choice procedure. We compared the exponential, the gamma and the Weibull psychometric functions, all of these having a temporal offset included, as well as the ex-Gaussian, and finally a new psychometric function, motivated from single-neuron studies by (Albrecht, Geisler, Frazor & Crane, 2002). The new psychometric function stands out by having a non-monotonous hazard rate which is initially rising from zero, then peaking, and finally decaying to a somewhat sustained plateau, mimicking closely observed instantaneous firing rates of monkey visual cortex neurons. The new psychometric function fits well to experimental data in both the present study and in a previous study of single-letter identification accuracy (Bundesen & Harms, 1999). Also, we conducted a follow-up experiment to test the ability of the psychometric functions to fit single-letter identification data, at different stimulus contrast levels; also in this experiment the new psychometric function prevailed. Further, after insertion into Bundesen's Theory of Visual Attention (Bundesen, 1990), the new psychometric function enables closer fits to data from a previous whole and partial report experiment.

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33.442

Is Sensory or Mnemonic Information Better for Matching Objects?

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A fundamental process in object recognition involves matching 'new' or recently encoded objects with 'old' or previously encoded objects. Recently encoded representations of old objects can be supported by current sensory input (i.e., the original image remains present in the visual field), or they can exist in a fully mnemonic manner, i.e., without current sensory support. Here, we asked whether matching processes were more efficient when an 'old' object's representation was (1) supported by sensory data or (2) was fully mnemonic (stored in visual working memory, WM). If matching requires representing the test (new) object at a high level (say, in visual WM), then matching might be faster when the 'old' object is maintained in visual WM without continuous (and potentially interfering) input from sensory sources. To test this, we presented observers with two faces (upright or inverted in different experiments) and required them to report "same" or "different" as quickly as possible. In Experiment 1, on half of trials both faces were presented simultaneously (sensory condition), and on remaining trials, one face was briefly (400 ms) presented and then followed by a 1500 ms retention interval prior to the presentation of the second, to-be-matched face (mnemonic condition). Response times were fastest for the mnemonic condition. In a second experiment, controlling for sensory

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load at the matching stage, we added another (sustained sensory condition) in which the first face remained visible during the retention interval and when the to-be matched face was presented at the end of the trial. We found that responses in the mnemonic condition remained fastest but only when faces were upright; face inversion gave the sustained sensory condition an advantage. The results of these experiments shed light on the processes contributing to high-level object representation and suggest important differences between sensory and mnemonic data.

33.443

Increased vSTM for Sequential Displays - Behavioural and Neuronal Dynamics

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It has been argued that the number of items that can be maintained in visual short-term memory is limited to 3 or 4 objects (Luck and Vogel, 1997). This widely held view has been recently challenged by work of Fecteau and Shapiro (VSS 2008). They showed that splitting the to-be-remembered item display into two sequential arrays increases vSTM dramatically. Here, we report data that replicate the basic behavioural finding and aim to extend it to the neuronal domain. A change-detection paradigm was used in which participants had to remember briefly flashed displays of coloured squares and white shapes. Objects were presented at random spatial positions within a bilateral array of 18 placeholders, with coloured squares appearing in one visual hemifield and white shapes in the other hemifield. The two memory sets (squares and shapes) were shown either in two temporally separated displays (sequential condition) or in one single display (standard condition). A second display containing placeholders but no target items was introduced in the standard condition to control for perceptual load. As a main result, we found a strong increase in k (set-size dependent estimate of vSTM capacity, Cowan, 2001) for sequential versus standard displays. vSTM increased irrespective of the probed display's position in the maintenance phase (presented as 1st or 2nd display). To shed light on the neuronal mechanisms underlying these effects, we chose a two-fold approach: (1) Measuring hemodynamic responses of perceptual and memory-related brain areas in sequential versus standard trials with fMRI, (2) examining the Contralateral Delay Activity (CDA, Vogel & Machizawa, 2004), a lateralized ERP measure, which is sensitive to the number of items stored in vSTM.

33.444

What Is Capacity? Grounding Cognitive Concepts in Neural Dynamics with a Dynamic Neural Field Model of Visual Working Memory

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Change detection tasks typically estimate adults' visual working memory (VWM) capacity to be 3-4 simple objects. To explore how capacity limits arise within a neural system, we used a dynamic neural field model of VWM to capture performance in change detection. In this model, objects are represented as "peaks" of activation that are maintained in cortical fields. Quantitative simulations show that the model must hold 5-6 peaks in VWM simultaneously to produce adult-like change detection performance. This suggests that standard methods of estimating capacity underestimate the resolution of the neural system. Moreover, the model provides novel insights into the multiple ways in which errors arise. In contrast to existing theories (e.g., Pashler's formula) which posit that false alarms reflect guesses, our model shows that false alarms reflect failures to consolidate all items from the sample array into working memory. Misses—which are not explicitly factored into capacity equations—arise due to decision errors when weak change signals are overcome by robust neural signals indicating sameness. In the final section of the presentation, we demonstrate that our model both captures existing data and generates novel predictions. In particular, the model predicts enhanced change detection for similar feature values which is consistent with recent empirical results probing change detection for both color and orientation. The model also predicts that working memories for close features will repel one another over short delays. This prediction was also successfully tested using a novel feature estimation task. Given that the model captures adults' performance and generates novel predictions, we contend it provides robust neural constraints on "capacity", effectively grounding this concept in real-time and task-dependent neural dynamics.

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33.445

Hippocampal-dependent implicit visual memory improves with practice, not sleep

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Sleep is shown to facilitate learning on a variety of tasks that require procedural memory. Evidence of replay during sleep of waking experience in rat hippocampus (Ji, 2007) has been proposed as a mechanism of the sleep-dependent learning process in humans (Stickgold, 2007). However, behavioral data in humans that support the notion of improved hippocampal-related memory due to sleep has been inconsistent (Frank, 2007). We asked whether sleep improved hippocampal-dependent implicit memory in a contextual cueing (CC) task (Chun & Jiang, 1998; Chun & Phelps, 1999). Sixty-nine subjects were tested twice on the contextual cueing task (Chun &Jiang, 2003). Subjects searched for a target (T) amongst distractors (L). In session one, half of the item configurations are repeated throughout the session (OLD) and half contain random item configurations (NEW). Session two tested three conditions 1) OLD configurations from session 1, 2) NEW configurations, 3) and a new set of 12 repeated configurations (NEW/OLD). Subjects were assigned to a Nap, Nocturnal Sleep, or Rest condition between the two sessions. We found an overall CC effect for session one (i.e. faster RT for OLD configurations compared with NEW), with no group interaction. The GroupXSessionXCondition ANOVA found no differences between groups, indicating that improvement between sessions was similar in subjects who slept and in those who did not sleep. Post-hoc tests showed no differences in session two between any of the groups in their retention of session one OLD or acquisition of session two NEW/OLD. All groups were also at chance in recognition of the OLD configurations. These results are further evidence of a lack of involvement of sleep in learning involving the hippocampus. Thus, the proposed mechanism of hippocampal replay as a general model for sleep-dependent learning may need to be reconsidered.

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33.446

Object appearance is not integrated with scene viewpoint in long-term memory

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Recently, there has been much debate about whether scene memory is detailed or abstract. Previous work has demonstrated that visual long-term memory (VLTM) can store detailed information about object appearance and information about scene-level viewpoint. However, it is not known whether these two types of information are integrated within episodic representations of scenes as they were viewed. In the current experiments participants studied a series of pictures, some of which were different viewpoints of the same larger scene. The viewpoints overlapped, so some of objects were visible in both viewpoints. However, one object's visual appearance was manipulated across the viewpoints (e.g., Viewpoint 1/Object A and Viewpoint 2/Object A'). Long-term memory for the studied scenes was tested using 2-alternative forced-choice (2AFC) tests. On some 2AFC trials, distracter scenes depicted novel conjunctions of previously studied object appearance and scene viewpoint information. For example, if an observer studied a scene depicting Viewpoint 1 with Object A and another scene depicting Viewpoint 2 with Object A′, then on the 2AFC test they would have to choose between Viewpoint 1 with Object A and Viewpoint 1 with Object A′ (i.e. a novel conjunction of viewpoint and object appearance). In three experiments using both incidental and intentional encoding instructions, participants were unable to perform above chance on 2AFC tests that required discriminating among previously viewed and novel conjunctions of object appearance and viewpoint information (Experiments 1a, 1b and 2). However, performance was better when object appearance (Experiments 1a, 1b and 2) or scene viewpoint (Experiment 3) alone was sufficient to succeed on the 2AFC test. These results replicate previous work demonstrating good memory for object appearance or viewpoint. However, the current results suggest that object appearance and scene viewpoint are not episodically integrated in VLTM. Thus, picture memory seems to be detailed but fragmented.

33.447

Unfiltered and Unforgotten: The Fate of Irrelevant Visual Stimuli in Elderly Adults

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The ability to hold visual information in mind after it is no longer physically present seems to decline with age. Our study investigates whether this age-related decline may be a derivative of the poor ability to filter out irrelevant information. It has been shown that the contents of visual short-term memory (VSTM) can be reflected electrophysiologically when the task involves ignoring irrelevant information. Specifically, we were interested in the contralateral delay activity (CDA) where a difference wave is computed by subtracting the ipsilateral from the contralateral activity when subjects view bilateral displays. The amplitude of this difference has been found to correlate with VSTM capacity. Furthermore, young adults with low capacity show a sustained increase in CDA when presented with irrelevant information, suggesting that they do not effectively ignore these distractors. Using EEG, we employed a VSTM paradigm where participants' attention was directed either to the left or to the right of a fixation cross and they were asked to perform a memory task consisting of colored squares with set sizes of one and three. In some trials, colored circles would be presented amongst the target squares and young and old participants were asked to ignore these distractors. Interestingly, the CDA response in elderly adults does not seem to discriminate between relevant and irrelevant items. This failure to prioritize relevant information may contribute to the typically observed age-related decline in working memory performance.

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Object Recognition: Reading

Sunday, May 10, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

33.449

A model of optimal oculomotor strategies in reading for normal and damaged visual fields

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Normally-sighted subjects typically read words by placing the maximal acuity zone of their retina (i.e. the fovea) directly on the word. In contrast, patients with macular lesions (i.e. central scotomata) need to place the fovea outside the word itself, thus using peripheral areas of the retina to read. It is assumed that patients preferentially use a particular peripheral zone called the Preferred Retinal Location (PRL). The correlation between this PRL and reading performance is still controversial, giving rise to several studies with both patients and simulated subjects.

In this study, we present a bayesian "ideal observer" analysis of single-word reading in normal readers and central scotoma patients. In the latter case, numerous fixations can be necessary before recognition occurs. Our approach to reading assumes that the optimal reading strategy is the one that optimizes the "Expected Information Gain" for each future fixation. This gain is calculated on the basis of the image pixel values and takes into account the information provided by pixels about letter and word identities. Importantly, the model predicts the 2D spatio-temporal pattern of saccades during reading by using only pixel-based information, in contrast with theories that use the pre-processed letter-slot approaches to model reading.

The implementation of the model shows that vertical strategies (i.e., placing scotoma above or below the word) are optimal for word reading. We found a similar pattern of results in a word recognition experiment where macular blindness was simulated with a gaze-contingent paradigm in normally-sighted observers. More generally, our results support the idea that information processing models can help define optimal oculomotor strategies and provide important insights for visuo-motor rehabilitation methods.

33.450

Direction Discrimination Training Removes Timing Deficits in the Dorsal Pathway that Impair Reading Ability

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Timing deficits resulting from sluggish magnocellular pathways are thought to underlie reading difficulties in dyslexics, those who have reading problems with no obvious neurological, sensory or ocular-motor deficits. Controlled validation studies in public schools showed that, for dyslexic children, reading fluency improved when children were trained, before directed reading, on direction discrimination 10 minutes twice a week for 15 weeks, but not when children were trained on word discrimination. In direction discrimination training, when only one level of background complexity was used, dyslexics' contrast sensitivity improved 5-fold and reading rates improved 2-fold on average. When 8 levels of background complexity were used, not only did contrast sensitivity improve 14-fold, but reading rates also improved 4-fold. Moreover, when direction discrimination training was administered individually using 14-16 complexity levels, more sessions, and was followed by training on reading fluency for 5 minutes using coached guided reading, reading rates improved 11-fold instead of only 4-fold. Furthermore, the more training on direction discrimination was administered, the more reading rates improved ($p < 0.001$). Significantly, the data from subsequent years show that these changes do not regress over time. These remarkable results from such a short amount of training can be explained in terms of removing the timing deficits in the dorsal pathway by tuning the sluggish magnocellular neurons over different backgrounds, so they are more sensitive, respond more quickly, and improve timing with linked parvocellular neurons. It is plausible to conjecture that sluggish magnocellular neurons cause a deficit in attentional focus, preventing the linked parvocellular neurons from isolating and sequentially processing the relevant information needed for reading. Direction discrimination training, optimal for activating the dorsal pathways at lower processing levels, improved reading fluency significantly, 4-11 fold. Data suggesting that direction discrimination training broadens the attention gateway, improving sequential processing, will also be discussed.

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33.451

Sensory Factors Limiting Horizontal and Vertical Reading Speed

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Reading speed is slower for text oriented vertically than horizontally. Yu et al. (VSS 2008) showed that slower reading of vertical text is associated with a smaller visual-span (the number of letters recognized with high accuracy without moving the eyes). Three low-level determinants of the size of the visual span are resolution (letter acuity at the tested letter position), mislocation (uncertainty about relative position of letters in strings) and crowding (interfering effects of flanking letters). In the present study, we asked which of these factors is most important in determining the size of the visual span, and in determining the horizontal/vertical difference. We measured visual-span profiles—plots of letter-recognition accuracy as a function of distance from fixation in letter positions—with trigrams (strings of three random letters) and also with isolated letters. The effect of resolution was estimated from isolated-letter profiles. Mislocation errors were extracted from trigram profiles. Errors due to crowding referred to the differences between isolated-letter and trigram profiles, taking into account mislocation errors. Consistent with our prior findings, we found that visual-span size (area under the profile) is smaller for vertical than horizontal text. When compared with a profile of perfect identification, the overall size reduction for vertically oriented text was 16.6 bits—1.1 bits were due to declining resolution from fixation, 2.9 bits to mislocations and 12.6 bits to crowding. For horizontal text, the overall size reduction was 5.3 bits—0.3 bits due to declining resolution, 1.3 bits to mislocations and 3.7 bits to crowding. We conclude that crowding is the major factor limiting the size of the visual span, and that the horizontal/vertical difference in the size of the visual span is associated with stronger crowding along the vertical midline.

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33.452

A Medium spatial frequency trough causes letter-by-letter dyslexia in normal readers

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Letter-by-letter (LBL) dyslexia is characterized by slow and laborious reading where reading latency increases markedly with the number of letters in a word. Interestingly, reading rate is also affected by high-level factors (i.e. imageability and lexical frequency), which suggests an implicit lexical/semantic access prior to conscious word identification. Fiset et al. (2006) recently proposed that the critical spatial frequencies for reading (between 2.5 to 3 cycles per letter) may be unavailable in LBL dyslexia and that implicit lexical/semantic access is mediated by lower spatial frequencies, which would fail however to offer information that is sufficiently accurate for explicit word recognition. To compensate, LBL readers would use high spatial frequencies for the sequential explicit identification of individual letters, which is the diagnostic feature of the disorder. The aim of the current study is to further investigate the special role of the medium frequencies for word recognition in normal readers. The critical medium spatial frequencies were filtered out from the words presented for overt reading, which therefore comprised only high and low (<2 and >6 cycles per letter) spatial frequencies. The results replicate the main features of LBL dyslexia. Reading latency increased linearly as a function of the number of letters in the word while being affected by imageability and lexical frequency. Error rates were relatively low, as in most LBL dyslexic cases. We thus caused letter-by-letter dyslexia in normal readers by depriving them of medium spatial frequency information. These findings are consistent with the crucial importance of this information and strongly suggest that dyslexics are truly unable to process these medium spatial frequencies for reading.

Acknowledgement: This research was supported by grants from the Natural Sciences and Engineering Research Council of Canada (NSERC) to Martin Arguin and Frédéric Gosselin and by a graduate scholarship from the Fonds Québécois de Recherche en Nature et Technologies (FQRNT) to Karine Tadros

33.453

Sensory and Cognitive Predictors of Reading Speed in Children

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Both higher-level cognitive factors and lower-level sensory factors influence reading speed. Previous work in our lab has identified visual-span size (the number of letters recognized with high accuracy without moving the eyes) as a sensory factor limiting reading speed. Here, we compare the effect of intelligence to the effect of visual-span size on reading speed. We also asked whether these cognitive and sensory factors have independent effects on reading speed. The trigram letter-recognition method was used to obtain a profile of letter recognition accuracy as a function of horizontal distance from the midline, and visual span was operationally defined as the area under this curve. Visual-span size and Rapid Serial Visual Presentation (RSVP) reading speed were measured in eleven native-English-speaking children (ages 10-14) and eleven adults (ages 18-20) with normal or corrected-to-normal vision. The letter size was 1° (x-height). Children also completed two subtests of the Wechsler Intelligence Scale for Children (WISC-IV). The Vocabulary subtest requires participants to give oral definitions of words, and the Block Design subtest of perceptual reasoning requires participants to replicate a geometrical design. Vocabulary score was a significant predictor of reading speed, explaining 51% of the variance. Block Design score was not a significant predictor of reading speed. Visual-span size was a significant predictor of reading speed in both children and adults, explaining 35% of the variance. The Vocabulary score and visual-span size were not independent predictors of reading speed, but were highly correlated ($r = 0.74$). Like vocabulary size, visual-span size can be expanded with practice. It is possible that this correlation between cognitive and sensory predictors of reading speed occurred because both vocabulary size and visual-span size increase with the amount of reading experience during childhood.

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33.454

Server-based website for low vision to access Google Map

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There are around 60 million persons worldwide with uncorrectable low vision. However, development of Internet technology that can help low vision patients to access the Web has far lagged behind that designed for blind users. We developed a new server-based website hosting Google map in a more accessible way called LowMap to help low vision users to access Google Map. LowMap hosts Google Map in our own server but sets the map parameters in a configurable way for low vision users. The web accessibility of Google Map includes two parts: the texts around the Map and the Map itself. To configure the text including the address and the driving directions, the low vision users themselves are able to adjust the font size, contrast, font style and letter spacing to the their most eligible ways. To configure the Map itself, we use Google API to implement a new feature to change the appearance of the driving directions. The new feature can overlay a new bold salient curve to the existing driving directions, so that the low vision users can easily read the driving direction curves appearing on the Map. We also deleted the complex texture of the Map to avoid the distraction of the readings. Overall, LowMap can present the low vision users with a more eligible and comfortable Google Map to access, to inquire the address and to read the driving directions. LowMap is the Google Map version for the low vision users.

Vision and Action: Posture, Wayfinding, and Whacking

Sunday, May 10, 8:30 am – 12:30 pm
Poster Session, Vista Ballroom

33.501

Does false representation of body in anorexia nervosa affect visual perception of action possibilities?

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Catching a ball or passing through an aperture without damage depends on vision and on a motor prediction that takes into account the physical dimensions of the body parts involved in the action; for instance, the shoulder width in order to pass through an aperture. A distortion of the representation of their own body is always found in patients suffering from anorexia nervosa: they believe that their body is fatter than actually is. This body image distorsion would increase their obsessive will of weight-loss. However, the precise nature of this cognitive bias and its all consequences are still unknown. Is it a mere 'state of mind', a false believe about one's self restricted to the aesthetic representation of body image? Does this cognitive distortion rather reflect an abnormal neural processing of the embodied self? Using a motorically driven perceptual decision task, we tested this latter hypothesis. Twenty-five patients and 25 control participants had to visually judge if an aperture could allow the passage without rotating the shoulders. The results showed that the critical ratio (critical aperture /shoulder width) was significantly higher in the patients. In this group, the critical ratio was also correlated with the degree of body concerns (Body Shape Questionnaire, Eating Disorder Inventory-2) and with the duration of disease. This finding suggests that the false believe about their body image, systematically reported by patients with anorexia nervosa, is an embodied misperception. It may take its source in a lived abnormal conscious experience of bodily forms and might be caused by abnormal processing in fronto-parietal networks.

33.502

The impact of aging on postural reactivity generated by simulated ophthalmic lenses distortions

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Purpose: The purpose of this study was to determine whether aging could have a significant impact on postural control in presence of dynamic optical distortions.

Methods: We used a full immersive virtual environment to simulate dynamic distortions normally produced by ophthalmic lens corrections for myopes and hyperopes. Two young and senior groups were tested and asked to stand still with feet together and arms crossed. Their task was to track a red ball with their eyes that was moving on the horizontal axis without moving the head. While tracking the ball, a dynamic distortion model was applied to the background room represented in a form of a grid. Body sway amplitude was calculated from the electromagnetic trackers positioned on the body.

Results: The data show that young subjects had a clear postural reactivity as a function of both negative and positive distortions. The body sway increased as a function of amplitude of the distortion demonstrating that it was the distortion itself that was generating postural reactivity. For the older observers, impact of distortion on postural reactivity was clearly lower than for young. Further, sway of older group was significantly lower regardless of distortion amplitude.

Conclusions: This is the first clear evidence that simulated ophthalmic lenses distortions have significant effects on postural control. Target pursuit tasks such as the one used here are often performed in naturalistic contexts. The present results have implications for understanding the different tolerances often expressed by older and younger observers to ophthalmic lens distortions. This would imply that new lens wearers of the older age group should have higher tolerances than new wearers from the younger age group. This aging effect could be due to the reduced resources of older observers for processing simultaneous sources of information (ball tracking vs. perceptual motion of background grid).

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33.503

Visual manifestation of body schema abnormalities in a case of alien hand syndrome

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Due to localized damage to right parietal cortex, LD lacks proprioceptive, kinesthetic and tactile sensation in her left arm. She quickly loses all awareness of the arm unless it is in view or in physical contact with an unaffected part of her body. Occasionally, she will unintentionally assimilate another arm in view, feeling that her arm's position is fleetingly transported to that location.

Davies (1973) found that afterimages of one's own limbs fade if the limb is moved away from the location at which the afterimage was formed, perhaps due to a conflict between visual and proprioceptive input. In Carlson et. al. (ECVP 2008), we found that this effect could be extended to grasped objects. LD's, normal (right) hand replicates the previous findings—movement of her hand and/or objects in its grasp caused their afterimages to fade. Objects moved via a manually-operated mechanical device did not cause fading. In contrast, movement of her alien (left) hand and a grasped object led to fading of the hand's afterimage, while the object's afterimage persisted.

The rubber hand illusion is induced in normal subjects by stroking their hand while they view a rubber hand being similarly stroked. As expected, LD had fleeting experiences of the illusion even without tactile stimulation. This was enhanced by dimly illuminating the rubber hand in an otherwise dark room—she could not shake the feeling that her left hand was at the rubber hand's position. When the experimenter manipulated the rubber hand, LD reported clear (and distressing) proprioceptive sensations. We found that this effect was dependent on several visual frames of reference. For example, a hand placed to the right of her body evoked no feeling if she faced and looked forward. But if she turned her head and/or looked to the right of the hand, the proprioceptive sensations returned.

33.504

Creating and shaping Body-action space

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Social and non-social contexts play a significant, but unclear, role in our everyday perceptions of people in action. In addition, attention to the space surrounding our hands and faces serve critical roles in our understanding of actions, intentions, and social communications. However, it is unknown how the space within our arms and hands reach influence action perceptions and how that space is modulated when it carries social information. Across multiple experiments, social and non-social contexts were integrated into human movement patterns. Participants compared animation pairs of a person's upper body movement patterns (hand and arm) and the relative distances traversed. Movement patterns, movement direction, and distances were varied. Accuracy levels differed across movement patterns. The body context expanded the ability to detect distances from movement direction as well as improve accuracy for smaller differences in distances. Social contexts enlarged the accuracy space created by the body alone. Accuracy space was further modulated by movement direction information from the social contexts. In sum, the body serves as a non-social context which improves distance judgments of movement patterns. The improvement may be attributed to the formulation of what is referred to here as

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"Body-action space". Social contexts appear to further expand and reshape the Body-action space. The formulation and utilization of Body-action space is proposed here, as well as how social cognitions tune this space.

33.505

Looking without seeing: Two puzzling findings

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We have observed that congenitally blind individuals sometimes orient their head toward a manual workspace when the manual task becomes challenging. To document this behavior we videotaped six congenitally blind participants while they attempted to string beads of varying difficulty. Two participants oriented their heads dramatically, in a manner that resembled actual looking. Three others showed partial orienting responses at task initiation, or head re-orienting when the task became difficult. One participant showed no evidence of head orienting toward the beading task; she likewise lacked social orienting during conversation. Debriefing interviews found that none of our participants were aware of having oriented their head toward the beads. It appears likely that head orienting serves as an embodied component of spatial attention.

To test whether head orienting would benefit beading performance of sighted individuals even when vision was blocked, we administered a controlled experiment in which blindfolded participants repeated a set sequence of 10 beads three times. Half the participants were required to orient their head down toward the workspace for the first twenty beads and then to orient straight ahead for the final ten. The other half were required to orient away at first and then toward the workspace for the final ten. Beading times for each bead were extracted from videotapes; they varied greatly by bead type. Beads of medium difficulty (70% success within one minute) were selected for analysis. To our surprise, sighted participants were faster at beading when their blindfolded face was oriented away from the workspace. This pattern was statistically evident between-subjects during the first sequence of ten beads and even more pronounced during the last sequence, following the switch in head orientation. The consequences of visionless orienting may differ depending on experience.

33.506

Looming detection within natural scenes and potential errors in roadside judgments

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Detection of looming is a critical for successful collision avoidance. Regan et al (1979 – 96) has been foremost in documenting humans' sensitivity to looming and MiD, but there are various methodological factors that make it difficult to extrapolate from these measures to performance in natural settings. The current study was concerned with looming thresholds in the context of roadside behaviour. Adaptive (BEST-PEST) staircase procedures were run using photo-realistic images of a motorbike or car presented for 200ms, in order to determine sensitivity to looming of vehicles in central or peripheral vision, under monocular viewing conditions and against a neural grey background or a realistic static road scene. Two critical TTC arrival time values were simulated: 5s (sufficient time to cross) & 3s (critical decision point). Vehicle images changed in size and expansion to simulate approach at different speeds, within a display configuration that ensured sufficient pixel resolution for all trials/steps. The participant's task was simple detection of looming (opponent edge motion) for a vehicle image when there was also lateral translation of the image. Thresholds for looming in these conditions were substantially higher than those reported by Regan et al under more constrained psychophysical conditions. We also found a significant increase in thresholds when stimuli were presented only 6deg in the periphery. The results suggest that, in displays that contain the contrast and edge-detail of natural scenes, and where other motion information may be present, the detection of looming may be significantly poorer than previously reported. This still allows for accurate detection if the object is foveated, but if in a cluttered scene the observer glances slightly off-target they may fail to detect fast approaching vehicles. This may be particularly a problem for smaller profile vehicles such as motorcycles and may explain driver errors with respect to these.

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33.507

The outer limits: How limiting the field of view impacts navigation and spatial memory

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Many optical devices limit the amount of the visual field that can be seen at any one time. Here we examine how these limits on Field of View (FoV) impair the ability to integrate visual information and make navigational decisions. Participants wore field-restricting goggles with separate groups fitted with either a 40° or 90° horizontal FoV. Subjects actively explored a maze-like environment over the course of 12 search trials. For each search trial, subjects were given a specific target and asked to find it as quickly as possible. The time and path walked to the targets were recorded on paper. Between each trial subjects were blindfolded and led to a new location in the environment. After the search trials, they completed a set of spatial memory tasks that included sketching a map of the search area, and judging the relative direction of and distances between objects. Search performance was measured by average walking speed, which was determined by dividing the path length by the search time for each trial. Participants with the narrower FoV walked significantly slower to the targets, but they increased their speed over time. Independent raters, who judged the sketch maps on layout, scale, and geometry showed a significant preference for the maps of the wide FoV group over the narrow FoV group. However, there was no effect of FoV for the relative direction and distance estimation task indicating a limited impact on the memory of locations of objects in the environment. In contrast, the results suggest that FoV restriction has a significant impact on the spatial representation of the layout of one's environment that needs to be considered in the design and use of devices that augment or enhance vision.

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33.508

Parietal processing of visual information specifying "where I'm going next"

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Field, Wilkie & Wann (2007) contrasted brain activation produced by travelling a curving trajectory across a ground plane with an otherwise identical stimulus that also included road edges providing advance information about changes in trajectory curvature. The addition of advance information activated a superior parietal area bordering, but distinct from, the parietal eye fields (PEF). If the novel parietal activation is due to processing of advance trajectory information then it should be driven by the distant part of the road, but not by the near road. If, on the other hand the novel parietal activation was due to lower level processing of the road edges, such as the recovery of form from motion, the parietal activation should be produced by either the distant or near road when these features are presented in isolation. Results confirmed the proposal that the superior parietal area processes advance information about changes in trajectory curvature. Relative to the ground plane only baseline condition, the near road caused an increase in the BOLD response confined to the MT+ complex, whereas the distant road activated MT+ and the parietal area. The MT+ activation produced by the near road was paralleled by a small improvement in the task of tracking instantaneous travel direction with a joystick using the flow field information. The joystick motion was open-loop and did not change the actual direction of travel. The improvement produced by adding the near road to the ground plane took the form of a reduction of tracking response lag. The parietal activation produced by the far road was accompanied by a larger reduction of the tracking response lag to zero. This suggests that the activity in the superior parietal area is specific to the processing of advance information relating to "where I'm going next" within a 1-2s prospective timeframe.

33.509

"Rips" and "folds" in virtual space: Ordinal violations in human spatial knowledge

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At one extreme, human spatial knowledge might preserve Euclidean properties of metric distance and angle; at the other, it might preserve topological relations such as neighborhood or graph structure. To investigate this question, participants learn one of two virtual environments: (1) a Wormhole maze that violates Euclidean structure by introducing two "wormholes" that seamlessly transport a participant between locations, and (2) a Euclidean control maze. We probe their spatial knowledge using a shortcut task. Participants walked in a virtual environment while wearing a head-mounted display (63˚ H x 53˚ V), and head position was recorded with a sonic/inertial tracker (70 ms latency). During training, they learned the locations of nine objects by exploring the maze and then walking from Home to each object, sufficient to learn their metric locations via vector subtraction. On test trials, participants walked from Home to starting object A, the maze disappeared, and they took a direct shortcut to the remembered location of target object B. In the Euclidean maze, participants tend to walk toward the metric target location, on average, although shortcuts are highly variable in both mazes. In the Wormhole maze, from some starting points participants tend to walk toward the metric location of target B on average, whereas from other starting points they walk through a wormhole to an alternative location B′. Such "rips" and "folds" in spatial knowledge even create reversals in the ordinal relations among objects. Participants are generally unaware of these inconsistencies, even though they are in principle detectable. The results suggest that spatial knowledge may preserve some local metric properties, enabling rough shortcuts, but is globally non-Euclidean. It might be characterized by a weighted graph in which the weights are globally inconsistent.

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33.510

The Contributions of Global and Local Object Landmarks in Human Wayfinding Behavior

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The ability to recognize and use object landmarks is crucial for efficient wayfinding. However, the roles of different types of landmarks in wayfinding remain to be clarified. In the current study, we examined how global landmarks and local landmarks were utilized differently in a virtual maze environment. There were three experimental conditions: a global-landmark condition with tall architectures that surrounded the virtual maze and were visible from almost everywhere, a local-landmark condition with cartoon pictures of common objects that were posted on the walls along the paths inside the maze and were only visible from certain locations, and a control condition that had no object landmarks. The participants learned the layout of the maze and the target positions through a series of trials. Their learning performance was assessed by traveling distance, time, and ratio of successfully found targets within time limits. The results of Experiment 1 demonstrated that while participants learned to navigate most efficiently in the local-landmark condition, their performance did not differ between global-landmark and control conditions. In Experiment 2 we increased the number of target locations for navigation in each trial, and the results showed that participants could benefit from both global- and local- landmarks as opposed to the control condition, though they still performed better in the local-landmark condition than in the global-landmark condition. Taken together, local objects seem to be easier to use as reference points than global objects. Global-object landmarks can still be used to assist wayfinding, but they may become useful only when there is high demand on memory of target locations.

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33.511

The Traveling Salesman Problem in the Natural Environment

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Is it possible for humans to navigate in the natural environment wherein the path taken between various destinations is 'optimal' in some way? This problem is traditionally framed as the "Traveling Salesman Problem" (TSP) — Given N cities to visit, what is the shortest path that connects them such that each city is visited only once? It has been shown that, when presented with an overhead, map-like presentation of the cities, subjects are exceptionally good at solving this optimization (error 2-3% longer than the optimum), even with very large Ns. (see e.g. Dry (2006) and MacGregor (2000)) In these experiments we evaluate human navigation performance when solving the TSP in the natural environment. Based on manipulations in these experiments we further investigate the effect of effort and its environmental affordance on navigation decisions. Two outdoor settings were used: A flat, open, 1/4 football field sized area and similar sized area with a variable terrain and obstacles. Fifteen locations in each area were marked with flags. From a random starting location subjects were instructed to walk to each location using the constraints of the TSP. Using a simple linear path-based metric, average performance in the flat-field condition was good (5% error) but was significantly worse in the variable-terrain condition (16% error). This suggests that subjects were not using a global representation of configurations to pre-plan their route, especially in the variable-terrain case. Because of this we hypothesize that subjects took a more 'local' approach. Based on the fact that the variable-terrain condition required a bit of 'hiking' and obstacle avoidance when compared to the flat condition we further hypothesize that the subjects took effort into account when planning their traversal. Lastly, we present a model that takes these local, ordinal decisions into account along with effort.

URL: http://www.skidmore.edu/~flip

33.512

The Importance of Body-Based Cues for Travelled Distance Perception

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When moving through space, both dynamic visual information (i.e. optic flow) and body-based cues (i.e. proprioceptive and vestibular) jointly specify the extent of a travelled distance. Little is currently known about the relative contributions of each of these cues when several are simultaneously available. In this series of experiments participants travelled a predefined distance and subsequently reproduced this distance by adjusting a visual target until the self-to-target distance matched the distance they had moved. Visual information was presented through a head-mounted display and consisted of a long, richly textured, virtual hallway. Body-based cues were provided either by A) natural walking in a fully-tracked free walking space (proprioception and vestibular) B) being passively moved by a robotic wheelchair (vestibular) or C) walking in place on a treadmill (proprioception). Distances were either presented through vision alone, body-based cues alone, or both visual and body-based cues combined. In the combined condition, the visually-specified distances were either congruent (1.0x) or incongruent (0.7x/1.4x) with distances specified by body-based cues. Incongruencies were created by either changing the visual gain

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or changing the proprioceptive gain (during treadmill walking). Further, in order to obtain a measure of "perceptual congruency" between visual and body-based cues, participants were asked to adjust the rate of optic flow during walking so that it matched the proprioceptive information. This value was then used as the basis for later congruent cue trials. Overall, results demonstrate a higher weighting of body-based cues during natural walking, a higher weighting of proprioceptive information during treadmill walking, and an equal weighting of visual and vestibular cues during passive movement. These results were not affected by whether visual or proprioceptive gain was manipulated. Adopting the obtained measure of perceptual congruency for each participant also did not change the conclusions such that proprioceptive cues continued to be weighted higher.

33.513

Do actors pick up information on the fly to perceive possibilities for action?

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Navigating through complex, dynamic environments requires actors to choose actions in ways that take into account their ever-changing movement capabilities. For example, deciding whether to pass through a gap between a pair of converging obstacles requires one to take into account both the state of the environment and one's locomotor capabilities. To what extent does the ability to take movement capabilities into account reflect what actors know about their locomotor capabilities versus what they learn based on information that is picked up "on the fly" while moving? We ran two experiments in which subjects judged whether they could pass through a shrinking gap between a pair of converging cylinders in a virtual environment. Distance to the convergence point and cylinder speed were manipulated such that the gap was passable on some trials but not others. In Experiment 1, judgments of passability were equally accurate regardless of whether judgments were made while subjects were stationary or moving, suggesting that actors can rely on what they know about their locomotor capabilities to make accurate judgments. To further test the contribution of information picked up on the fly, we ran a second experiment in which subjects walked for 3 m before the cylinders began converging. The task was to judge within 1 s after the onset of cylinder motion whether the gap was passable. On a small percentage of catch trials, the visual gain in the virtual environment was increased such that subjects moved 150% faster than normal. Subjects were more likely to perceive the gap as passable on catch trials with increased visual gain. The findings suggest that actors can rely on what they know about their locomotor capabilities to make accurate judgments before movement is initiated, but that visual information also contributes when judgments are made on the fly.

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33.514

A Dissociation Between Perception and Action in the Material-Weight Illusion

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In the famous size-weight illusion, the smaller of two objects of equal weight is perceived as heavier than the larger one. Remarkably, however, people quickly learn to scale their grip and load forces to the actual rather than perceived weights of the objects, despite continuing to experience a robust size-weight illusion. In other words, there is a clear dissociation between perceived weight and the scaling of the forces required to pick up the objects. A similar illusion, where the material of the object (as revealed by its visual appearance) affects its perceived weight has also been described (the 'material-weight illusion' Seashore, 1899). In the current study, we investigated whether or not a similar dissociation between perceived weight and the scaling of grip and load forces could be demonstrated in this illusion. We recorded the grip and load forces when participants picked up objects of different materials (metal, wood, and polystyrene), constructed to have the same size and mass as one another. On each trial, we also recorded participants' judgments of the perceived weight of the objects. The classic perceptual effects of the 'material-weight illusion' were replicated; e.g., participants ranked the metal block as lighter than the blocks made of other materials. Nevertheless, we also found a similar dissociation to that seen in the earlier 'size-weight illusion' work between perception and action. In other words, after only one or two trials, all objects were gripped and lifted with the same forces, despite being perceived as having different weights.

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33.515

Smooth pursuit and manual interception

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Why do people generally pursue objects with their eyes while they move to intercept them? To find out we compared interception in two tasks with the same spatial and temporal requirements (1cm and 100ms) but in which different eye movements would maximize the critical spatial resolution. People had to either hit a target that was moving behind a line at the moment that it passed a gap in the line, without hitting the line, or to hit a target moving in front of a line into a gap in the line. The average pursuit gain during the last 200ms before the hit was 0.2 when hitting through the gap and 0.7 when hitting into the gap. The standard deviation in the hand's position as it passed the (fixated) gap was 3mm when hitting through the gap. The standard deviation in the hand's position relative to the (pursued) target was 6mm when hitting the target into the gap. The difference can be interpreted as a standard deviation in matching the timing of the hand to that of the target of 24ms. The average variability in the target's position at the moment of the hit was almost 8mm (40ms) when hitting through the gap, indicating that people are less good at timing interception on the basis of the retinal image of the target approaching the fovea than on the basis of the pursued target's position. The corresponding variability was similar when hitting into the gap, in which case the gap's image moved across the retina. In both tasks we found large systematic errors in the target's position with respect to the gap at the time of the hit. These errors were consistent with subjects relying heavily on previous trials for timing their hit. Thus, making appropriate eye movements is important for interception.

33.516

Combining information across time for successful catching

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We measured the movements of the ball and of the hands of a thrower and a catcher in a natural one-handed catching task. We investigated how visual information is used by randomly occluding the catcher's sight. We can capture the probability of successfully catching the ball by combining two kinds of information. The first is information that allows one to predict the ball's trajectory. This ability is larger when more of the initial part of the trajectory (including the motion of the thrower's hand before the ball is released) is visible, and is modelled as a cumulative Gaussian centred near the moment of release. The second is information that allows one to guide one's hand to the ball. This ability decreases as the ball approaches the hand, because the time left to adjust the movement becomes too short. It is modelled as an inverted cumulative Gaussian centred about 200 ms before the catch. Both Gaussians have widths of about 170 ms. The ability to make good use of either source of information shows how flexible human movements are despite the limitations imposed by neuronal resolution and delays.

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33.517

Internal models in two-dimensional target motion prediction and interception

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Prediction is a central skill in human life. As our environment is constantly changing, both as a consequence of our actions and independently of us, it's necessary to anticipate when and where future events will happen, in order to be able to synchronize our actions with them and to proficiently interact with the world (e.g. Gredebäck et al. 2002). The study of interception abilities represents a good option to investigate this topic, as interception is a quite common task and, at the same time, it strongly requires anticipation skills. In fact it wouldn't be possible to catch any target acting in a purely reactive manner, due to the visuo-motor transmission delays of the human body (Zago & Lacquaniti, 2005). In our experiments we measured how different parameters of two-dimensional target motion (i.e. curvature, speed and acceleration) affected the predictive strategy adopted by subjects. Two predictive tasks were compared: one involving the only visual estimation of the arrival point of a virtual target and the other requiring subjects to directly intercept the virtual target by pointing on it with their index finger (vision plus motor involvement). This way it has been possible to understand whether the goal of a predictive effort affects how prediction is performed. The study of the recorded index finger motion allowed us also to study the kinematic features of predictive actions. Particular attention was devoted to understand if an internal model of target motion is built and exploited in prediction. Moreover a further investigation was performed to evaluate whether habituation to a gravitational environment (i.e. where objects move according to the gravitational laws) plays a role in determining predictive performances.

33.518

Sub-cortical responses to looming objects: An fMRI study of human interception of footballs

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Detecting the time to collision (TTC) of an approaching object is imperative to species' survival. Cells in the pigeon nucleus rotundus have been found to respond to high rates of looming. This would hint that a similar function might be found in sub-cortical areas of primates, such as the thalamic nuclei and superior colliculus (SC). We examined whether an equivalent response to looming stimuli would be found in the human SC using fMRI. Within a Siemens 3T scanner we presented virtual footballs in five conditions: a fast ball, which approached the viewer and disappeared when TTC = 0.33s; a standard ball which disappeared at TTC = 1s; a large ball (TTC = 1s) but which matched the fast ball for final optic size. Two control conditions presented a reverse ball, which matched the speed of the fast ball but moved away from the viewer and a static ball which faded in over a matched period. Participants (n = 14) were required to press a button when the ball would arrive (TTC = 0), reach a distal location or reach full luminance in the control conditions. Percent signal change in SC was significantly higher for the fast ball compared to all other conditions. The large, reverse and static balls, however, resulted in higher signal change values than the standard ball suggesting that a proportion of the SC activation was associated with lower level visual effects. A second experiment used simple dot ball stimuli to balance for low level visual effects. SC activity for fast balls was higher than for standard speed balls and marginally higher than balls matched in terms of local motion and luminance, but without the looming signals. Together these findings suggest that a subset of cells in the SC respond to looming signals signifying an approaching object.

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33.519

Visually perceived distances map onto different forms of throwing for adults and children

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This study is about the dynamics and kinematics of visually directed throwing. How is it, we ask, that people look at a target ranging from 1 - 30 meters in distance and know how to try to throw a beanbag to reach the target? For near-by targets, adults and children alike maximize their precision by freezing most degrees of freedom and swinging from only one joint whereas for far away targets they maximize their force by swinging from elbow, shoulder, waist and with a running start. In Study 1 4-6 year old children and adults were asked to look binocularly at targets ranging from 1 to 30 meters away and try to throw a bean bag to reach the target. In Study 2 children and adults were asked to throw again, but without any information about their results. And in Study 3 children and adults were asked to throw after viewing the targets monocularly as well as binocularly. The results show that even the preschool aged children varied the forms to fit with the varying target distances: For near-by targets they tended to maximize precision by swinging from only one joint, whereas for far-away targets they maximize force by swing from elbow, shoulder, waist and with a running start. Binocular viewing did not influence the form of throw or the accuracy of throwing under these conditions.

Binocular Vision: Brain and Behavior

Sunday, May 10, 8:30 am – 12:30 pm
Poster Session, Vista Ballroom

33.520

Spatial stereoresolution

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The highest frequency disparity grating which can be perceived as a corrugated surface is around 3-4 cycles per degree (Tyler 1974; Bradshaw & Rogers 1999; Banks et al. 2004), much lower than the analogous limit for luminance gratings. This low limit has been explained in terms of an initial encoding of disparity into piecewise frontoparallel patches (Banks et al. 2004, Nienborg et al. 2004): the stereoresolution limit reflects the smallest windows across which interocular correlation is measured. Existing studies of stereoresolution have all used sinusoidal variations in disparity. This probably reflects practice in the luminance domain, where "over a wide range of spatial frequencies the contrast threshold of a grating is determined only by the amplitude of the fundamental Fourier component of its waveform (Campbell & Robson 1968). Yet there is no theoretical reason to expect this to hold in the disparity domain. Under the explanation proposed by Banks et al. (2004), higher stereoresolution would be expected with square-wave disparity gratings, in which disparity alternates between two values, than with sine-gratings in which disparity varies smoothly. Square-wave gratings are piecewise-frontoparallel, and so present less effective disparity "noise" to a matching process which assumes disparity is locally constant. Furthermore, recent evidence suggests that cells in V2 are specialized to detect disparity edges, which occur naturally at objects boundaries and are important in scene segmentation (von der Heydt et al. 2000, Bredfeldt & Cumming 2002). These edge-detectors would be expected to be driven more strongly by square-wave disparity gratings than by sines. We tested this expectation by comparing

stereoresolution in random-dot patterns portraying horizontally-oriented disparity corrugations with square-wave and sinusoidal profiles. To our surprise, there was little difference in the stereoresolution measured with the two grating types. We discuss the implications for the piecewise-frontoparallel model of disparity encoding.

33.521

The effects of surface shape on sensitivity to disparity-defined stimuli corrupted by binocular decorrelation

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The perception of the shape of surfaces defined by binocular disparity requires the matching of regions between the left and right images. The stereoresolution for discriminating such surfaces is relatively low, and it has been argued that this is constrained by (i) the size of the smallest window available in the matching process and (ii) an assumption that disparity is constant within this window (Banks et al, 2004, Journal of Neuroscience, 24, 2077-2089). We investigated, in addition to the constraints imposed by this matching process, the impact of other factors determining the detection of surfaces. To do this, we presented observers with disparity-defined surfaces that were corrupted by binocular decorrelation, and determined the degree of correlation required for their detection. This was done using a 2AFC procedure, in which one interval contained a target surface, and the other contained uncorrelated noise. Detection thresholds were measured for (i) slanted surfaces, over a range of slants and tilts and (ii) sinusoidally corrugated surfaces, over a range of spatial frequencies, amplitudes and orientations. We found that performance differed depending on the type of surface presented. For corrugated surfaces performance peaked at low spatial frequency and amplitude. This result can be explained by a model that predicts a matching process in which disparity is assumed to be constant within a local region. However, we found that for slanted planar surfaces, performance improved at larger magnitudes of slant. We conclude that this result cannot be attributed to the limitations imposed by the sampling process.

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33.522

Transfer of Perceptual Learning Between Local and Global Random-Dot Stereograms

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Several studies reported that stereothresholds assessed with local-contour stereograms and complex random-dot stereograms (RDSs) are different. Dissimilar thresholds may be due to differences in the properties of the stereograms (e.g., spatial frequency content, contrast, inter-element separation, area) or to different underlying processing mechanisms. This study examined the transfer of perceptual learning of depth discrimination for local RDSs to global RDSs with similar properties, and vice versa. If global and local stereograms are processed by separate neural mechanisms, then the magnitude and rate of training for the two types of stimuli are likely to differ, and the transfer of training from one stimulus type to the other should be minimal. Based on the results of a previous study, we chose 3.7-deg RDSs with element densities of 1.15% and 15% to serve as the local and global stereograms, respectively. Fourteen inexperienced subjects with normal binocular vision were randomly assigned to either a local- or global- RDS training group. Stereothresholds for both stimulus types were measured before and after 7700 training trials (10 sessions X 10 blocks X 77 trials). Each subject's stereothresholds were normalized to the pre-training measurement for the trained condition and the average data were fit with an exponential equation. Stereothresholds for the trained condition improve for approximately 3000 trials, by approximately 0.23 log units for local and 0.15 log units for global RDSs, and level off thereafter. Neither the rate nor the magnitude of improvement differ statistically between the local- and global-training groups. Further, no significant difference exists in the amount of improvement on the trained vs. the untrained targets for either training group. These results are consistent with the operation of a single mechanism to process both local and global stereograms.

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33.523

Local binocular depth contrast effects on surface edges

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Many studies have shown that binocular depth contrast is related to global processing of disparities. In contrast, there have been few studies demonstrating local depth contrast of surfaces analogous to that of luminance domain. In this study, we demonstrate local interaction in depth by placing a depth gap adjacent to a curved depth surface. Test stimuli were horizontally oriented convex/concave cylindrical surfaces. Two planar surfaces (inducer) were placed adjacent to the above and below curved edges of test stimuli with crossed/uncrossed disparity. The results showed that a convex surface placed next to an inducer with uncrossed disparity had a flatter appearance while concave surface had a flatter appearance with an inducer having crossed disparity. To demonstrate that the effects were caused by local edge interaction, we used two other types of inducers. First, we placed the inducers adjacent to the right and left edges of test stimuli. The results showed much less flattening effects, suggesting that the effects were not caused only by the depth position of the inducers but by the local depth contrast. Second, we used inducers whose depths were vertically alternated with square wave oscillation. The disparities of inducers adjacent to the edge of test stimuli were either crossed or uncrossed. If depth contrast effects occur only globally, there should be no effect of local depth position adjacent to test stimuli because the average disparities of inducers were both zero. If the effects are local, they should depend on the depth position of the inducer adjacent to test stimuli. The results showed that a convex surface had a flatter appearance when an inducer was behind at the edge of test stimuli while concave surface was flattened when inducer was in front. These results also suggest that there is a local depth contrast effect in depth domain.

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33.524

The effect of binocular disparity on the detection of curved trajectories

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The current study examined the roles of binocular disparity and object motion on the detection of curved trajectories. Subjects were shown computer generated displays of a lit sphere (diameter of 3.8cm) that traveled through the display at eye height from a starting position (22.3cm to the left of and 138.5cm away from the observer) to an ending position (15.3cm to the right of and 100.8cm away from the observer). On each trial subjects were shown two displays. In one display the sphere followed a straight trajectory; in the other it moved in either a concave or convex arc relative to the x-axis. A two-alternative forced choice procedure was used without feedback and subjects were asked to indicate which display simulated a curved trajectory. A BEST PEST procedure was used to adjust the radius of the circle that defined the arc to determine the point of subjective equality (PSE). Two independent variables were manipulated: viewing condition (binocular vs. monocular) and arc direction (concave vs. convex). The four conditions were run in separate blocks and order was counterbalanced across participants with a Partial Latin Square design. We found that subjects' PSE was lower for binocular (mean radius of curvature of 98.0cm) as compared to the monocular condition (mean radius of curvature of 72.4cm). Additionally concave trajectories were easier to detect than convex trajectories. These results support the notion that binocular information is important for the detection of curved trajectories. The results also indicate the importance of the sign of curvature, suggesting that the rate of change of disparity is important in detecting curved trajectories.

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33.525

The coarse vs. fine dichotomy in stereopsis: a matter of scale

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Is disparity processing subserved by a single mechanism that spans all disparities or by two distinct mechanisms that operate over different disparity ranges? Data from depth pedestal experiments have proven divided on this issue, likely due to the wide range of stimuli and tasks used, and to variables such as stimulus size and retinal eccentricity.

In an effort to resolve this issue we exploit a result from Wilcox and Hess (1995) who showed that the coarse (2nd-order) system dominates processing for diplopic targets. Further, 2nd-order stereopsis depends critically on scale, as the upper limits for stereopsis increase with increasing stimulus width. Here we used a 1AFC method of constant stimuli to measure discrimination thresholds for a test bar relative to a reference bar positioned at depth pedestals ranging from 0 to 1 deg (n=5). The stimulus parameters were selected so that the target and reference would become diplopic within the test range. Not surprisingly, discrimination performance was degraded as pedestal disparity was increased. This occurred over a large range of disparities within the fusable range. However, outside the fusable range we find a dramatically different pattern of results; discrimination performance plateaus, remaining constant in spite of increasing diplopia. Our data echo those of Ogle (1952) and others, but with important differences that are tied to the test disparity relative to the stimulus width. We argue that these data reflect a neural dichotomy between coarse and fine processing that is tightly tied to scale rather than absolute disparity.

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33.526

Percept-related differences found in the pupillary response to physically identical luminance changes

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[Purpose] The present study produced different perceptual changes with a physically identical stimulus sequence by utilizing binocular rivalry of dichoptic white and black disks and asked which change the pupillary response depended upon in perceptual experience or in physical stimulation.

[Methods] At the start of each trial, the observer dichoptically viewed white and black disks (first stimulus), white to the left eye and black to the right eye. Both disks were presented on a gray background (4 cd/m2) and their relative luminances to the background were +0.3 (white) and -0.3 log units (black), respectively. The observer was instructed to press a key when a designated disk was exclusively dominant. The key press initiated a stimulus change; the first stimulus was ramped off and then the second stimulus of 2-sec duration was ramped on over a 300-ms period. As the second stimulus, either the same dichoptic white and black disks or binocular white disks were presented. When the designated disk was black and the second stimulus was binocular white disks, for example, the perceptual change was black to white. But when the designated disk was white, the same stimulus sequence produced the perceptual change of white to white. The pupillary response was recorded from the left eye during stimulation.

[Results and Discussion] The pupillary response changed depending upon the percept; the constriction amplitude was larger and the response latency was shorter when the associated perceptual change was black to white than when it was white to white. Moreover, the steady-state pupil size just before the observer's key press also exhibited a percept-related change; i.e., the pupil size was smaller when the designated disk was white. These findings suggest that, although the pupillary response to luminance changes is believed to be mainly mediated by subcortical pathways, it also exhibits percept-related modulation.

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33.527

The influence of TMS over MT on perceptual memory in structure-from-motion rivalry

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Background. Ambiguous images confront the visual system with inconclusive or conflicting information. In response perception wavers seemingly unpredictably between alternative interpretations. Several factors influence the system's choice between conflicting percepts, thereby revealing mechanisms of perceptual organization. One such factor is prior perception: once an ambiguous image has been encountered, perception on subsequent encounters depends on what was previously perceived. The neural basis of this memory is uncertain. Here we investigate whether the memory traces can be altered by transcranial magnetic stimulation (TMS) applied during memory retention.

Methods. An ambiguous structure-from-motion stimulus was presented intermittently and observers reported perception on every presentation. The blank interval between presentations was varied in a blocked fashion. At long blank durations the interaction between consecutive percepts is known to result in priming: the same percept tends to repeat over presentations. At short blank durations one finds mostly suppressive interactions: perception alternates on consecutive presentations. We applied triple pulse TMS at 25 Hz over the human middle temporal area and associated areas (hMT+) during the blanks that separate presentations.

Results. For four observers we found that TMS over hMT+ increased the probability for perception to alternate from one stimulus presentation to the next, relative to no TMS and to TMS over the vertex. This suggests that perceptual memory traces in structure-from-motion rivalry may reside in hMT+. Current models of perceptual memory treat these traces as a form of neural adaptation. Within the context of these models our results can be interpreted as an elevation of adaptation due to TMS.

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33.528

Coarse and fine disparity sensitivity in human visual cortex

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Disparity-selective neurons have been reported in many areas of primate visual cortex; however, the circuitry of depth perception, in particular the areas that reflect stereopsis rather than more basic disparity mechanisms, remain elusive. Here we explored this proposed functional specialization in humans, by measuring fMRI activity related to depth judgments made at coarse and fine disparities.

Two horizontally aligned 8° × 8° dynamic RDSs were presented at 0°, 0.1°, 0.35° or 0.7° pedestal disparities and symmetrically arranged in depth around fixation. Additional depth was added to each plane with a sinusoidal profile (amplitude 0.2°, which was increased in one plane and decreased in the other by $\Delta x/2$). Subjects indicated which sinusoid had the greater amplitude, whilst maintaining central fixation. Consistent discrimination performance was achieved by adjusting the value of Δx. RDSs at zero disparity were used as the baseline. Functional and anatomical data were acquired in a 3T scanner at 2.2×2.2×2.5 mm and 1×1×1 mm resolutions, respectively. Visual areas were defined with standard retinotopic mapping.

The BOLD response increased linearly with pedestal disparity in V1, V2, hV4 and V7, but followed an inverted-U function in other areas. Further analysis of the pooled response from early (V1, V2 and V3), ventral (hV4, LO1 and LO2) and dorsal (V3A, V7 and MT) areas revealed a greater activation to nonzero than to zero pedestal disparity in the dorsal region. The response in the IPS also followed this pattern. By contrast, activation in early and ventral visual cortex did not change across pedestals. These results suggest that: (a) there are differences in sensitivity to fine and coarse disparity in the dorsal and ventral visual pathways; (b) dorsal visual areas are more strongly engaged when the task requires judgments between different values of coarse disparities, a result consistent with recent single-unit studies.

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33.529

A simultaneous depth and rivalry paradigm imaged with fMRI

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Psychophysical experiments have shown that it is possible to simultaneously perceive binocular depth and rivalry in plaids. Depth may be perceived from the near-vertical components, while the diagonal components undergo rivalry, as long as the components are in different spatial frequency or orientation bands (Buckthought & Wilson, 2007).

Here we used fMRI at 3T to image activity in visual cortex while human subjects perceived depth and rivalry simultaneously from plaids. This was compared to the activation obtained with near-vertical or diagonal gratings in which depth or rivalry alone was perceived. In conditions with depth, an interocular orientation disparity (5 degrees) was used to produce tilt, and this cue alternated every three seconds between top tilted forward or backward. Hence, the perceived depth alternated dynamically, analogous to the rivalry percept. Six subjects performed either a rivalry or depth task with the plaid or grating stimuli by indicating when alternations occurred. In three experimental conditions the spatial frequencies of the near-vertical and diagonal components were, respectively: (a) 2.5, 6.4 cpd; (b) 6.4, 2.5 cpd; (c) 6.4, 6.4 cpd.

We found that the network of activated cortical areas was remarkably similar for the rivalry and depth task. When subjects viewed plaids, some areas were activated more during the depth task than the rivalry task independent of spatial frequency (e.g. posterior superior temporal sulcus), while in other regions the bias was for the higher (e.g., calcarine cortex) or lower spatial frequency component (e.g., MT+). Placing depth and rivalry components in different spatial frequency bands allowed us to find greater differences between the two. Activation when depth and rivalry were perceived in isolation (gratings) was higher than when depth and rivalry were perceived simultaneously (plaids), consistent with inhibitory interactions between the mechanisms for depth and rivalry.

We conclude that depth and rivalry are subserved by similar mechanisms, and are perceived simultaneously by coexisting in different spatial frequency or orientation channels. Binocular vision models must be revised to incorporate these findings.

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33.530

High-resolution imaging of the human thalamus and superior colliculus during binocular rivalry

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Introduction. Binocular rivalry is known to suppress the eye-specific layers of the lateral geniculate nucleus (LGN) in humans, but the spatial resolution has been insufficient to discriminate between the magnocellular (M) and parvocellular (P) sections. It is also unknown whether the perceptual alternations during binocular rivalry, and hence our awareness, are reflected in the activity of the pulvinar or superior colliculus. Therefore we employed high-resolution functional magnetic resonance imaging (fMRI) to study binocular rivalry in these structures.

Methods. Subjects' brains were scanned with a 3 T MRI scanner and a multi-channel head coil. The spatial resolution was enhanced beyond the hardware limits of the scanner using a post-processing super-resolution technique. Subjects viewed stimuli through anaglyph glasses to isolate each eye. Alternating hemifield flickering checkerboard stimuli were used to determine the eye dominance of each voxel in the subcortical structures. To induce binocular rivalry, subjects were shown a rapidly rotating stimulus consisting of two full-field orthogonal gratings independently presented to each eye. The subjects indicated the perceptually dominant grating via key presses. The amplitude of the perceptual modulations were determined through the average fMRI response time-locked to the subjects' perceptual responses.

Results. Binocular rivalry modulated the activity in each of the subcortical structures. In the LGN, the sign of the modulation was related to the laminar structure of the nucleus, with but no differences were observed between voxels belonging to the M or P sections.

Conclusions. The phenomenon of binocular rivalry can be measured throughout the human visual system, including the subcortical visual nuclei, suggesting that these structures contribute to our awareness. No special role in binocular rivalry could be attributed to either the M or P sections of the LGN.

33.531

Electrophysiological correlates of motion-induced blindness

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In Motion-Induced-Blindness (MIB), salient targets superimposed on a global moving-dots pattern are perceived to disappear and reappear alternatively after prolonged viewing (Bonneh, Cooperman, & Sagi, 2001). This oscillation of target disappearance and reappearance in MIB reflects an alternation state of conscious experience that occurs with unvarying stimulus over time. However the relationship between this kind of alternation state and the ongoing brain activities has been less studied (cf. Donner, Sagi, Booneh, and Heeger, 2008). Here we investigate the changes in the frequency spectrum of the electroencephalogram (EEG) on the perception of MIB. We collected brain activities specifically associated with the timing when observers reported (1) the illusory disappearance of the MIB target (the MIB condition), (2) the real disappearance of the target (the real-disappearance condition), and (3) the motor responses as in the former two conditions but now a blank field was seen (the motor-control condition). The average power spectra of the 1 sec pre- and post-response periods were computed for the three conditions, and so were the amplitudes of total power and relative band powers of the delta (0.5–4 Hz), theta (4–7.5 Hz), alpha (7.5–13 Hz), beta (13–30 Hz), and gamma (30–70 Hz) frequency bands. The results revealed that MIB targets led to larger and smaller amplitude spectra in the relative power of the delta and alpha bands, respectively, compared to the motor control. Moreover, MIB targets led to smaller amplitude spectra both in the delta and alpha bands compared to the real-disappearance condition. These results imply that the perception of the disappearance of MIB targets could be reflected in the delta and alpha rhythms of the EEG, which may explain significant variability in the perceptual processes.

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33.532

Do the same lateral interactions support collinear facilitation and binocular summation?

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The two key components of the early visual processing architecture are ocular dominance columns (domains driven by either the left or right eye) and orientation preference domains that are selectively activated by a particular stimulus orientation. The pattern of these two circuits is shaped by selective local and long-range (tangential) lateral connections and is sensitive to changes in stimulus contrast and context manipulation with different levels of saturation.

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In this study we recorded Event-Related Potenlials (ERPs) in 9 healthy volunteers in order to find the neuronal correlated of binocular processing of stimuli of similar orientation but with either similar or different contrast presented to the two eyes simultaneously. Our previous studies provided evidence for N1 peak amplitude modulation in by collinear context (Sterkin et al., 2008). Moreover, we also found a robust correlation between N1 peak amplitude and backward masking effect (Sterkin et al., 2007). Here we measured the latency and amplitude of P1 and N1 peaks (mean latencies of 219 and 278 ms, respectively) in ERPs using vertically orientated Gabor patches (GPs) of low (7%) and high (20%) contrast that were presented using either binocular, monocular or dichoptic stimulation, yielding a total of 8 conditions.

Saturation in P1 amplitude but not in latency was observed. Moreover, N1 amplitude was affected by robust contrast changes with no saturation in latency. Thus, changes in the P1 amplitude reflect binocular summation, whereas N1 amplitude are sensitive to contrast changes per se, indicating that P1 and N1 amplitude represent activity of different cortical sources and arguing against consecutive processing. Our results suggest that earlier P1 modulation reflects local processing, whereas later N1 effects underlie processes that are activated at a certain contrast threshold and initiate the spread of activity to other populations and horizontal summation.

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33.533

Visual awareness correlates with layer-specific activity in primary visual cortex

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Whether or not activity in the primary visual cortex (V1) is directly related to the visibility of a stimulus is a long-standing debate. To investigate the basis of existing discrepancies in the literature, we measured the BOLD response, along with laminar electrophysiological signals, in area V1 of two behaving monkeys, and correlated responses there with the perceived visibility of a salient stimulus.

We show that stimulus visibility can be reliably derived from the fMRI signal, but not from neuronal spiking activity. We further demonstrate by laminar sampling of V1 local field potentials (LFP) that there is an uneven distribution of percept-related current changes between the different cortical laminae.

Thus, we show that fMRI and neurophysiological signals, while generally in good agreement, become uncoupled during perceptual suppression. Furthermore, our data reveals that if a visual stimulus goes unperceived, there is a drop in the membrane currents in the upper layers of V1.

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33.534

Early stages of figure-ground segregation: ERP components associated with face-vase perception

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In a series of three experiments, we recorded ERPs associated with subjects' perception of or attention to the faces or the vase in the ambiguous face-vase figure. In the first experiment, subjects viewed the face-vase figure and reported their perceptions by pressing one of two buttons. Each button-press immediately triggered a probe flash to either the face region, the vase region, or the borders between the two. In the second experiment, the same three probes were presented while subjects selectively attended to the face or vase region in order to detect rare longer-duration probes. In the third experiment, subjects performed the same selective attention task but the probes were flashed to regions with no clear figure-ground configuration (two peripheral regions and one central region were divided by sparsely-dotted lines). ERP recordings showed the well-known face-specific N170/VPP component elicited by probes to the face region to be larger when subjects perceived or attended to the faces. Preceding the N170/VPP, two earlier components were identified. First, when the borders between the face and vase regions were probed, ERPs over parietal-occipital scalp regions differed in amplitude as early as 110ms after probe-onset depending on subjects' perceptual/attentional state. This component most likely reflects boundary detection and border ownership assignment, and its source was estimated to lie in ventral-posterior lateral occipital cortex (LOC). Second, when the face or vase regions were probed, occipital ERPs were more positive (~150-200ms) when that region was perceived as figure (vs. background) or attended (vs. unattended). This component was considered to reflect figure-ground segregation processes, and source localization suggested ventral-anterior LOC generators. In the third experiment, none of these early components were produced, which rules out the possibility that they reflect a simple enhancement of probe-evoked activity by spatially directed attention. Instead, these early components appear to reflect contour detection and figure-ground segregation processes that can be modulated by attention.

33.535

Deterministic neural process for stochastic perception

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Perceptual multistability refers to spontaneous switching between two (or more) likely interpretations of a stimulus, and has been thought to represent a stochastic neural process underlying perception. Previous psychological studies have shown that the interval between perceptual switches follows a gamma distribution, but that the exact time of switching is highly unpredictable. In this study, we sought to predict the timing of a future perceptual switch given Magnetoencephalography (MEG) data measured up to the current time. MEG was measured while subjects viewed a bistable motion display (Dynamical Dot Quartet), and reported the timing of perceptual switches by button press. Using a subset of the data, we trained a statistical model (Gaussian Process Regression) that predicted the relative time until the next switch within a single epoch (100%, start-of-percept; 0%, end-of-percept) from MEG signal patterns at single time points. Absolute time until the next switch can be estimated by combining the relative prediction and the absolute elapsed time since the last switch. For all subjects, the model reliably predicted the future time of a perceptual switch with an error of <1.5 s (RMSE) at 3 s before the actual switch. The performance largely exceeded that of the optimal prediction model based on behavioral reports (error of > 8 s at 3 s before actual switch). Relevant MEG sensors for the prediction were found in left frontal areas, in accordance with previous fMRI studies on perceptual multistability. The accurate prediction cannot be attributed to eye movement artifacts, since the prediction based on EOG was comparable to or worse than that of the behavioral model. Our findings demonstrate that future events in stochastic multistable perception can be reliably predicted from brain activity, suggesting a deterministic neural process underlying the dynamics of perceptual multistability.

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Multisensory Processing: Cross-modal Perception

Sunday, May 10, 8:30 am – 12:30 pm
Poster Session, Vista Ballroom

33.536

Vibrotactile activation in areas MT, MST and FST revealed by intrinsic-signal optical imaging in anesthetized New World monkeys

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Recent findings indicate somesthesis can activate cortical areas in humans classically identified as visual or multisensory. To examine possible influence of tactile activation on functional organizations for orientation in visual areas, we used intrinsic-signal optical imaging to map patterns of activation in areas surrounding the posterior tip of the superior temporal sulcus (presumed MT/MST/FST) in anesthetized owl monkeys. Visual stimuli of drifting oriented gratings and random dots were used to localize MT, MST, and FST. Tactile stimuli known to elicit the percepts of pressure, flutter or vibration (sinusoidal indentations of 2, 30 or 200 Hz) were applied to the glabrous skin of an immobilized fingerpad. Imaging runs included vision alone, tactile alone, and vision plus tactile conditions.

The MT/MST complex showed greater activation to visual stimulation than for vibrotaction. The vibratory stimuli alone activated areas likely to be MST and FST. In contrast to somatosensory cortex, modular architectures for vibration were absent. Pairing vibrotactile with visual stimuli led to smaller activations when compared to visual stimulation alone. These results reveal that vibratory stimuli activate MST and FST while globally reducing the activation in MT to visual stimuli. These findings suggest a differential role of vibrotaction in MT, MST and FST.

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33.537

Cross facilitation of visual and haptic motion

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We investigated visual and tactile motion perception and multimodal integration by measuring velocity discrimination thresholds over a wide range of base velocities and spatial frequencies. The stimuli were two physical wheels etched with a sinewave profile, one seen the other felt, allowing for the simultaneous presentation of visual and haptic velocities, either congruent or in conflict,. Stimuli were presented in two separate intervals and subjects required to report the faster motion in 2AFC, using visual, tactile or bimodal information. Both visual and tactile and bimodal 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. Most interestingly, a tactile pedestal facilitated a visual test and vice versa, indicating facilitation between modalities. The facilitation occurred only for motion in the same direction, over a narrow range of velocities. It did not occur for neutral stimuli like sound beeps (ruling out reduction of temporal uncertainty), nor for motion in opposite directions, even when subjects knew that the motion was in the opposite direction (ruling out a "cognitive" facilitation"). This results suggest that visual and tactile motion signals pass through a common neural mechanism, allowing one to facilitate the other.

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33.538

Visual-haptic integration during pointing movements

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Many perceptual cue combination studies have shown that humans integrate information across modalities as well as within a modality in a manner statistically close to optimal. Here we asked whether the same rules hold in the context of movement planning tasks. We tested this during a pointing task where information about the target location was provided either by haptic or by visual or by both visual and haptic feedback during the pointing movement. Visual information was provided by briefly flashing three dots sampled from a Gaussian around the target position with a standard deviation of 4 cm. Haptic information was provided by pushing the index finger upwards using a PHANToM haptic interface. The strength of the force pulse (1 N to 3.5 N) indicated the target position. We measured the distance from hit point to target location and subjects earned money for minimizing this distance. We could well account for this data after extending the common maximum-a-posteriori (MAP) model for cue combination by adding a term that compensates for motor noise. Our model assumes that subjects select a target point by optimally combining a prior and all available sensory information. In addition, motor noise is present in both unimodal and bimodal trials and cannot be reduced further. The model parameters were fitted for all conditions simultaneously on a trial-by-trial basis. The model accurately predicts visual and haptic weights as well as subjects' performance. To test whether synchronicity influences the way the nervous system combines cues, we also analyzed situations in which visual and haptic information was presented with temporal disparity. We find that for our sensorimotor task temporal disparity had no effect. Sensorimotor learning appears to converge to the same near optimal rules for cue combination that are used by perception and to make use of all the available information.

33.539

Adapting the figure-ground cue of convexity: haptic feedback changes the visual perception of depth

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Numerous visual effects suggest that scene statistics are internalized by the human visual system and priors appear to be updated constantly (Adams et. al. 2004). Burge et al. (2008) found a statistical relationship between convexity and metric depth in natural scenes and showed that the visual system behaves as if it exploits this relationship. If the statistical relationship between convexity and depth changes does the visual system learn that change? Can haptic feedback adapt the influence of convexity on visual depth perception? To investigate, we designed an experiment with three phases: a pre-adaptation phase in which the effect of convexity on depth percepts was measured, an adaptation phase in which haptic information about the depth step was provided and a post-adaptation phase in which any change in the effect of convexity on depth perception could be assessed. In the pre-adaptation phase we replicated the results of Burge (2008). Observers were shown different pairs of consistent and inconsistent displays in a 2IFC paradigm and were asked to select the interval in which they saw the less separation between the near and far regions. For the adaptation phase (monocular), our subjects were divided into two groups: group A received haptic feedback indicating that the concave region was always near, while group B received haptic feedback indicating that the convex region was always near. Afterwards, we re-measured the visual effect of convexity on depth perception and found that the adaptation with concave region near reduced the effect (i.e. convexity was now worth less disparity) while the adaptation with convex region near increased the bias (i.e. convexity was now worth more disparity). After one day both adaptations were still present. We conclude that haptic feedback changes the visual perception of depth and that if the statistical relationship between convexity and depth changes this change is learned.

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Tactile localization is affected by simultaneously presented visual stimuli

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In the classic ventriloquism effect the perceived location of auditory and visual stimuli are shifted towards each other. Actually cues from almost any modality can be affected by information from other modalities, and the combined perception is often predictable from statistically optimal integration theory in which cues are weighted according to their reliability. Surprisingly, there have been no reports of the perceived location of touches being influenced by the optimal integration of touch with another sense. We therefore measured the perceived location of touch-light pairs. In experiment 1 supra-threshold tactile stimuli were presented either simultaneously with a light (required for the ventriloquism effect) or offset by 500ms (outside the window in which ventriloquism occurs). Subjects fixated a point positioned between two tactile stimuli separated by 7cm. Lights were presented in the same place as the touch or shifted along the arm by 3.5cm. Participants reported whether the light appeared left or right of the touch. If ventriloquism occurred, then subjects should be worse at discriminating the relative positions of the touch and light since they would be pulled closer together. When the lights and touches were presented asynchronously, participants correctly identified their relative positions. However, when they were presented synchronously, participants made more errors in identifying their relative positions suggesting that the stimuli were shifted towards each other or 'ventriloquised'. In experiment 2 subjects reported the perceived position of a visual, tactile, or visual-tactile pair relative to a visual reference line. While the perceived position of the visuo-tactile pairs was influenced by both component stimuli, surprisingly, the variance of the multimodal responses did not decrease as would be predicted if they were integrated statistically optimally. These results are generally compatible with visuo-tactile ventriloquism. Reasons for the disassociation between the predictability of the position and the variance will be discussed.

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33.541

Visual motion cues affect tactile motion perception

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Perceptual judgments about a sensory stimulus can be affected by simultaneous stimulation of another sensory modality. However it is not clear to what extent these cross-modal interactions are due to changes in sensory processing or to changes in the subjective decision about the output of that process. The present study explores how visual cues for motion affect the perception of motion in the tactile modality. Participants judged the direction (left vs right) of a textured surface moving briefly across the pad of their right index finger. This tactile motion was accompanied by the superimposed image of a textured surface that was either static or moving. Compared to the static image or non-coherent motion cues, coherent visual motion strongly biased the reported direction of tactile motion. We used the participants' confidence ratings for their tactile motion judgments to construct Receiver Operating Characteristic (ROC) curves, plotting hits against false-alarms. The presence of coherent visual motion skewed the ROC curve: the curve was positively skewed by the visual stimulus moving in the same direction as the tactile motion, and was negatively skewed by visual motion in the opposite direction. This distortion establishes that the visual motion cues changed the variance of the underlying distributions of sensory evidence for left vs right tactile motion. That is, the perceived tactile motion had less variability when accompanied by congruent visual motion than when accompanied by incongruent visual motion. Therefore, visual motion sharpened perception of congruent tactile motion and/or added noise to perception of incongruent tactile motion.

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33.542

Keep your eye on the rabbit: Cross-modal influences on the cutaneous rabbit illusion

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The experience of touch is often accompanied by visual confirmation. A light tap on the arm, for instance, might come with the sight of a friend's hand, a landing bug, or an experimenter's probe. We explored this link between vision and touch by investigating how a visual stimulus can modulate the perception of illusory touch. The cutaneous rabbit illusion is a robust tactile illusion that results from two discrete sets of taps delivered at separate locations on the body—traditionally, two points on the forearm. Rather than feeling taps at the two veridical locations, subjects experience a series of taps "hopping" along the skin's surface between the two points. Using light emitting diodes (LEDs) at the true and illusory sites of tactile sensation, we tested whether visual stimuli can enhance or attenuate perception of the cutaneous rabbit illusion. The results from an initial experiment suggest that LED activation mimicking the "hopping" percept strengthens the illusion, whereas flashing lights at the discrete tactile stimulation sites weakens it. Further experiments aim to verify that these reports reflect subjects' actual experience and not a response bias.

33.543

Not peripersonal space but the working area of the hand determines the presence and absence of the visual capture of the felt hand location in a mirror along the sagittal plane

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Based on the mirror-box techniques of Ramachandran and colleagues, when normal healthy participants views their left arm in a mirror positioned along the midsagittal plane, the impression of viewing his right hand (virtual right hand) visually captures the felt right hand location and participants rarely notice their unseen real right hand location behind the mirror, which is far from the virtual hand. To investigate the relationship between this illusion and peripersonal space, we evaluated the spatial limit of the illusion along the sagittal plane. Participants put their left hand on the mirror at a fixed position. In each trial, they were required to put their right hand at random position and to tap the mirror six times with all fingers synchronously with both hands , and were required to report whether they felt their right hand behind the mirror was located mirror-inversed position to their left hand or not. Their hand and finger positions were recorded using the infra-red motion-capture system (Library co. ltd.). The plot areas of their wrist position showed that the illusion was seen almost anywhere in the working area of the right hand except at the limit, which suggests that it is not peripersonal space but that the muscle tensions and signals from the subjects' joints may erase this illusion when the arm posture is unnatural. To further test this possibility, we kept the observers' right wrist positions the same as the virtual wrist. Their real right hand was always within their peripersonal space. The participants randomly twisted their right hand along the sagittal plane while keeping their wrist location the same. Again, the illusion disappeared when they twisted their hand to the limit. These results suggest that the strong muscle tensions and signals from joints can overcome visual capture and recalibrate the visual-proprioceptive conflict.

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33.544

The Time Course of Proprioceptive Drift in the Rubber Hand Illusion

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In the well-known rubber hand illusion (RHI, Botvinick & Cohen, Nature, 1998), synchronous tactile stimulation of a subject's invisible hand and a visible rubber hand (placed at a fixed lateral distance) induces a drift of perceived location of the real hand towards the rubber hand. The purpose of this study was to investigate the spatio-temporal characteristics of this proprioceptive drift.

To this end, we measured the perceived position of the participants' index finger in relation to a small visible probe using an adaptive two-staircase method and a forced-choice task. We determined perceived finger location by fitting a psychometric function to the responses. Prior to introducing the rubber hand at a distance of 17cm from the real hand, we determined the perceived finger location in darkness. The time course of the RHI was then determined in three phases: pre-test while only looking at the rubber hand, prolonged synchronous tactile stimulation, and post-test again without touch but with visible rubber hand. The synchronous stimulation was fully controlled using two PHANToM force-feedback devices.

The perceived finger location immediately shifted 1.4cm towards the rubber hand when in view. This shift rose to an average of 6.3cm after 8min of tactile stimulation. The distribution of responses indicates that the proprioceptive drift is truly gradual. As previous work suggests (cf.Holmes et al., P&P, 2006; Tsakiris & Haggard, JEP, 2005), these findings show that the RHI involves both immediate effects that result from multisensory integration as well as gradual recalibration effects with a time constant of several minutes. After 5mins of post-test, a drift of 4.9cm remained, showing that recalibration produces an after-effect with respect to both the baseline measure recorded in darkness and the pre-test. We will further investigate the determinants of the gradual build up and decay of the drift.

33.545

Two Studies of Phantom Sensations: (1) Mirror Therapy for Bilateral Amputees; (2) Mirror Symmetric View of Self Causes Paresthesias in Some Non-Amputees

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Ramachandran, Altschuler and others have shown that the mirror reflection of a moving intact limb can cause phantom sensations in nonamputees, and reduce phantom limb pain in single-limb amputees. Peterzell and colleagues report that these effects sometimes are increased using multiple mirrors ("out-of-body" reflections) or stroboscopic self-motion ("the phantom pulse") (VSS 2006, 2007). Two new mirror-symmetry effects are reported here.

(1) Ramachandran's mirror technique was used on two amputees, albeit with amputations below BOTH knees. The mirror was positioned to reflect the left side of each amputee's body as he sat in a folding chair viewing the mirror. I (the experimenter) positioned my left leg underneath the chair, facing the mirror. As I moved my left ankle and toes slowly and predictably, the amputee watched the reflection and imagined that he was seeing and moving his missing right ankle and toes. While viewing the mirror for 10 minutes, both individuals reported a sense of (a) movement in the right phantom ankle and toes, (b) a growing or "telescoping" of the shrunken, retracted phantom limb to normal size, and (c) a temporary reduction of stress and pain in the phantom right ankle, foot and toes.

(2) Non-amputees faced a computer screen, viewing realtime images of themselves with either the left or right half flipped to create a mirror-symmetric face and torso. When observers placed the visible hand's palm at the midline (creating the illusion of two hands in prayer), some subjects felt warmth or tingling in the visible palm and fingers. In responsive individuals, similar effects were obtained by the illusory touching of fingers, forearms, and feet; "touching" one's tongue to its mirror image caused a sense of mild electric shock.

Results may suggest ways to optimize pain treatments, and further elucidate visual processes underlying phantom sensations.

33.546

Visual capture may influence body-based judgments of object extent

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The "mirror illusion" shows that when viewing one hand's reflection in a mirror while the other hand is hidden behind the mirror, the perceived location of the hidden hand will be strongly influenced by the visual information from the mirror reflection. Holmes, Crozier and Spence (2004) demonstrated the effect of this visual capture of hand position on a spatial localization task in which visual information influenced reaching movements towards a target when there was conflict between vision and proprioception. Our goal was to test whether visual capture with the mirror illusion would influence judgments about the extent of an object made with the hands. In this experiment, participants viewed their visible hand and its reflection in a mirror after the unseen hand was positioned at one of four locations on a tabletop. Because the visible hand was positioned fourteen cm from the mirror, the unseen hand appeared to be fourteen centimeters from the mirror. After viewing the visible hand and its reflection while simultaneously performing simple finger movements with both hands, participants viewed a block and had to move their unseen hand to a position that would allow them to grasp the block between their two hands. Movements of the unseen hand relative to the visible hand were biased by the visual information, reflecting errors in moved hand position that increased as the visual-proprioceptive conflict increased. Because this experiment aligned the object with the center of the body and required the movement of only one hand relative to the end of the object, the finding does not provide definitive evidence for an effect of visual capture on judgments of extent. Additional experiments are necessary which will dissociate object extent and egocentric location by displacing the object relative to the observer.

33.547

Rotating sound fields can facilitate biomechanical self-motion illusion ("circular vection")

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While both biomechanical and moving auditory cues have been shown to elicit self-motion illusions ("circular vection"), their combined influence has never been investigated before. Here, we tested the influence of biomechanical vection (participants were seated stationary above a platform rotating at 60°/s and stepped along) and auditory vection (binaural recordings of two sound sources rotating at 60°/s) both in isolation and together. All participants reported biomechanical vection after a mean onset latency of 33.5s. Interestingly, even though auditory cues by themselves proved insufficient to induce vection in all but one participant, adding rotating sounds significantly enhanced biomechanical vection in all dependent measures: Vection onset times were decreased by 35%, vection intensity was increased by 32%, and participants had a stronger sensation of really rotating in the actual lab (28% increase). In fact, participants were able to update their orientation in the lab in all but the pure auditory condition, suggesting that their mental representation was directly affected by the biomechanical and auditory cues - although perceived self-rotation velocities were typically below the stimulus velocities. Apart from its theoretical relevance, the current findings have important implications for applications in, e.g., entertainment and motion simulation: While spatialized sound seems not by itself sufficient to induce compelling self-motion illusions, it can clearly support and facilitate biomechanical vection and has earlier been shown to also facilitate visually induced circular vection (Riecke et al., 2005, 2008) and thus support information from other modalities. Furthermore, high-fidelity, headphone-based sound simulation is not only reliable and affordable, but also offers an amount of realism that is yet unachievable for visual simulations: While even the best existing visual display setups will hardly be confused with "seeing the real thing", headphone-based auralization can be virtually indistinguishable from listening to the real sound und thus can provide a true "virtual reality".

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URL: http://www.siat.sfu.ca/faculty/Bernhard-Riecke

33.548

How do SCUBA divers know which way is up? The influence of buoyancy on orientation judgements

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One's perception of the direction of up is influenced by a number of cues including the nature of the visual display (visual cues), the orientation of the body (idiotropic cues), and gravity (gravity cues). Normally these cues exist in close agreement, but in unusual environments, including underwater and outer space, these cues may be placed in conflict and some cues may not be available at all. NASA uses underwater training to give astronauts a sense of reduced gravity cues as being underwater cancels many body cues to orientation while leaving the otolith-transduced cue unaltered. SCUBA divers report re-orientation illusions when underwater especially when visual cues to orientation are reduced. Here, we investigate how advanced SCUBA divers integrate visual, idiotropic and gravity cues to orientation.

Perception of self-orientation was measured using the Oriented Character Test (OCHART, see Dyde et al., 2006). OCHART requires observers to recognize an oriented character (here the letter 'd' as either a 'p' or a 'd' as it is presented in different orientations). Divers viewed the OCHART probe through an underwater window at approximately 4' depth. Each OCHART session consisted of 672 trials; four different visual backgrounds, 24 different character orientations, and seven repetitions. The influence of the body's orientation was manipulated by having divers assume two different orientations while completing these tasks: (1) right-side down and (2) upright. Observers performed the task both in and out of the water.

Divers in a right side down orientation showed a reduced reliance on visual cues underwater compared to performance on dry land, revealing a decrease in the visual effect on average. This finding is consistent with results from short duration parabolic flights where a reduced reliance on visual cues is also found (http://journalofvision.org/6/6/183/).

33.549

Spatial adaptation following tool use

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Hand-related visual-tactile (bimodal) cells have visual receptive fields (vRFs) that overlap and extend moderately beyond the skin of the hand. Electrophysiological evidence suggests, however, that this vRF will grow to encompass a hand-held tool following active tool use but not after passive holding (Iriki et al., 1996). Why does active tool use, and not passive holding, lead to vRF adaptation? One possibility is that vRF adaptation depends on motor adaptation: before a tool can be considered functional, the motor system must learn to predict and control the tool's motion in response to forces applied both by gravity and the actor. Another possibility is that vRF adaptation depends on visual adaptation: active tool use allows the user to see the length and capabilities of the tool. We tested these hypotheses by isolating visual training from motor training. Participants made speeded pointing movements to visible targets with a novel, weighted tool. Participants in the active training group performed self-generated actions. Active training provided both motor and visual experience with the tool. Participants in the passive training group were moved passively to each target by an experimenter. Passive training provided visual experience with the tool, but no motor experience. Finally, a no-training control group received no visual or motor tool-related experience. After training, we varied whether the tool was placed near or far from the target display and measured how quickly participants detected targets using a modified cueing paradigm. The active training group detected the target more quickly than other groups, and the active group was faster when the tool was placed near, rather than far from the target display. This tool location difference was not present for either the passive-training or control groups. These results suggest that motor learning influences how visual space around the tool is represented.

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33.550

Visual-haptic integration: Evidence for dynamic rescaling of visual and haptic signals during tool use

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For integration of information from vision and haptics to be effective, the brain should only combine information referring to the same object. This could be achieved by considering the similarity of signals in the two sensory channels. For example, if there is a large conflict between two size estimates it is unlikely that they originate from the same object. Humans are adept at using tools such as pliers, however, which systematically change the relationship between (seen) object size and the opening of the hand. Here we show that the brain takes this change into account when using a tool, and integrates "conflicting" signals near-optimally. Subjects judged the separation between two planes in a two-interval forced-choice task. We first measured discrimination thresholds in visual- and haptic-alone conditions to predict performance when both cues were available. We then measured visual-haptic thresholds when subjects grasped the objects using a virtual tool, which simulated pliers. By moving the pivot, the pliers either magnified or minified the haptic signal. Haptic size at the hand was constant. Large and small (visual) objects were used, resulting in "correct-gain" conditions, in which the visual size and the opening of the hand, although different, were appropriate given the "gain" of the tool, as well as "incorrect-gain" conditions. In the "correct-gain" conditions, discrimination performance was better than single-cue performance, and was close to the optimal predictions. In the "incorrect-gain" conditions performance was at the level of, or worse than single-cue performance, suggesting that visual and haptic signals were not integrated. We conclude that the brain can take into account, dynamically, changes in the scaling of haptic and visual signals introduced by tools, and appropriately combines signals that were caused by the same object, independent of conflicts between the visual size and the opening of the hand.

Acknowledgement: Supported by EPSRC and ORSAS

Perceptual Organization: Brain Mechanisms

Sunday, May 10, 2:45 – 4:15 pm
Talk Session, Royal Palm Ballroom 1-3
Moderator: Harriet Allen

34.11, *2:45 pm*

Common processes for segmentation by time and motion

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Segmentation of an image can be accomplished via a range of cues, including colour, motion, time, and depth. We compared brain activity for two segmentation cues (motion and time) to investigate whether there may be one cue invariant central process for segmentation.

Participants performed a visual search task in a 3T Philips MRI scanner. Participants indicated whether an inverted T shape target (embedded in a display of rotated T shape distractors) was left or right of fixation. In the baseline condition there were no consistent cues to segmentation. In the motion segmentation condition, half the T's, including the target, moved down the screen. In the temporal segmentation condition, half the items (not including the target) appeared 2s earlier than the remainder (similar to the 'preview search' paradigm). Participants benefited from segmentation as evidenced by faster RTs in both segmentation conditions relative to the baseline.

Segmentation by motion was associated with increased BOLD activity in bilateral medial temporal areas, precuneus and superior parietal lobes. Segmentation by time was associated with increased activity in the bilateral precuneus. Part of the precuneus was significantly active in both segmentation conditions, and the magnitude of this activity increased with increasing behavioural benefit from the cue (in both conditions). In the time but not the motion condition, the behavioural benefit was inversely correlated with activity in early visual areas consistent with inhibition of early distractors.

Segmentation by both of the cues investigated here appears to involve both cue-invariant mechanisms mediated by part of the precuneus, in addition to cue-specific mechanisms operationalised by different parts of the lower level visual system.

34.12, *3:00 pm*

Analysis of the Context Integration Mechanism in Border Ownership Coding

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Border ownership neurons in the visual cortex (V2, V1) show an influence of image context far beyond the classical receptive field (CRF) that emerges less than 30ms after response onset. The nature of the fast context integration mechanism is not well understood. Three different hypotheses have been proposed: (H1) suppression/facilitation from the non-classical surround (Sakai and Nishimura, J. Cogn. Neurosci. 2006); (H2) propagation of signals along the V2 contour representation (Zhaoping, Neuron 2005); (H3) feedback from higher-level cortex (Craft et al., J. Neurophysiol. 2007; Jehee et al., Vision Res. 2007).

To test these hypotheses we recorded neurons in area V2 of alert fixating macaques and studied border ownership modulation with fragmented figures. We used "Cornsweet figures" which can be fragmented without creation of new contours. The contours of squares were decomposed into four corners and four edges. While one edge was centered on the CRF, the presence of the fragments outside the CRF was varied (factorial design).

Cornsweet figures generated border ownership signals nearly as strong as solid figures. The fragments outside the CRF produced facilitation on the preferred border ownership side as well as suppression on the non-preferred side. In the mean across cells, all locations on either side contributed about equally. Fragments far from the CRF influenced the responses also in the absence of fragments closer to the CRF, and without the extra delay that would be expected from intracortical propagation, arguing against H2. About four of the seven fragments on either side contributed significantly, on average, whereas H1 predicts that no more than one or two would have an influence. The results were consistent with H3, namely feedback from a higher-level area close to V2, which allows all parts of the contours to influence the responses independently and implies no differential delays.

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34.13, *3:15 pm*

Modulatory effects of attention on the sensitivity to real and implicit motion: a high-density EEG study

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When Glass patterns are sequentially presented, they evoke a percept of coherent motion that is often mistaken for real motion. These "dynamic" Glass patterns (dGPs) have little coherent motion energy and the corresponding motion percept has been referred to as being "implicit". We measured whole-head visual evoked potentials (VEPs) to dGPS and to a nearly identical limited lifetime coherent motion display. Sequential random dot patterns were either spatially offset (implicit motion) or spatiotemporally offset (real motion with lifetime of two frames). The dGPs portrayed a concentric global pattern and the coherent motion displays portrayed rotary motion. The global organizations alternated with randomized versions at 0.83 Hz. The local elements changed at 30 Hz. We evaluated the effect of endogenous attention on VEP responses by asking observers to detect decrements in the coherence of our dot patterns or to perform an unrelated letter identification task near fixation. Responses to the update of the local elements (30 Hz) were slightly larger for real motion than for dGPs, and were not affected by the task. These local responses were restricted to an occipital source. The global responses (0.83 Hz) were larger and sharper for dGPs than for real motion. Directing attention to pattern coherence increased the global response amplitude to implied and real motion by about a factor of two relative to the responses measured during the letter task. These global responses were maximal at more anterior electrodes than the local responses, suggesting extrastriate sources. There was considerable overlap in the scalp topography of the global responses suggesting that dynamic Glass patterns and real motion stimuli activate some of the same cortical areas. Processing in these areas is highly modulated by endogenous attention. Our data further demonstrate that sensitivity local and global structure in implied and real motion is mediated by different mechanisms.

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34.14, *3:30 pm*

Cortical representation of texture and scale studied with fMRI

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Relatively little is known regarding the cortical representation of variations in texture appearance in humans. We used a carry-over fMRI design (Aguirre 2007 Neuroimage) to test if 1) the perceptual similarity of textures is reflected in the similarity of neural population codes; and 2) if these representations co-localize with neural populations sensitive to spatial frequency.

A texture space was created using two gray-scale photographs of natural textures (stucco and wood grain). One perceptual dimension was defined by parameter adjustment of steerable pyramids between the textures, and the other dimension by variation of image scale (essentially a change in spatial frequency distribution). Multiple exemplars of each point in the texture space were created by steerable pyramid synthesis. Iterative behavioral testing (RT to distinguish same and different pairs) established the orthogonality of the two dimensions and the equal, regular, and linear effect of perceptual steps in the space.

During scanning, participants observed a continuous stream of texture exemplars (1500 msecs / texture), ordered to counterbalance position in the texture space. Participants monitored for the infrequent appearance of a texture target not from the space. Exemplars for a given point in the texture space was randomized amongst three alternatives, minimizing pixel-to-pixel correspondence of textures. Covariates modeled a continuous modulation of neural adaptation proportional to changes in either texture or scale.

Across subjects, voxels sensitive to texture variation and scale variation were observed within ventral visual areas. Texture variation generally produced a proportional recovery from adaptation within ventral LOC, while scale variation produced recovery in earlier visual areas. The degree of overlap in the cortical response to the two dimensions of texture space varied across subjects. We are currently investigating if the degree of overlap may be related across subjects to performance on behavioral tests of integral or separable perception of the dimensions.

URL: http://cfn.upenn.edu/aguirre/

34.15, *3:45 pm*

Representation of broadband edges and spatial phase congruency in human visual cortex

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Spatial phase information is essential for image perception, because important visual features such as edges are perceived at locations of maximal phase congruency (Morrone and Burr, 1988). Step edges, which require phase-sensitive pooling of different spatial frequencies, are common in natural images (Griffin, Lillholm, and Nielsen, 2004). A study on natural image statistics suggests that outputs from the primary visual cortex (V1) are optimally analyzed by pooling different spatial frequency bands together to extract broadband edges (Hyvärinen, Gutmann, and Hoyer, 2005).

Here we studied responses to changes in relative phase alignments in grating stimuli and selectivity to phase congruency using functional magnetic resonance imaging (fMRI). In experiment 1, fMRI adaptation design comprised compound grating stimuli with two spatial frequency components (f = 0.4 cpd and 3f = 1.2 cpd at 7.6 deg eccentricity). Subjects were adapted to one phase alignment, and then they were shown compound gratings with different relative phase alignments. Areas V1, V2, V3/VP, V4v, V3AB, and LOC showed an increase in the fMRI response as function of the relative phase difference compared to the adaptation stimulus (Page's L test, $p < 0.01$ for each area). We controlled that these responses were not explained by differences in local contrast or position.

In experiment 2, we compared fMRI responses to compound grating stimuli (f, 3f, 5f, 7f, 9f) with congruent and random phase structures. Areas V1, V2, V3/VP, V4v, V3AB, and LOC showed stronger responses for the congruent stimuli (Wilcoxon's signed rank test, $p < 0.05$ for each area) with a gradual increase in the phase congruency selectivity along the ventral stream from V1 to LOC (Page's L test, $p < 0.001$).

Our results indicate that in the human visual cortex, phase relationships across spatial scales are extracted from the visual stimulus to locate broadband features like boundaries of an object.

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34.16, *4:00 pm*

Neural correlates of perceptual grouping in the occluded diamond illusion

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Scene segmentation in cluttered environments relies on the use of global features to interpret ambiguous local features. Changes in the spatial context of moving objects can dramatically change the interpretation of identical motion inputs. A clear demonstration that the spatial context can control how local motion information is interpreted is the Occluded Diamond illusion (Lorenceau and Shiffrar, 1992) in which the perceived motion of local elements is modulated by the presence of an occluding surface. We created a version of this illusion in which one set of bars oscillates periodically at 2 Hz up and down and the other set oscillates left and right at the same frequency. When the two groups are presented on a uniform background, they each appear to move independently. However, when visible patches simulating an occluding surface are placed between them, the bars group together and move coherently as a unit.

We studied the modulatory effect of occluding surfaces on cortical activity by recording high-density EEG in 4 subjects. While the occluder itself evokes no time-locked activity, it strongly modulates the perceptual interpretation and the neural response. The dominant effect on the EEG is an increase in the amplitude of the 4th harmonic response when the occluder is present and the oscillating bars are seen as a single coherent object. This effect is consistent with a two stage model in which the first stage comprises motion energy units that are separately responsive to the orthogonal inputs and a second non-linear grouping stage that pools across orientations when the occluder is present. Rectified motion signals from the first stage that are combined via a second-order non-linearity at the second stage of the model will result in non-linear interaction terms that are fourth order with respect to the input.

Face Perception: Temporal Effects and Dynamics

Sunday, May 10, 2:45 – 4:15 pm
Talk Session, Royal Palm Ballroom 4-5
Moderator: Guillaume Rousselet

34.21, *2:45 pm*

Temporal dynamics of face spatial frequency processing: an fMRI masking experiment

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When processing a face stimulus, the human visual system tends to strongly integrate its constituent features (eyes, nose, mouth, etc) in a so-called holistic representation. Such feature integration mainly occurs in face-sensitive regions located in bilateral fusiform gyrii. Behavioural studies showed that feature integration relies on the extraction of low spatial frequencies (LSF) while high SF (HSF) underlie more local aspects of feature analysis. Following coarse-to-fine models of vision, we propose that the LSF-driven feature integration is an early and fast stage of face perception, in contrast to the longer-lasting extraction of detailed feature cues in HSF. By means of an event-related fMRI design, the present study investigated the temporal dynamics of face LSF and HSF processing in the network of face-sensitive cortical regions. Faces were flashed at 75, 150, or 300 msec, followed by a Gaussian mask. They were band-pass filtered to preserve low or high SF. At short stimulus durations, face-sensitive regions located in bilateral fusiform gyrii and superior temporal sulci responded more strongly to LSF than HSF faces. At longer durations, the same regions were more active for HSF than LSF faces. This pattern did not replicate for phase-scrambled versions of the stimuli. Taken together our findings suggest that face perception proceeds following a coarse-to-fine scenario, with an early and fast LSF-driven feature integration being relayed by the slower accumulation of HSF local information.

Acknowledgement: We thank Julie Haubrechts for her help during the recording and processing of fMRI data.

34.22, *3:00 pm*

Age-related delay in information accrual for faces: Evidence from a parametric, single-trial EEG approach

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We investigated age-related changes in visual processing speed in a face discrimination task using ERPs. Younger (n=13, mean age=22) and older (n=18, mean age=70) observers performed a spatial, two alternative forced choice task between 2 faces. Emphasis was on accuracy, not speed. Stimulus phase was manipulated in a parametric design, ranging from 0% (noise), to 100% (original stimulus). Behavioural 75% correct thresholds were on average lower, and maximum accuracy was higher, in younger

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than older observers. The earliest age-related ERP differences occurred in the time window of the N170: Older observers had a significantly stronger N170 in response to noise, but this age difference decreased with increasing phase information. These effects were not due to changes in brain signal variance. Overall, manipulating phase had a greater effect on ERPs from younger observers. This result was confirmed by a hierarchical modelling approach. ERPs from each subject were entered into a single-trial multiple linear regression model to identify variations in neural activity statistically associated with changes in image structure (Rousselet, Pernet, Bennett & Sekuler, BMC Neuroscience, 2008). The main model parameters were stimulus phase noise, kurtosis, and a measure of local phase coherence. The fit of the model, indexed by R2, was computed at multiple post-stimulus time points: peak R2 was similar in the two groups, but it occurred at a longer latency in older observers. Overall, our results suggest that older subjects accumulate face information more slowly than younger subjects. Despite the overall age-related group differences, within each age group chronological age did not predict any of the results.

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34.23, *3:15 pm*

Does Temporal Integration of Face Parts Reflect Holistic Processing?

Olivia Cheung[1] (olivia.cheung@vanderbilt.edu), Jennifer Richler[1], Stewart Phillips[1], Isabel Gauthier[1]; [1]Department of Psychology, Vanderbilt University

Holistic processing of faces can be revealed in the composite task by failures of selective attention to a face half under instructions to ignore the other half. In the normal version of this task with both parts presented simultaneously, interference from the irrelevant half is due to holistic processing and not response interference (Richler et al., in press). However, failures of selective attention are also found when parts are separated briefly in time (Singer & Sheinberg, 2006; Anaki et al., 2007). Here we ask whether such temporal integration may reflect response interference, especially when irrelevant information is presented first. Participants learned to name faces, two “Fred” and two “Bob”. At test, composites were formed by top and bottom halves of different learned faces. The halves of each composite were presented either 50ms or 200ms apart. Participants named only the target halves. When the irrelevant half was presented 200ms or 50ms before the target half, naming was slower when the irrelevant half was from a different face with a different name vs. a different face with the same name, suggesting response interference. When the irrelevant half was presented 50ms after the target half, response interference was again observed, and naming was also slower when the irrelevant half was from a different face with the same name vs. the same face, indicative of holistic processing. No response interference or holistic processing was observed when the irrelevant half was presented 200ms after the target half. These results suggest that 1) temporally separated face halves are processed holistically only when the target half precedes the irrelevant half briefly (50ms), and 2) although the irrelevant half presented before the target half for up to 200ms is nonetheless processed, the face composite is not processed holistically and interference from the irrelevant half instead arises from response conflict.

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34.24, *3:30 pm*

The human brain recognizes individual faces faster from shape than surface reflectance diagnostic information

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Recent behavioral studies have shown that an individual human face can be recognized rapidly and efficiently by means of two main sources of information: diagnostic three-dimensional (3D) shape and two-dimensional (2D) surface reflectance (texture and color) information (O'Toole et al., 1999; Lee & Perrett, 2000; Jiang et al., 2006; Russell et al., 2006, 2007). However, the time-course of the respective contribution of these two sources of information during the faster recognition of individual faces remains unclear.

Here we aimed at clarifying the temporal characteristics of neural representations of shape and reflectance information diagnostic for individual faces. We used a 3D morphable model (Blanz & Vetter, 1999) to generate pairs of face stimuli that were either identical, varied in 3D shape only, in 2D surface reflectance only, or in both 3D shape and 2D surface reflectance. During a face identity adaptation paradigm in event-related potentials (ERPs) (Jacques, d'Arripe & Rossion, 2007), sixteen participants discriminated individual faces in these 4 kinds of pairs, in which the first (adapting) face was presented for several seconds (~ 3000 ms) rapidly followed (ISI ~250 ms) by a target face (200 ms).

While participants' behavioral matching performances were as accurate and fast for diagnostic 3D shape as for 2D surface reflectance, the time-course of brain activation following the target face indicated that shape was diagnostic of facial identity at about 160 ms (during the face-sensitive N170 time window) well before reflectance, especially in the right occipito-temporal cortex. Both kinds of information combined at about 250 ms, leading to equally large effects as reflected several hundreds of milliseconds later in the observers' behavior. These observations indicate that diagnostic information about a particular individual's face accumulates faster in the occipito-temporal cortex for 3D shape than 2D reflectance diagnostic cues.

34.25, *3:45 pm*

Masking in a high-level gender discrimination task is essentially entirely pre-cortical

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Our ability to detect animals in briefly flashed natural scenes is reduced when a high contrast dynamic mask is presented within about 40 ms and masking is complete at the shortest delays (Bacon-Macé et al.,Vision Research, 2005). It is generally assumed that such masking involves high-level interference. To investigate more precisely when and where this interference occurs, we designed a task that systematically varied mask-target delay and the type of presentation (monocular, binocular and dichoptic). A large number (216) of face photographs were briefly flashed (1 frame with a 200 Hz vertical refresh rate, i.e. for 5ms), and subjects reported whether the face was male or female. Masking was produced using 4 frames (20 ms) of the high contrast spatial patterns used in the Bacon-Macé et al study. When the target face and masks were presented binocularly, or monocularly through the same eye, we obtained a classic masking function with accuracy dropping to 50% chance level when the masks occurred immediately before or after the target. Forward masking was still very strong with 4 blank frames between the mask and target (i.e. ISI = 20 ms), dropped by about one third at 40 ms, and only disappeared when the interval was 100 ms. Backwards masking was also complete with the shortest intervals, but did not last as long, with performance reaching nearly normal levels with a gap of 40 ms. In contrast, when the target and masks were presented to different eyes (dichoptic presentation), there was essentially no masking effect whatsoever, even when the two stimuli are presented simultaneously. The inevitable conclusion is that the masking is produced at levels in the visual system where inputs from the two eyes have yet to be combined, i.e. in the retina, geniculate and layer IV of primary visual cortex.

Acknowledgement: EU Project “Decisions in Motion”, ANR Project “NatStats”

34.26, *4:00 pm*

Other-Race Faces All Look Alike to Me and My N170

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Human beings share an extremely efficient biological skill in recognizing faces, with the exception of other-race (OR) faces: the so-called other-race effect (ORE). As reported by Feingold (1914) nearly a century ago, this face recognition impairment is accompanied by the popular belief that "other-race faces all look alike!" Behavioural data and computational models have provided clear evidence that this popular belief is not accounted for by the paucity of physiognomic variations in OR faces, but by a genuine lack of expertise with the latter category. Interestingly, no study has yet provided an explanation for the neural mechanisms underlying this "visual illusion" in faces. Here we exploited the neural adaptation approach to investigate this question. Visual adaptation reduces activity of a neural population when two successive inputs activate same but not different subpopulations. Electrophysiological studies have shown that only repetition of same identities lead to smaller amplitudes on the face-specific N170 component, revealing sensitivity of the N170 to individual face categorization. However, since different OR faces are perceived as similar, one would predict no OR identity modulations on the N170 in an adaptation paradigm.We recorded electrophysiological signals of Western Caucasian (WC) and East Asian (EA) observers while presented with two sequentially presented WC or EA faces from same or different identities. The facial expression of the images was changed across repetitions to avoid pixel adaptation effects. Images had normalized colour-space and luminance. In line with previous electrophysiological findings, repetitions of same identities elicited more adaptation compared to different identities for SR faces. As predicted, OR faces elicited the same level of adaptation regardless of face identity for both groups of observers. These results provide a neural explanation for the 'all look alike' effect and provide novel insights in the explanation of the ORE for faces.

Neural Mechanisms: Encoding and Decoding

Sunday, May 10, 5:15 – 7:00 pm
Talk Session, Royal Palm Ballroom 1-3
Moderator: Nicole Rust

35.11, *5:15 pm*

Pattern motion selectivity of local field potentials in macaque visual cortex

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Local field potentials (LFPs) are low-frequency fluctuations in electrical activity that correspond to the total synaptic activity generated locally around the recording electrode. LFPs correlate well with EEG and fMRI BOLD signals and hold great promise for the design of brain-machine interfaces. However, it is unknown whether the LFP signal encodes the input from distant brain areas or the local processing within a circuit. Thus elucidating the source of the LFP signal is fundamental to our understanding of brain circuitry and for the interpretation of brain imaging studies.

We recorded single-units (SUs) and LFPs from a total of 229 sites from visual cortical areas V1, MT and MST of two awake, behaving macaque monkeys. We used grating and plaid stimuli to determine the motion direction selectivity of these areas. The number of pattern-selective SUs increased from V1 (6%) to MT (25%) to MST (60%) with only 9% of MST neurons being component-selective. Based on the scarcity of component selectivity in MST SU responses, we reasoned that a strongly component-selective LFP signal is likely to be a signature of visual feedforward input from lower cortical areas (e.g. V1, V2, V3 or MT). Consistent with this idea, we found robust component-selective LFP responses across all frequency bands, suggesting that feedforward input is responsible for a surprisingly large fraction of the LFP signal. Furthermore, the LFPs in MT were almost entirely component-selective, as is the feedforward input to this area from V1. Pattern-selective LFPs were found in the higher (gamma) frequency bands in MST, and they emerged in time before pattern-selective spiking activity. These results suggest a surprisingly strong link between the stimulus selectivity of cortical LFPs and that of the feedforward sensory input.

Acknowledgement: We are grateful to Julie Coursol and Cathy Hunt for technical assistance. This work was supported by a grant from the Canadian Institutes for Health Research to C.C.P. (MOP-79352). F.A.K. was supported by a fellowship from the Fonds de la recherche en santé du Québec (No dossier 13159). J.M.G.T. was supported by a fellowship from the National Science and Engineering Research Council (PGS D3-362469-2008).

35.12, *5:30 pm*

Influence of contrast on the pattern direction selectivity of macaque MT neurons

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Neurons in area MT can integrate the motion of 1D image elements to signal the 2D motion of complex patterns. This pattern direction selectivity is typically studied using plaids composed of two identical, high-contrast gratings. We wondered how pattern motion computation would be affected when we reduced the contrast of one of the plaid's components to make "hybrid" plaids.

We recorded from 73 MT neurons in anesthetized, paralyzed macaques while presenting drifting gratings and plaids with several component contrast ratios. The tuning of MT neurons to gratings was unaffected by contrast, but their preferred directions for plaids were strongly dependent on the ratio of component contrasts. When the component contrasts were unequal, even when each component evoked a strong response, plaid responses were dominated by the higher contrast component. At contrast ratios of 4:1 or greater, the lower contrast component had little or no influence on the plaid response, even though it was effective when presented alone. This "winner-take-all" interaction between component gratings may be partly mediated by cross-orientation interactions in earlier visual areas, but appears also to involve interactions in MT.

In human observers, we measured the perceived direction of plaids with different component contrasts and found a similar trend. Subjects veridically perceived the direction of pattern motion when the component contrast ratio was 2:1. At higher contrast ratios, subjects showed a strong bias towards the direction of the higher contrast component. We conclude that the pattern motion computation in MT neurons depends on contrast, and may underlie the perceived direction of plaids composed of unequal contrast components.

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35.13, *5:45 pm*

Orthogonal circuits for binocular disparity and ocular dominance in visual cortex

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The ability to detect small differences in inter-ocular retinal disparities is a critical means for accurately determining the depth of moving objects. In mammals, the first neurons along the visual pathway that encode binocular disparities are found in the visual cortex. However, a precise functional architecture for binocular disparity has never been demonstrated in any species, and coarse maps for disparity have been found in only one primate species. Moreover, a popular approach for assaying the developmental plasticity of binocular cortical neurons employs monocular tests of ocular dominance to infer binocular function. The few studies that examined the relationship between ocular dominance and binocular disparity of individual cells used single-unit recordings and have provided conflicting results as to whether ocular dominance can predict the selectivity or sensitivity to binocular disparity. We used two-photon calcium imaging to sample the response to monocular and binocular visual stimuli from nearly every adjacent neuron in a small region of the cat visual cortex, area 18. We show that local circuits for ocular dominance always have smooth and graded transitions from one apparently monocular functional domain to an adjacent bin-

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ocular region. Most unexpectedly, we found a map in the cat visual cortex that had a precise micro-architecture for binocular disparity selectivity. At the level of single cells, ocular dominance was unrelated to binocular disparity selectivity or sensitivity. When the local maps for ocular dominance and binocular disparity both had measurable gradients at a given cortical site, the two gradient directions were orthogonal to each other. Together, these results suggest that from the perspective of the spiking activity of individual neurons, ocular dominance cannot predict binocular disparity tuning. However, the precise local arrangement of ocular dominance and binocular disparity maps provide new clues on how monocular and binocular depth cues may be combined and decoded.

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35.14, *6:00 pm*

Motion processing in the ventral pathway: evidence for direction maps in macaque V2 and V4

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Motion processing in monkey visual cortex occurs in the dorsal pathway V1 to MT. However, neurons sensitive to motion directions were also found in many ventral areas including V2 and V4. The structure and function of direction selective neurons in these areas are less studied. Using intrinsic signal optical imaging, we imaged cortical response to moving stimuli (gratings and random dots) in both anesthetized and awake, behaving macaque monkeys. Cortical areas V1, V2 and V4 were imaged in the same map to facilitate comparisons. Our preliminary results showed that, unlike the primary visual cortex in cats and ferrets, macaque V1 does not contain a direction map. However, cortical regions that were preferentially activated by moving stimuli were found in two downstream areas V2 and V4 (the ventral pathway). These motion-sensitive regions in V2 and V4 contain directional-selective domains and form patches of direction maps. In V2, the motion direction maps are located in the thick stripes and exhibit overlap with orientation maps. In V4, direction-selective domains avoid both color-selective regions and orientation-selective regions. Based on these observations and our previous finding of motion contour selectivity in V2 (Lu et al 2007 VSS), we suggest that ventral stream areas V2 and V4 may also play important roles in analyzing motion-related information, perhaps, for example, for the purpose of figure-ground segregation based on motion contrast.

35.15, *6:15 pm*

Balanced increases in selectivity and invariance produce constant sparseness across the ventral visual pathway

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While several studies report neurons in inferotemporal cortex (IT) that are highly selective for particular objects or images, other studies report that neurons in IT tend to be broadly tuned. To investigate how selectivity changes across the ventral visual pathway, we compared the responses of neurons in a mid-level visual area (V4) and a high-level visual area (IT). We first assessed the selectivity of neurons in each area by determining how well each population could discriminate between natural images and “scrambled” versions of those images that have the same low-level structure but configured randomly. We found that the V4 population discriminated between members of the two image sets with similar fidelity whereas discrimination by the IT population was considerably degraded for the scrambled images. These results suggest that IT neurons are in fact more selective than V4 neurons in terms of the image features that drive these cells. As a second estimate of selectivity, we measured the tuning bandwidth of neurons for natural images (“sparseness”). Surprisingly, we found that distributions of sparseness values were indistinguishable between V4 and IT. How can the selectivity for natural image features increase while the tuning bandwidth for natural images remains constant? One possibility is that increases in selectivity for particular image features are offset by increases in tolerance for the (e.g.) position and scale of those features. We found that indeed, measures of tolerance were higher in IT than V4. These results confirm that neurons increase both their selectivity for image features and their tolerance to changes in the position and scale of those features as signals propagate through the ventral pathway. Remarkably, the rates of increase of these two parameters appear to be set such that the tuning bandwidth for natural images is maintained across each stage of cortical processing.

35.16, *6:30 pm*

The phase of ongoing EEG oscillations predicts visual perception

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The state of the cortex at the moment information about a stimulus reaches it can affect how this information will be processed. In particular, neuronal oscillations that induce large variations in local electrical fields could influence certain aspects of the neuronal response. While the amplitude of ongoing oscillatory activity is known to correlate with perceptual performance, the influence of oscillatory phase on perception remains unknown. Since phase varies on a much faster time scale than the more sluggish amplitude fluctuations, phase effects are more likely to reveal the fine-grained neural mechanisms underlying perception. We presented brief flashes of light at the individual contrast threshold while EEG was recorded. Even though the stimulus on each trial was identical, subjects detected approximately half of the flashes (hits) and entirely missed the other half (misses). Phase distributions across trials were compared between hits and misses. We found that shortly before stimulus onset, each of the two distributions exhibited significant phase concentration, but at different phase angles. This effect was strongest in the theta and alpha frequency bands at frontal midline electrodes. In this time-frequency range, oscillatory phase accounted for at least 16% of variability in detection performance and allowed the prediction of performance at the single trial level. This finding indicates that the detection threshold fluctuates over time along with the phase of ongoing EEG activity, supporting the notion that ongoing oscillations shape our perception, possibly by providing a temporal reference frame for neural codes that rely on precise spike timing.

35.17, *6:45 pm*

Decoding velocity from population responses in area MT of the macaque

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The responses of neurons in area MT are thought to underlie the perception of visual motion in primates. However, recent studies indicate that the speed tuning of these neurons changes substantially as contrast is reduced (Pack et al., 2003; Krekelberg et al., 2006), in a way that seems inconsistent with the reduction in perceived velocity seen psychophysically.

To understand this apparent discrepancy, we measured the responses of MT neurons in anaesthetized macaque to a broad-band compound grating stimulus for a broad range of velocities and contrasts. We presented the same stimuli to all neurons, adjusted only for receptive field location and preferred direction. As in previous studies, contrast profoundly affected the responses of the neurons, producing shifts of their preferred velocities toward slower speeds, as well as changes in response amplitude and tuning bandwidth. We constructed a “labeled-line” velocity decoder that operates on a neural population that includes the measured set of 59 neurons, along with a “mirror” set tuned for the opposite direction. We find that operating on this population that represents both positive and negative velocities allows the decoder to capture the key characteristics of human velocity estimation and discrimination, including speed biases at low stimulus contrast.

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We also examined optimal linear and (non-linear) Bayesian decoders, and found that they produce nearly veridical percepts when operating on the full neural population. Restricting these decoders to operate on a small set of model neurons whose response properties are obtained by averaging over subsets of neurons with similar tuning leads to qualitatively good matches to the perceptual data, but only when the decoder is optimized for stimuli drawn from naturalistic prior distributions over speed and contrast. We conclude that MT response characteristics are well matched to the statistics of the natural world, such that linear decoding is close to optimal.

Visual Search: Mechanisms and Models

Sunday, May 10, 5:15 – 7:00 pm
Talk Session, Royal Palm Ballroom 4-5
Moderator: Ruth Rosenholtz

35.21, *5:15 pm*

Does visual search involve a salience map?

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Most visual search theories (e.g., Itti & Koch, 2000; Treisman & Sato, 1990; Wolfe, 1994) suggest that signals from each perceptual dimension (e.g., color, orientation, size) are first analyzed separately and then integrated onto a "salience map". The notion of a salience map is central to accounts for many search phenomena. A core prediction of the use of a salience map is that across-dimension noise should impair a within-dimension search. However, in most situations across-dimension distractor heterogeneity does not reduce search efficiency (e.g., Treisman, 1988). In this study, we examined factors that may underlie this absence of an effect. In four experiments participants engaged in visual search tasks with target dimensions including color, orientation and size. We found that across-dimension heterogeneity did not influence search efficiency when we varied task (detection or compound search tasks), target salience, or task relevance of the non-target dimension. These results suggest that the lack of an across-dimension effect was not due to a ceiling effect (i.e., noise being too weak to impair a pop-out search) or top-down suppression to the non-target dimension. It appears that integration of dimensional signals does not occur naturally. However, in a situation where across-dimension distractor heterogeneity was introduced alongside heterogeneous within-dimension distractors, search efficiency was reduced. This suggests that the salience map may be engaged only when it is deemed necessary; for example, when dimension-specific signals do not guide search effectively. Taken together, these results suggest that visual search may be primarily driven by dimension-specific maps. Across-dimension signals may be integrated only when dimension-specific guidance is absent.

35.22, *5:30 pm*

The benefits of similar neural representations of the target for saccades and perception revealed by virtual evolution of an ideal searcher with two separate processing pathways

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Purpose: Behavioral reverse correlation shows that the visual mechanisms driving perception and saccades utilize similar neural representations of the target. We suggested that diverging target representations would result in an inefficient coupling between eye movement planning and perceptual judgments (Eckstein et al., 2007). However, there is no theoretical analysis or empirical evidence to support the hypothesis that a mismatch in target representations would result in suboptimal search performance. Here, we use computational models of multiple fixation search (ideal searcher and ideal saccadic targeting) in conjunction with genetic algorithms (virtual evolution) to demonstrate the benefits on search accuracy of having similar neural representations of the target mediating saccade selection and perceptual decisions.

Methods: We considered an ideal searcher (Najemnik & Geisler, 2005) and an ideal saccadic targeting model (Beutter et al., 2003) with different templates mediating the deployment of eye movements and the final perceptual decisions. Each template was a linear combination of Gabor functions representing V1 simple cells. We virtually evolved the saccade and perception templates to maximize accuracy in the final perceptual decision detecting a Gaussian target embedded in either: 1) white noise, 2) 1/f noise, and 3) 400 calibrated natural images.

Results: Findings with white and 1/f noise confirmed that the genetic algorithm can converge to the optimal linear templates which for these statistically stationary Gaussian backgrounds can also be calculated from closed form expressions. Critically, the process of virtual evolution resulted in similar underlying templates for saccades and perception for all backgrounds and models considered. A mismatch between the saccadic and perception templates resulted in search performance deficits. Conclusion: The similar neural representations of the target in the human brain for saccades and perception optimizes search and might be expected to have evolved through natural selection in the neural systems responsible for visual search.

35.23, *5:45 pm*

Modeling visual search in a thousand scenes: The roles of saliency, target features, and scene context

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Three sources of guidance have been proposed to explain the deployment of attention during visual search tasks. (1) Saliency reflects the capture of attention by regions of an image that differ from their surroundings in low-level features (i.e., Itti & Koch, 2000). (2) Attention may also be guided towards image regions that look like the search target (Wolfe, 2007); for example, attention may be directed towards red objects when searching for a red-colored target. (3) The context of a scene is also likely to guide attention: in the real world, objects are constrained to appear in particular locations (for example, cars appear on streets), so attention may be guided to these locations during search (Torralba et al., 2007).

We attempted to predict human search fixations using computational models of the three sources of guidance (saliency, target features, and scene context) in a large database of human fixation data (14 observers searching for pedestrians in 912 outdoor scenes). When tested individually, each model performed above chance but scene context provided the best prediction of human fixation locations. A combined model incorporating all three sources of guidance outperformed each of the single-source models, with performance driven predominantly by the context model. The combined model performed at 94% of the level of human agreement in the search task, as measured by the area under the ROC curve.

We compared performance of the three-source model of search guidance to an empirically-derived model of scene context. For this comparison, a "context oracle" was created by asking human observers to specify the scene region where a target was most likely to appear. This context oracle predicted human fixations as well as the three-source computational model. We discuss the implication of these results for future models of visual search.

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35.24, *6:00 pm*

A Crowded Model of Visual Search

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Items within a crowded window defined by Bouma's Law -- which states that the critical spacing between items for crowding to occur is approximately 0.5E -- appear "jumbled," such that target/distractor discrimination becomes intractable. In typical visual search displays where inter-item separation is small, crowding likely exerts a significant influence on performance. Presently, we examine the relationship between crowding and visual search in two ways.

First, we explored whether the "critical spacing" for crowded perception predicts search performance. In the context of visual search, Bouma's Law means that peripheral targets are more likely to be crowded and thus indistinguishable from distractors. Guided by this basic intuition, we constructed a model of visual search that can identify only "uncrowded" items and executes saccades as needed to identify previously obscured items. Can this model feasibly predict search reaction times (RT)? We show that for typical search displays the number of predicted fixations is an approximately linear function of set size. Thus it is trivial to fit the nearly linear RT vs. set size functions found for many search conditions. The resulting parameters are also quite plausible: approximately 400 ms decision time, and 200 ms / fixation.

Can the information available from viewing multiple crowded items predict search difficulty? We applied a model of visual crowding based upon a texture representation of stimuli by joint statistics defined over position, phase, orientation and scale. We have previously shown that this model predicts "crowded" identification across a range of conditions. This model allows the creation of visualizations of the information available under crowding, which we call Mongrels. These Mongrels successfully predict: Easy feature search for a tilted line among vertical, difficult conjunction search, search for T among L, and search for O among Q, and easy search for Q among O.

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Sunday Sessions

35.25, *6:15 pm*

Searching aerial images: Evidence for scene constraints in the absence of global context

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Will specifying the target region of a scene immediately before a search task improve search efficiency? To answer this question we had subjects search aerial images for a UFO target, which appeared hovering over one of five scene regions: water, fields, foliage, roads, or buildings. Aerial images were used to sever learned spatial relationships between a scene and its regions (e.g., a road could appear at any position and orientation in a scene). Prior to search scene onset, subjects were either told the scene region where the target could be found (specified condition) or were asked to search for the target in the absence of region information (unspecified condition). The absolute locations of targets and target regions within scenes were unpredictable. Search times were faster and fewer eye movements were needed to acquire targets when the target region was specified. Subjects also tended to fixate the cued region sooner and distributed their fixations disproportionately in this region. A lesser (but above chance) preference to fixate in the target region extended to the unspecified condition, which we attributed to appearance-based target guidance after ruling out guidance by low-level feature contrast. Importantly, the search differences observed between specified and unspecified conditions cannot be explained by either bottom-up saliency-based models or top-down models that use target appearance to guide search. Nor can Bayesian approaches that rely on learned spatial associations between a scene and its regions explain this cuing effect, as these spatial relationships varied unpredictably from trial to trial. Rather, we interpret these differences as evidence for the use of highly flexible referential scene constraints to confine search to the cued scene region, similar to the constraints commonly used in spoken discourse. Such constraints require the modification of existing theories to include segmentation processes that can rapidly bias search to cued regions.

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35.26, *6:30 pm*

Don't underestimate the Force: Learning to have a hunch in visual search

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Experts at specialized search tasks, such as baggage security or breast cancer screening, sometimes report an immediate intuition that a target (e.g., weapon or tumor) is present, even when they cannot immediately localize it. Search is still required for confirmation. This hunch seems to be based on implicit perception of some statistical regularity in the image. In order to study this phenomenon experimentally, we had observers search for a T among Ls. On valid target present trials, letter size varied systematically across the display (large at center, smaller in periphery). On valid target-absent trials, letter size varied unsystematically. On invalid trials, this size cue was reversed. Cues were 90% valid.

We measured RT while 24 naïve observers performed 1000 learning trials with unlimited exposure. Additional, 100 trial pre- and post-learning blocks measured accuracy for 250 ms "glimpses" of the display. We defined "learner" (n=6), "non-learner" (n=7), "intermediate" (n=5) groups based on whether observers became significantly faster on valid than invalid target-absent trials during learning (6 observers with high errors on learning trials were excluded). Performance across groups was otherwise similar. Debriefing showed no evidence of explicit size cue learning. Nevertheless, learners improved significantly from pre-test glimpses (d'= 0.6) to post-test glimpses (d'=1.2, $t(5)=4.9$, $p<0.01$), while non-learners did not (d' = 0.7-0.8). Intermediate observers were intermediate (d'= 0.5-0.9). Our learners became better at telling target-present from target-absent trials in a glimpse, without knowing why.

Note that this "hunch" is different from contextual cueing. In contextual cueing, observers learn that THIS display always contains a target at THIS location. Our observers learn that a CLASS of displays is likely to contain a target. This ability could be of general use (e.g. knowing that this type of landscape is likely to contain food) and may underpin the first-glimpse hunches of experts.

35.27, *6:45 pm*

Training determines the target representation for search

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Purpose: Visual search is facilitated when observers are pre-cued with the target image. This facilitation arises in part because the pre-cue activates a stored representation of the target. We examined whether training designed to alter the nature of this representation can influence the specificity of the cueing effect.Methods: The experiment involved a training session and, 1-2 days later, a testing session. For both sessions, the stimuli were photo-composites of coral reef scenes and the targets were images of tropical fish. The observer's task was to judge whether a fish was present in each reef scene. During training, observers practiced searching for 3 exemplars of 4 fish species. Half the observers searched for the 12 fish in 12 separate blocks (blocked-by-fish group), the other half searched for the three fish belonging to each species in separate blocks (blocked-by-species group). During testing, the observers were shown a brief pre-cue one second before the search stimulus. The pre-cues were either identical to the target, the same species as the target, or, as a control, the word "fish". Prediction: During training, we expected that the blocked-by-fish group would develop a specific representation for each of the 12 fish images, while the blocked-by-species group would develop a more general representation of the 4 fish species. We expected this difference to show up during testing as a difference in the specificity of the cueing effect. Results: For the blocked-by-fish group, pre-cues facilitated search for identical targets but not same-species targets. For the blocked-by-species group, pre-cues facilitated search for identical targets as well as same-species targets.Conclusion: The pattern of cueing effects suggests that observers trained on the same visual search stimuli can form different representations of the target.

3D Perception: Space

Sunday, May 10, 2:45 – 6:45 pm
Poster Session, Royal Palm Ballroom 6-8

36.301

Breaking space: intransitivity of distance judgements

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Many experiments support the idea that observers generate a distorted representation of space, but the proposed transformation between physical and perceived space is generally a simple homography (i.e. a 1:1 mapping between points). Here, we show that perceived space can 'break' in such a way that the perceived distances of two objects can, at the same time, obey both D1 > D2 and D1 <D2. We demonstrate this in the unusual situation of an expanding virtual room (Glennerster et al, 2006, Current Biology 16(4), 428-432), which appears stable to observers despite large changes in size.

In an immersive virtual reality environment, observers in a brick-textured room viewed a reference square in one interval and judged whether a comparison square in the second interval was closer or farther away. The virtual room was visible throughout the trial and it either remained static or increased in size by a factor of 4 between intervals. The squares were placed either in the middle of the room or adjacent to the wall, where the effect of room expansion on distance judgements was greater. Interleaving 4 different psychometric functions, we determined the distances at which 4 pairs of objects were perceived to be at the same distance, allowing us to infer the relative perceived distance of two objects (O1 and O3) via two different intermediate objects. Specifically, the ordering of perceived distances of the objects was O1 > O2a > O3, while simultaneously O1 <O2b <O3. Thus, our results demonstrate a paradoxical, intransitive ordering of perceived distance and challenge the idea of a single representation of visual space.

Acknowledgement: Supported by the Wellcome Trust

36.302

Hilltop (non) occlusion: A new cue for perceiving (the absence of) slope

Anna Ruff[1] (aruff1@swarthmore.edu), Zhi Li[1], Frank Durgin[1]; [1]Psychology Department, Swarthmore College

Geographical slope perception is notoriously susceptible to error. Hills tend to appear steeper than they are. Similar errors occur for perceived optical slant of smaller surfaces (frontal tendency). Like perceived optical slant, perceived geographical slope increases with viewing distance. This suggests that slope overestimation may also be due to a frontal tendency in optical slant perception. Ooi et al. (2001) have argued that a frontal tendency makes even flat surfaces appear sloped. How then, do we ever see large flat surfaces as flat? One important cue that may distinguish hills from fields is that hilltops tend to occlude the objects beyond them, whereas fields do not. Although a large flat surface might end at a ravine from which trees emerge, and a gradual hill might end at the base of a building that it does not really occlude, the occlusion of distant objects is generally a reliable indicator that a surface is sloped. We created four immersive virtual scenes in which we manipulated the slope (from 0 to 7 deg) of a grassy surface (40 or 70 m long). We also manipulated the presence or absence of partial occlusion, by that surface, of familiar objects (elephants, person, bus, truck) that have parts (wheels or feet) that normally contact the ground. The objects were simulated as being on a horizontal surface atop the hill (no occlusion) or lowered by one meter as if into a ravine on the crest of the hill (partial occlusion). When occlusion was present verbally-judged slope was significantly steeper (by about 10 deg) than when occlusion was absent. Judgments in the occlusion condition were similar to those typically reported for real outdoor hills (e.g., 5 deg was judged to be 20 deg), whereas judgments in the non-occlusion condition were lower and thus more accurate.

36.303

Hills look less steep from the edge: Proprioceptive error and frontal tendency affect the perception of downhill slopes

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A steep incline looks very steep from the top, as others have documented. However, we observed that such an incline appeared less steep when standing at its edge. Why should slopes appear more exaggerated when standing back from the edge where gaze can be nearly parallel to the slope (making head orientation a perfect cue)? And why should slopes appear less steep as one approaches the edge? To address the first question, we asked people wearing a head-tracker and blindfold to tilt their heads down by amounts ranging from 10 to 60 deg. The values of actual head pitch observed were always about half that requested, suggesting that proprioceptive error could play a substantial role in downhill slope overestimation. Before answering the second question, we sought to document the perceptual phenomenon using immersive VR. Our software corrected optical distortions of HMD optics. We simulated a sloped surface with 3D blades of grass to provide a rich stereo environment in a scene that also contained a visible horizon. Participants judged 20 slopes (4-42 deg, by steps of 2) while standing at the edge of the hill or from a meter back. A golf ball 2 m down the hill served as a reference point, but participants began each trial looking toward the horizon. Between and within subjects, all slopes were judged much shallower when standing near the edge. Between-subject effects were by 20 deg for the steepest slopes analyzed, consistent with our observations of real hills. Whereas frontal tendency can help explain slope overestimation when facing a hill from the bottom, proprioceptive error may be fundamental to explaining overestimation from the top (see Hajnal & Durgin, this VSS). Nonetheless, effects of frontal tendency can account for why slopes appear less steep when standing near the edge.

36.304

The perception of slope by eye, hand, foot, and finger: Evidence for an amodal vertical tendency

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Some believe that palm boards are more accurate measures of perceived slope than are verbal reports. But the apparent accuracy of palm boards is accidental. Haptic perception of surface orientation by hand and by foot is distorted, similarly to visual distortions of slope at a distance. This has nothing to do with the dorsal system: For a small surface sloped 30 deg, viewed within reach, we have found that palm-board matching results in settings of 18 deg, whereas matching with an unseen free hand is quite accurate. Evidently proprioceptive information is altered by contact with a supporting surface. In contrast to purely visual accounts of slope misperception (frontal tendency) and in contrast to accounts appealing to behavioral potential our investigations of slope suggest a more general principle that surfaces (large and small) appear more vertical as perceptual information about them becomes less reliable or less well-calibrated. In studies of frontal tendency in visual slope perception, for example, we have controlled for viewing distance and found that surfaces viewed more frontally are indeed subject to less distortion than surfaces viewed obliquely, but slope overestimation still occurs at distances of about 1.7 m for small surfaces viewed with gaze fully frontal. Haptic perception of the slopes of ramps in sighted and blind individuals is extremely exaggerated. Ramps feel steeper than they look. The only case of haptic slope perception that we find to be fairly accurate (via verbal judgments) is for surfaces explored by a single finger, so that computations of slope could be made from calibrated position information. For this task, slope perception was accurate for sighted blindfolded participants, but congenitally blind observers showed a vertical tendency, probably because they lack near space calibration from vision: Blind observers were more accurate than sighted at retracing the slope without feedback.

36.305

The Intrinsic Bias of Space Perception Is Updated During Walking

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Space perception depends on both external depth information and the visual system's intrinsic bias. The latter plays a larger role in reduced-cue environments. In total darkness, it constructs our perceptual space such that a dimly-lit target is perceived at the intersection between the projection line from the eye to the target and the implicit slant surface delineating the intrinsic bias. Given the reliance on the intrinsic bias, it would be strategic for the intrinsic bias to be independent of the observer's egocenter (body). This idea will be validated if the intrinsic bias is updated when the observer walks to a different location in the dark. Thus our main experiment tested observers at three viewing-locations: (i) original location; (ii) forward location (observer walked forward from the original location by 1.25m); (iii) backward location (walked 1.25m backward). After arriving at each viewing-location, observers stood for ~17s before a 5Hz flickering target (0.22 deg) was displayed for 1s at one of six predetermined target-locations (2-7m). Observers reported the perceived target location (distance and height) using the blind walking-gesturing task. We found that judged target locations from all three viewing-locations are fitted by a single, rather than three separate, slant curve (surface). This indicates that when one moves to a different viewing-location, the intrinsic bias is not tagged with the body but remains at the original location prior to moving, i.e., the intrinsic bias is updated. Our further experiments revealed the characteristics of the updating operation. We found that space updating: (1) though less perfect, occurs even when observers moved a longer distance (2.5m) from the original location; (2) is restricted to a viewing-location with the same facing-direction as the original location (does not occur when the facing-direction is orthogonal); (3) is also revealed using the verbal report task.

36.306

Perspective-taking changes perceived spatial layout

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Perception of spatial layout is affected by numerous non-optical variables. For example, people who are fatigued, in poor physical condition, or burdened by a heavy load perceive distances to be further and hills to be steeper than unencumbered people (Bhalla & Proffitt, 1999). In addition, fear can influence one's perception of heights (Teachman et al., 2008), and being in the presence of a friend (i.e., social support) makes hills appear shallower (Schnall et al., 2008). The present study investigated whether stereotypes and attitudes also influence perception of spatial layout. In particular, we tested whether priming participants with an elderly stereotype affects their imagined time-to-walk to a target. A common stereotype is that the elderly are less physically fit than young people, so it takes them more time to traverse a distance than a young person. Thus, participants primed with an elderly stereotype should have slower imagined time-to-walk estimates than participants primed with a young stereotype (neutral condition). When examining the effects of priming, female participants in the elderly condition imagined that it would take longer to walk to a target, relative to males. A measure of implicit attitudes suggests that this gender effect is partially due to empathy: female participants, who have more positive and empathetic views towards the elderly, may be more likely to have slower imagined times-to-walk because they embody the behavior of the elderly. However, participants who harbor more negative views of the elderly may be less affected by the manipulation and may actually show behavior that contrasts with the primed social group. We are currently investigating whether this difference in imagined times is due to participants misperceiving the target distance as being longer or the walking speed as being slower. This research suggests that the ability to take another's perspective can influence perception of spatial layout.

36.307

Aging and egocentric distance judgments in 3-D scenes

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Previous studies have shown age-related decrements in various perceptual tasks. In the current study we examined whether there is an age-related difference in judging egocentric distance in 3-D scenes. In two experiments older and younger observers viewed an outdoor scene (a large lawn field) and judged the egocentric distance of a target positioned at varying distances. Two tasks were used: verbal response and blind-folded rope pulling. In Experiment 1 the physical distance of the target (4, 6, 8, 10, or 12m) and viewing condition (monocular or binocular) were manipulated. The order of viewing condition was counterbalanced across observers. On each trial an observer looked at the target in the scene and determined its physical distance. The observer was encouraged to scan the ground plane between his/her feet and the target. Observers then either verbally reported the physical distance or put on an eye-mask and pulled a rope to match the physical distance of the target. Overall, we found older observers reported more depth than younger observers. Younger observers showed foreshortening (a well documented finding in the literature). Older observers on average made highly accurate responses. In Experiment 2, we examined if this age-related difference in egocentric distance judgment was due to difference in internal scale. On each trial a 3-feet long rod was positioned horizontally in front of the observer and observers were instructed to use the rod as a reference when judging the distance of the target. For the rope pulling task the same length was shown to the observer on the rope. Only binocular viewing was examined. The results were similar to that obtained in Experiment 1, suggesting that age-related differences in egocentric distance judgments were not due to differences in internal scale.

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36.308

Verbal and Spatial Reasoning Abilities Predict Far Distance Size Estimation Performance in Middle Childhood

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The ability to estimate distant objects' sizes improves during childhood. Previous studies suggest that this developmental change results from increasing use of deliberate strategies that compensate for inaccurate perception of size at a distance. We conducted two studies to examine whether strategy use and size-estimation accuracy depend on verbal reasoning, spatial reasoning, and cognitive impulsivity. In each study, 6- to 9-year-olds viewed standard discs at 6.1 and 61 m, and chose from a set of nearby discs one that matched the standard. They were also asked to explain their choices. Study 1 (N = 26) included tests of verbal reasoning (WISC-III Verbal Similarities) and cognitive impulsivity (Matching Familiar Figures – 20). Study 2 (N = 32) included the verbal reasoning test and a spatial reasoning test (WISC-III Block Design). In both studies, children who reported deliberately adjusting their size estimates to take distance into account made more accurate far-distance estimates than those who reported no such strategy use. In addition, verbal reasoning and spatial reasoning were significantly correlated with far-distance strategy use and size estimation performance, and each kind of reasoning accounted for unique variance in strategy use. Cognitive impulsivity was not correlated with strategy use or size estimation accuracy. None of these variables was correlated with near-distance size estimation or strategy use. In sum, children who score high in verbal and/or spatial reasoning generally make accurate size estimates or overestimate size when viewing distant objects and report deliberately adjusting their size estimates to take distance in account; while children at comparable ages who score lower in these abilities tend to underestimate distant objects' sizes and report no strategy use. These findings suggest that developmental changes in far-distance size estimation accuracy may result from the development of reasoning abilities needed to use deliberate strategies for judging size.

36.309

The connection effect in the disconnect between peripersonal and extrapersonal space

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Previous studies suggest that line bisection performance shows a leftward bias when completed in peripersonal (near) space and a rightward bias in extrapersonal (far) space, even in an immersive virtual environment (Gamberini, Seraglia, & Prifits, Neuropsychologia, 2007). Furthermore, extrapersonal space can be remapped as peripersonal space by extending reach through tool use; using a stick for bisecting far lines shows the leftward bias whereas using a laser pointer shows the rightward bias. With a head-mounted display showing a computer-simulated environment, participants bisected lines by controlling a free-floating dot, a free-floating hand, or a hand connected by an arm. Lines appeared on a lectern in front of the seated participants while a real lectern provided tactile feedback to match the visual display. Due to large order effects across blocks for mode of bisection (arm/hand/dot), comparisons were made between participants using the first condition encountered. Peripersonal (<75cm away) vs. extrapersonal (60cm added to viewing distance, >90cm away) conditions were blocked and counterbalanced as a within-participants factor. At one point in the experiment, between blocks of trials, a virtual needle appeared. Galvanic skin response measured autonomic reaction to watching the needle poke the hand/dot controlled by participants. As a control, half watched the needle poke a second hand/dot. A partial replication of Gamberini et al. (2008) showed a distinction between the arm and dot conditions with the expected leftward and rightward biases, respectively.

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36.310

Kicking to Bigger Uprights: Field Goal Kicking Performance Influences Perceived Size

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Perception relates not only to the optical information from the environment but also to the perceiver's performance on a given task. The current investigation presents evidence that the perceived height and width of an American football field goal post relates to the perceiver's kicking performance. Participants who made more kicks perceived the field goal posts to be farther apart and perceived the crossbar to be closer to the ground compared with participants who made fewer kicks. Interestingly, the current results show perceptual effects related to performance only after kicking the football but not prior to kicking. We also found that the types of performance errors influenced specific aspects of perception. The more kicks that were missed left or right of the target, the narrower the field goal posts looked. The more kicks that were missed short of the target, the taller the field goal crossbar looked. These results demonstrate that performance is a factor in size perception.

36.311

Common processing for two perceptual tasks in different spatial dimensions in response to identical visual stimuli

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The frontoparallel orientation of an eccentric luminescent line presented in darkness causes visual mislocalizations in both the perception of elevation (VPEL) and the perception of the vertical in the frontoparallel-plane (VPV). However, when two such lines are centered at equal distances relative to the observer's median plane, then if the lines are parallel they influence VPV but not VPEL, and if the lines are counter-rolled (bilaterally-symmetrical) they influence VPEL but not VPV (Matin & Li, 1994). Thus, despite the similar influences of line orientation on both discriminations, the summation of influences from two lines implies distinct integration processes. The current study compared the VPEL and VPV settings of 30 observers in response to the same set of stimuli. Measurements were made on observers with monocular viewing with each of 5 orientations in the frontal plane, 0° (erect), ±7.5°, and ±15°, with each of four stimuli: 1) one left-line, 2) one right-line, 3) two parallel-lines, and 4) two counter-rolled-lines. Each stimulus line was 70°-long and centered at 25° horizontal eccentricity. We correlated across observers the effect of orientation (defined as the slope of setting-vs-orientation) of the same set of stimuli on both discriminations, and found substantial correlations between the two discriminations (average of absolute r-values=0.56). We also correlated across observers the effects of individual off-vertical orientations of the same set of stimuli on both discriminations, and found substantial correlations between the two discriminations (average of absolute r-values=0.43). The two separate correlational analyses agree and indicate a similar response to line orientation in both discriminations. In light of the evidence for distinct integration processes, these findings support the view that the two discriminations may share common orientation processes that later distribute to separate integration processes.

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36.312

The role of shadow in 3D object representation: Evidence from shadow-specific priming

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An open issue in visual object recognition concerns the structure and organisation of long-term memory (LTM) representations of object shape. While much research effort has focussed on the so-called 'viewpoint-debate', relatively less work has examined the structure of shape representations. Here we test contrasting hypotheses about the degree of abstractness in shape representation – examining, in particular, the extent to which intrinsic shadow caused by scene illumination affects the recognition process. One hypothesis is that LTM shape representations are shadow invariant, and that filtering shadow from the image during perception incurs a time cost. Alternatively it may be that while LTM representations are shadow invariant, shadow provides information that facilitates the recovery of 3D object shape. An alternative hypothesis is that LTM representations are shadow-specific and that changes in shadow will incur costs resulting from mismatches in the memory representations. These contrasting claims were examined in two experiments. In Exp 1, Ss memorised four targets rendered with intrinsic shadow from a larger set of novel objects. Recognition memory was examined in a target/non-target discrimination task using primes containing no shadow or intrinsic shadow. The results showed that priming was shadow-specific, being larger for primes containing the same intrinsic shadow as the memorised targets (for both familiar and novel viewpoints). In Exp 2, an object matching paradigm was used in which Ss matched novel objects for shape across variations in shadow. RTs were faster for objects with no shadow than for those with intrinsic shadow. This pattern of results suggests that (1) at some level, LTM representations of objects are shadow-specific consistent with some recent hierarchical image-based models (e.g. Riesenhuber & Poggio, 2002; Current Opinion in Neurobiology, 12, 162-168), (2) intrinsic shadow information can also hinder the recovery of 3D object shape during perception, presumably because it increases task complexity.

36.313

Non-linear calibration of a non-see-through head mounted display

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Immersive virtual reality is becoming an increasingly powerful tool for studying visuo-spatial perception in moving observers. However, the validity of results depends critically on an accurate calibration of the visual display.

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We have developed a system for calibrating a head mounted display (HMD) using camera calibration techniques (Gilson et. al.,J. Neuroscience Methods, 173, 2008). The method represents a significant advance over previous methods requiring subjective judgements by someone wearing the HMD (e.g. SPAAM, Tuceryan et al., Presence-Teleop. Virt., 11, 2002). Here, we report two refinements: (i) an extension to non-see-through HMDs and (ii) the modelling and reduction of non-linear distortions.

We placed a camera inside a stationary HMD and recorded a chequerboard image generated by the HMD. Without moving the camera, the HMD was then removed and images taken of tracked objects. The chequerboard vertices permit object image locations to be translated to HMD coordinates. 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. These include the aspect ratio and angular subtense of the display, the location of the optic centres and the 3D orientation of each display as well as non-linear distortions. We calibrated and tested on separate sets of data, to assess the generalizability of each calibration.

Our calibration method yields reprojection errors of around 3 pixels. This generalizes well to other data sets with reprojection errors typically less than 6 pixels, or less than 15 pixels for non-see-through HMDs. Additionally, modelling non-linear distortions in the HMD image can further reduce reprojection errors by as much as 30%.

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URL: http://virtualreality.physiol.ox.ac.uk/research.html

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36.314

What's so special about the N170? Modulation of N170 by geometric shape attributes of three-dimensional (3D) objects

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Previous studies have shown that the N170 component of the event-related potential, although widely associated with face processing, is sensitive to a range of stimulus variables including proficiency of subordinate-level perceptual categorisation (expertise), and, more recently, some measures of variance in low-level image similarity (e.g., ISVP). Here we report results from an ERP study designed to examine the time-course of encoding different geometric shape attributes (edges, surfaces and 3D volumes) during object recognition. A whole-part matching task was used in which Ss were shown a whole novel 3D object followed by a part comparison stimulus containing a sub-set of geometric shape information from the whole object (edges, surfaces or 3D volumes). Ss were instructed to decide whether the part stimuli matched or did not match information in the preceding stimulus. Consistent with earlier published evidence (Leek et al., 2005: JEP: HPP, 31, 668-684) Ss were faster at matching surface and volumetric parts than edges to whole objects indicating a role for surface-based primitives in 3D shape representation. Analyses of the ERP data showed distinct patterns of modulation of the N170 (but not P1) component according to object part-type. Temporal segmentation analyses revealed two distinct scalp topographies within the N170 time period, one for the volumetric part condition and another for the surfaces and edges. The LAURA source localisation algorithm placed the generators of the N170 maps in the ventral occipito-temporal cortex, regions known to support object recognition processes. The N170 modulation cannot be accounted for by either face-selective or expertise-related processes, or in terms of low-level perceptual variance measures such as ISVP. Rather, the data suggest that (1) the N170 responds to relatively high-level and complex geometric attributes of 3D object structure and, (2) different geometric primitives are associated with unique topographical ERP distributions in ventral occipito-temporal cortex.

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Memory: Working and Short-term Memory

Sunday, May 10, 2:45 – 6:45 pm
Poster Session, Royal Palm Ballroom 6-8

36.315

The Nature of the Capacity Limitations in Visual Short-Term Memory

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Several studies have explored the nature and in particular the limitations of human visual short-term memory (VSTM) (e.g. Luck & Vogel, 1997). A VSTM capacity limit of about 3 to 4 objects has been found, thus confirming results from earlier studies (e.g. Sperling, 1960). However, Alvarez and Cavanagh (2004) have argued that VSTM capacity is more dependent on the visual complexity of the objects rather than the number of objects per se.

We hypothesize that VSTM capacity is not only dependent on the complexity of a given object (like for example curvature and intersections) - what could be coined objective complexity - but more importantly how complex a given stimulus appear to the individual subject - what in contrast could be called subjective complexity. Many studies like Alvarez and Cavanagh seem to describe objective complexity and its influence on capacity limitations, but this may only reflect some of the aspects affecting the limited capacity of VSTM.

In a series of studies, we have explored how the familiarity of different types of stimulus-sets influences the capacity limitations in VSTM. We use a change detection paradigm (Pashler, 1988) to estimate VSTM capacity. In Experiment 1 we test four different groups with different reading skills from novice to expert readers, and in Experiment 2 we test native versus non-native readers of Japanese. In Experiment 3 we test both the capacity and encoding speed of young adults without any prior training as they learn to read either Arabic or Japanese.

Our results indicate that VSTM capacity for familiar items - compared to unfamiliar - is larger, irrespective of their visual complexity, hereby suggesting that visual long-term memory representation and training play an important role in regard to the capacity limitations of VSTM.

36.316

Measuring VSTM 'iconic' memory capacity in 6-month-old infants

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Introduction: 'Whole report' tests underestimate memory capacity; the crucial innovation was the partial report (Sperling, 1960). However, typical same/different tests of infants' memory - where infants' reactions are tested when a change is made to a set of objects, say, while briefly occluded or invisible - amount to whole report. Purpose: Adapt and apply a partial report test of infants' very short term (VSTM), 'iconic' memory span. Method: Over two blocks of 20 trials, ten infants (age range: 5;0-6;30) were presented with a set of 4 identically-shaped, but differently-colored items, spaced symmetrically around central fixation. After a 1 second exposure, a randomly chosen pair of neighboring items disappeared. After 500 msec, the two items reappeared, always with one changed to a new color and the other unchanged. This display remained for 2 seconds (eye-movements were recorded throughout the trial with a Tobii eye tracker). The sudden offset of the two items itself was the partial report post-cue, designed to draw attention and trigger their coding from VSTM into more durable short-term memory. Only by remembering all items in the set would infants be able to distinguish between the changed vs. unchanged items. Results: In what amounts to a 2AFC, we measured which of the two items was 1) fixated more frequently and 2) for a greater total time. For a set size of 4, infants showed positive 'novelty' effects, looking more often and longer at the changed item. Preliminary tests with set size 6 suggest positive results as well. Conclusion: We created a partial report paradigm for

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infants. Infants remembered two items cued randomly from a set of 4 (with suggestive results from set size 6, and work with higher set sizes ongoing), indicating a capacity of VSTM iconic memory of at least 4 items.

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36.317

Durability of feature-based and object-based representations in visual short-term memory

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Recent studies of visual short-term memory (VSTM) suggest that people may remember one of two types of visual representations from a set of objects that recently disappeared. One type of representation is feature-based, and contains separate, unbound features for each object (e.g., one contains an object's color, another its location). The other type is object-based, and contains all the features of one object bound together. Debates persist about how VSTM supports these two types of representations. We report a new study in which we investigate how long each representation lasts after a stimulus disappears.

We conducted an experiment using a change-detection task with colored squares as stimuli. We varied the retention interval between the two displays from 1-4 seconds to test for decay of memory for the first display. Additionally, we included two types of changes. On new-color trials, the colors of two squares would change to two new colors, and on switch trials, the colors of two squares would switch places. Changes on new-color trials can be detected if any color information has been retained, but changes on switch trials can be detected only if bound color-location information has been retained. Thus, the amount of feature-based and object-based information can be estimated separately by performance on these two types of trials.

We found that the amount of feature-based information stayed constant at about 1.4 items' worth over 4 seconds, whereas the amount of object-based information shrank from 2.4 to 1.7 item's worth between 1-4 seconds. These results suggest that the feature-based information stored in VSTM is more durable than object-based representations.

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36.318

Visual short-term memory for abstract patterns: Effects of symmetry, element connectedness, and probe quadrant

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Purpose. Most of the studies on the characteristics of visual short-term memory (VSTM) used somewhat familiar stimuli, such as simple visual attributes (e.g., color, orientation), entry-level objects, faces, or natural scenes. However, with these types of visual material, it is difficult to completely rule out the influence of individual subject's prior knowledge or familiarity with the stimuli. Therefore, the goal of the present study was to explore the nature of VSTM for unfamiliar, abstract patterns spreading on a 5*5 checker board.

Methods. We used Corel Draw (v.11) to generate the stimuli, and E-Prime 2.0 to run the experiments. The subjects sat at a viewing distance of 57 cm with a chin rest. Each trial began with a fixation cross, then an abstract pattern (made of 12 or 13 red squares) within the 5*5 checkers appeared for a fixed duration, and a probe X located in one of the four quadrants appeared. The subjects' task was to judge whether the square in which the X located overlapped with the red pattern or not. Experiment 1 investigated the effects of overall pattern symmetry (asymmetrical v.s. symmetrical), element connectedness (high v.s. low), and probe quadrant (upper-left, upper-right, lower-left, and lower-right). Experiment 2 further explored the effects of the stimulus sizes, in which three sizes were used (20°×21°, 13°×14°, 6.8°×7.2°).

Results. Based on error rate data, results of Experiment 1 showed significant effects of element connectedness, symmetry, and quadrant of probe, indicating that memory for abstract pattern was more accurate when the pattern was symmetrical, had a higher connectedness, and easier to recall for probes located in the upper-left quadrant. Results of Experiment 2 showed a mild size effect, where more errors occurred with larger stimulus size. Further data collection is in progress.

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36.319

Dual impact of extra-foveal processing in human visual short-term memory

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Little is known about the role of extra-foveal processing in VSTM, despite its potential importance in maintaining active scene memory. This study investigated extra-foveal processing in VSTM in two object-position recognition experiments using five observers. Unfamiliar, nonverbal 1/f noise discs served as stimuli, minimizing confounds arising from verbal labeling and semantic association. At study, observers viewed 5 equally spaced 2 deg stimuli in a 13 deg ring, either simultaneously (experiment 1) or sequentially (experiment 2). A random start position was pre-cued with a spatial probe. In experiment 1 (extra-foveal processing enabled), stimuli were viewed consecutively in a clockwise direction, guided by an auditory prompt every 650ms until all study stimuli were fixated. In experiment 2 (extra-foveal processing disabled), the auditory prompt coincided with the onset of the next stimulus and the offset of the previous stimulus. At test, following a 1000ms ISI, a centered target stimulus was displayed, flanked by spatial markers at the 5 study stimulus positions. Observers attempted to identify the spatial position occupied by the target in the preceding study display (5AFC). Hit rates were calculated for each temporal index (1=earliest, 5=latest) at which target stimuli were presented in the study display. In general (over the earliest 3 temporal indices), hit rate was significantly higher in experiment 1 than in experiment 2 [$F(1,4)=26.18$, $p<0.01$]. At the fourth temporal index, hit rate was not significantly different between the experiments [$t(4)=0.49$, $p=0.65$]. At the fifth temporal index, hit rate was significantly lower in experiment 1 than in experiment 2 [$t(4)=-2.75$, $p=0.05$]. Results suggest extra-foveal processing in VSTM for object-position recognition exhibits a trade-off between facilitation and inhibition. Facilitation is incurred after the target has been foveated, decreasing the impact of retroactive interference; conversely, inhibition is incurred before the target has been foveated, increasing the impact of pro-active interference.

36.320

Experience-dependent distortions in working memory for metrically similar colors

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Studies of spatial recall have revealed systematic delay- and experience-dependent distortions in working memory (WM) for spatial location. For example, metric memory for location shows delay-dependent biases away from perceived reference axes, such as the midline symmetry axis of a task space. Additionally, recall responses are biased in the direction of previously responded-to locations when locations are recalled in the absence of salient cues. To account for these findings, we have proposed a dynamic field theory of spatial cognition where locations are represented as "peaks" of activation maintained in cortical fields. The metric distortions seen in studies of spatial recall arise in the model as a result of reciprocal coupling between WM, perception, and LTM. In the present study, we explore whether these same signatures of neural interaction are seen in tasks that probe working memory for color.

To look for delay- and experience-dependent biases in WM for color, separate groups of participants estimated either "Close" colors (30º separation in color space) or "Far" colors (80º separation). Participants only saw two

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different colors throughout the experiment: a 'B' color that remained the same across the Close and Far conditions, and an 'A' color that was either clockwise or counterclockwise in color space from the 'B' target. We predicted that participants in each condition would form LTM traces of the target colors seen across trials, but the nature of the LTM traces should differ across conditions. Specifically, for the Close condition, LTMs of the target colors should blend together, leading to strong activation around an average remembered color. Consequently, WM for the 'B' target should be attracted toward the 'A' target across delays. This is precisely what was found, supporting the proposal that WM for color relies on the same dynamic neural principles proposed to underlie SWM in our model.

36.321

Contralateral delay activity is sensitive to the spatial distribution of items in working memory: An ERP study

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Recent studies have established a neurophysiological index sensitive to the number of items maintained in visual working memory (VWM). The amplitude of this ERP waveform – a widespread negative deflection appearing contralateral to the visual hemi-field containing VWM targets – approaches asymptote as the number of targets reaches VWM capacity and is known as contralateral delay activity (CDA; Vogel, McCollough, & Machizawa, 2005). In previous studies, VWM targets were always presented in different locations, a constraint imposed by their simultaneous appearance. Thus, it remains uncertain whether the CDA reflects the number of items encoded or, perhaps instead, the number of locations requiring attention. In the current study, participants maintained either 1 or 2 color squares in VWM; in the larger set size, targets were presented sequentially, so that they could appear either at the same or different locations. If the CDA is sensitive only to the number of objects, its amplitude should be the same regardless of whether the objects appeared in a single or multiple locations. In contrast, if the CDA is sensitive to the number of spatial locations, its amplitude should be the same for a single object and two objects presented in a single location, and in both of these conditions its amplitude should be smaller than when two objects are presented in different locations. The data were consistent with the latter prediction: CDA amplitude was highest for two squares appearing at different locations, while amplitudes in response to a single square and two squares appearing at the same location were equivalent. These results suggest that at least some components of the CDA are sensitive to the number of locations occupied by VWM targets rather than to the number of targets per se.

36.322

Estimating visual working memory capacity with whole and single probe test arrays

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Estimates of visual working memory capacity vary considerably across individuals. These estimates appear to reflect a stable cognitive trait of the observer because they are consistent over time and are strongly predictive of performance related to high-level cognitive processes such as abstract reasoning and fluid intelligence. One common measure of capacity is the change detection procedure (e.g., Luck & Vogel, 1997) in which observers are shown an array of simple objects that must be remembered over a retention period. Memory for the array is then measured with the presentation of a "test array" in which the observer must detect a change in the identity of one of the objects from the original array. In the present study, we examined the psychometric properties of two variations of the test array presentation: a whole-probe test in which all of the items from the memory array are present; and a single-probe test in which only a single item from the memory array is evaluated. We measured memory capacity in these two conditions across two separate sessions separated by a one-week interval. At the group level, we found that both whole-probe and single-probe conditions yielded comparable memory capacity estimates as well as strong test-retest correlations across the two sessions. However, at the individual level, we observed that low memory capacity subjects showed a large benefit in performance for single-probe conditions relative to whole-probe conditions, while the high capacity subjects showed a slight cost in performance for single-probe test arrays. Together, these results are consistent with previous work that has suggested that low memory capacity individuals are highly susceptible to attentional distraction and interference.

36.323

Visual working memory capacity can be assessed independent of comparison errors

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Measures of working memory capacity (K), derived from performance in change detection tasks (Cowan, 2001; Vogel et al., 2001), estimate that we can hold 3-4 items in visual working memory (VWM). Such measures assume that incorrect responses arise solely from a failure to store items, and do not take into account that comparison errors (CEs) may occur when internal VWM representations are compared to perceptual inputs during the probe stage of a VWM task. However, since these assumptions are likely incorrect (Awh et al., 2007; Zhang & Luck, 2008), K underestimates actual capacity according to the rule, Kmax = capacity * (1 - CE rate), where Kmax is the maximum estimate of K for any VWM set size (N). This equation also predicts that K will increase with increases in N until N corresponds to capacity. Thus, the value of N at which K peaks should be a better estimate of capacity than K. Here we experimentally demonstrate that this measure of capacity is independent of CEs by adding perceptual noise to the probe (85% of probe pixels assigned a random color) in order to increase comparison errors. In the task, participants had to memorize the color and location of 2-7 briefly presented squares. After a 2.4s retention interval, VWM was tested using a single-probe procedure in which participants indicated whether the probed color was shown in the correct location. Addition of perceptual noise reduced the K values measured at any setsize, demonstrating that K estimates are sensitive to CEs. However, K values peaked around N=4 regardless of the presence of perceptual noise, suggesting that this analysis provides a measure of WM capacity that is robust to CEs. We will discuss the application of this analysis for estimating the influence of stimulus complexity and sample-test similarity on VWM capacity.

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36.324

Location and Meaningful Visual Detail Influence Crossmodal Working Memory Capacity

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Complex objects have been found to occupy more space in visual working memory--as measured by lowered change-detection accuracy with such stimuli--than simple colored shapes (Treisman, 2006; Xu, 2002). While this result is consistent with verbal working memory findings showing reduced apparent capacity with longer words (Baddeley, 2007), other research has demonstrated that features contributing to object recognizability can help visual working memory capacity (Olsson & Poom, 2005; Alvarez & Cavanagh, 2004). Complex objects' memory load was further examined in a sequence of experiments adapting classic visual change detection procedures (Vogel et al., 2001) to measure crossmodal (auditory and visual) working memory capacity. The adapted method involves rapid sequential presentation of image-sound pairs, with a test pair appearing after a short delay (800-1000ms). Images are placed equidistant from each other in the initial array, approximately 3.5° from a central fixation. The images chosen depicted non-animate objects (e.g. apple, ball, book, glass); associated sounds consisted of 400ms recordings of animal sounds or pure tones. While in one experiment (N=12), meaningful images were better cues for crossmodal associations than colored balls, this result failed to replicate in an identical later study and in a related study: image type was not a signifi-

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cant source of variation either time. All three studies made location as well as visual image features available as cues for the audiovisual associations, presenting each test pair in its original location. In a follow-up experiment (N = 13), test items were displayed in the center of the screen, removing location as a possible cue. Full-color photographs provided greater cross-modal change detection accuracy than grayscale drawings (from Rossion & Pourtois, 2004) (M-photo 57.7%, M-grayscale 49.2%, p=.01). Overall, meaningful visual detail improved short-term recall for crossmodal associations when image location was not available as a parallel cue.

36.325

Assessing sensory gain during the maintenance of information in working memory

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Visual Working memory (WM) involves an encoding stage, in which a perceptual representation of a visual stimulus (e.g., 90° line) is consolidated into a WM representation, and a maintenance stage, in which this representation is held in memory during a delay period. While the mechanisms in early visual cortex that support encoding are relatively well understood, much less is known about how activity in these same areas contributes to the maintenance of a mnemonic representation during the delay period. Here we present a psychophysical method designed to examine how gain is applied to the sensory neurons that represent the remembered stimulus during the delay period of a difficult WM task. On each trial, we briefly presented a to-be-remembered oriented stimulus (the sample stimulus). On 64% of the trials, a test item which either matched the sample or differed by ±10° (a mismatch) appeared after a 1200ms delay. Importantly, the relatively high frequency of these trials induced an expectation for a WM trial. On the remaining 36% of the trials we probed the distribution of neural gain in early visual cortex after a variable delay (400ms or 1200ms) by measuring contrast detection thresholds for a single orientated stimulus rotated by 0°, ±10°, or ±20° with respect to the sample. We found that the shape of the gain profile differed between the short and long delay periods, suggesting that subjects may not maintain a static representation of the sample. Furthermore, the shape of the gain profile differed across subjects, suggesting the existence of individual differences in the way people represent and maintain items in visual working memory.

36.326

A Bilateral Advantage for Resolution in Visual Working Memory

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Various studies have demonstrated enhanced performance when visual information is presented across both visual hemifields rather than in a single hemifield (the bilateral advantage). For example, Alvarez and Cavanagh (2005) reported that observers were able to track twice as many moving visual stimuli when the tracked items were presented bilaterally rather than unilaterally, suggesting that independent resources enable tracking in the two visual fields. Motivated by similarities in the apparent capacity and neural substrates that mediate tracking and visual working memory (WM), the present work examined whether or not a bilateral advantage also arises during storage in visual WM. Using a recall procedure to measure the precision with which orientations were held in WM, we found a reliable bilateral advantage; recall error was smaller with bilateral sample displays than with unilateral displays. To test whether these results were due to differences in encoding quality, we measured recall error with simultaneous and sequential stimulus displays. The bilateral advantage was just as large with sequential displays, showing that this effect was not due to encoding differences. Thus, we conclude that the bilateral advantage extends beyond the initial acquisition of visual information, such that mnemonic resolution is reliably enhanced by bilateral presentations of the to-be-stored items.

36.327

Indexing the Maintenance of Objects in Visual Working Memory by Spatial Selection

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Theories have proposed that visual working memory representations of objects are maintained by a spatial rehearsal mechanism. To test this hypothesis we used two different approaches. First, we tracked observers' eye movements during a change-detection task with memory arrays of one, three, or six objects. During the blank retention interval subjects shifted gaze to the locations the objects previously occupied in the memory-sample array benefiting task performance. Second, we tested the hypothesis that drawing attention away from the object locations during the retention interval would impair memory for the objects. We confirmed this hypothesis using a concurrent fixation probe detection task during the retention interval. These findings support models in which object representations are maintained by spatial mechanisms.

36.328

The interactive nature of multiple stimulus representations in visual-short term memory

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Previously we found sequential deflections of encoding-related lateralization (ERL) waveforms in event-related brain potentials, suggesting that multiple levels of stimulus representation activate in different time windows (Shin, Fabiani, & Gratton, 2006). The ERLs reflect lateralized brain activities elicited by the degree of matching or mismatching between laterally-presented memory-sets and centrally-presented probes. Here we further investigated the nature of one of the ERLs (reported in Shin et al., 2006), showing a smaller ERL in the set-size 4 than in the set-size 2 condition, observed about 400 ms poststimulus at posterior electrode sites. Twenty participants performed a memory search task, in which a memory-set of homogeneous or heterogeneous letters with two letters in each hemifield and a two-letter probe in the center were presented in sequence. To test local suppression hypothesis, we varied distances of memory-set letters (close vs. far) but kept eccentricity of the letters from fixation constant. To test partial matching hypothesis, we presented probe letters completely or partially matching to the memoy-set items. Data showed that the ERL was larger (a) in the complete-match than in the partial-match condition at all times; (b) in the far than in the close condition for the heterogeneous memory-set letters; (c) in the close than in the far condition for the homogeneous memory-set letters. These results support both local suppression and partial matching hypotheses, indicating that stimuli are represented in an interactive way and activation of the representations is maximized at a complete match of probe with memory representation. Also, perceptual grouping influences memory representations and their activations.

36.329

Multiple physiological markers of visual short-term memory: convergence and divergence

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Maintenance of centrally presented objects in visual short-term memory (VSTM) leads to bilateral increases of the BOLD response in IPS/IOS cortex (Todd & Marois, 2004), while maintaining stimuli encoded from a single hemifield leads to a sustained posterior contralateral negativity (SPCN) in electrophysiology (Vogel & Machizawa, 2004). We recorded the BOLD signal using fMRI, magnetoencephalography (MEG), and electroencephalography (EEG) while participants encoded visual stimuli from a single hemifield. The EEG recorded over parietal cortex showed the SPCN, as did MEG activation in superior IPS. However, no SPCN-like activation (meaning a contralateral-ipsilateral difference that increases with the increase of mnemonic load) was observed in the BOLD signal for superior IPS, disconfirming the hypothesis that the SPCN and BOLD activation in IPS are two markers of the same neuronal process. Furthermore, left inferior occipital (IO) cortex was prominent by being the only BOLD activation showing an SPCN-like pattern: an increase of activation with higher load, only for right hemifield stimuli. Right IO, however, showed an increase of the BOLD signal for stimuli encoded from both hemifields. Given that the SPCN and the magnetic equivalent (the SPCM) have been shown to occur bilaterally, IO cannot be the locus of SPCN. The different results will be discussed in regard to the various physiological markers of VSTM.

36.330

Grey matter volume explains individual differences in visual short-term memory capacity

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The capacity of visual short-term memory (VSTM) is highly limited, but it does vary substantially across individuals, ranging from 1.5 to 5 objects (Vogel et al., 2001). Individual differences in VSTM capacity seem to be imposed by processing bottlenecks in the intraparietal sulcus (IPS) and lateral occipital complex (LOC) as BOLD activity in these areas mirrors behavioral estimates of VSTM capacity (Todd & Marois, 2004; Xu & Chun, 2006). Moreover, it seems that the filtering efficiency of the IPS is controlled on a trial-to-trial basis by the prefrontal cortex and the basal ganglia (McNab & Klingberg, 2007). Here, we report a study employing voxel-based morphometry (VBM) that focuses on the relation between VSTM capacity and grey matter volume in the IPS, the LOC and the basal ganglia. We acquired anatomical scans of 53 healthy subjects, who additionally performed a standard VSTM task (see Luck and Vogel, 1997; only oriented rectangles were used). We found that people with high VSTM capacity had increased grey matter volume in the IPS (bilateral), the LOC (bilateral) and the basal ganglia (bilateral, but more prominently in the right hemisphere) in addition to a few more brain areas. Noteworthy is that people with high VSTM capacity also had increased grey matter volume in the right superior frontal gyrus. Altogether, it seems that individual differences in VSTM capacity are driven by anatomical differences in the LOC, the IPS, the basal ganglia and the prefrontal cortex that in turn give rise to the functional differences that were evident in previous studies (Todd & Marois, 2004; Xu & Chun, 2006; McNab & Klingberg, 2007).

36.331

Global mechanisms of sensory recruitment during working memory maintenance

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According to the sensory recruitment hypothesis, information is stored in working memory via sustained activity in the same sensory regions that encode memoranda. In a recent study, we reported that patterns of delay activity in primary visual cortex (V1) reliably indexed specific feature values (color, orientation) of remembered objects (Serences, Ester, Vogel, & Awh, in press, Psychological Science). Here, we asked whether stimulus-specific delay activity would also be observed in cortical regions that were not activated by bottom-up stimulation, as has been observed during sustained attention to motion stimuli (Serences & Boynton, 2007, Neuron). Observers were shown an oriented grating in either the right or left visual field, followed by a post-cue that instructed them to remember or forget this orientation across a 16s delay period. Our analysis was restricted to voxels that showed the strongest contralateral (relative to ipsilateral) responses during a separate set of functional localizer scans. Consistent with prior reports, the pattern of activation in both contralateral and ipsilateral regions of V1 enabled accurate classification of the to-be-remembered orientation during the encoding phase of each trial. Moreover, we found that a similar activation pattern was maintained throughout the delay period in both contralateral and ipsilateral regions of V1. Importantly, these delay period effects were absent in trials with the "no-memory" postcue, showing that positive results during "remember" trials were not a passive effect of encoding the sample stimulus. Thus, the sensory regions that are recruited during rehearsal in visual WM extend beyond the regions that respond in a bottom-up fashion to the memoranda. This type of spatially-global gain modulation may serve to enhance mnemonic acuity by increasing the number of neurons dedicated to representing the memoranda.

36.332

The neural correlates of visual working memory consolidation: A time-resolved fMRI study

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The attentional blink (AB) reveals a profound deficit in detecting the second of two temporally proximate targets. It has been argued that the AB results from the capacity-limited process of consolidating information into visual working memory (Chun & Potter, 1995; Jolicoeur, 1998). While a network of parieto-frontal brain regions is believed to play a key role in the AB (Marois et al., 2000, 2004), it is unknown if these regions are involved in working memory (WM) consolidation, as the behavioral model would predict.

Here, we used time-resolved fMRI to isolate brain regions involved in WM consolidation. Subjects performed a visual WM task in which they encoded, in separate blocks of trials, either the color or the face identities of two colored-face stimuli. The stimulus display was shown for 500ms or 1500ms before mask presentation, which were the durations—as determined in pilot experiments—necessary for the consolidation of two colors and two faces, respectively. If a brain region is sensitive to WM consolidation, face-related activity should last longer than color-related activity in the 1500ms condition, reflecting the longer face consolidation time for faces than colors. However, there should be no activity duration difference between faces and colors in the 500ms condition because WM consolidation would be limited to 500ms for the two stimulus conditions. A region-of-interest analysis revealed precisely this pattern of activation in the left posterior lateral prefrontal cortex (LPFC) and bilateral intraparietal sulci (IPS), brain areas previously implicated in the AB. Because subjects were also required to concurrently perform a demanding stimulus-dimming task throughout stimulus presentation, these findings cannot simply be accounted for by differential attention to the displays. Rather, we conclude that these activation results reveal the neural trace of WM consolidation and provide neurobiological support for the consolidation theory of the AB.

Attention: Endogenous and Exogenous

Sunday, May 10, 2:45 – 6:45 pm
Poster Session, Orchid Ballroom

36.401

Involuntary but not voluntary orienting modulates the splitting of attention

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Background: The focus of attention need not be unitary but can be split between noncontiguous locations. However, in the absence of a suppressive mechanism triggered by external noise (e.g. distractors) attention appears to be scaled rather than split (Awh & Pashler, 2000). This need for a suppressive mechanism to induce splitting suggests that involuntary but not voluntary orienting of attention may modulate the splitting of attention. Involuntary orienting may have both suppressive and excitatory effects, whereas voluntary orienting may have only suppressive effects (Lu

& Dosher, 2000). Based on these findings, we predicted that when orienting was voluntary, attention would be split via a suppressive mechanism but when orienting was involuntary, attention would split or scaled depending on task demands for suppression or enhancement. The hypothesis was tested in two experiments that manipulated the orienting and distribution (the scale of the attentional focus) of attention and the level of external noise. Method: A cued search task precued location of a target digit in a search array of distractor letters. Conditions were: orienting type (involuntary and voluntary); distribution type (constricted, scaled, or split); external noise (high and low). External noise was manipulated by the distance between stimuli (i.e. near and far) in Experiment 1 and the similarity between stimuli (i.e. low and high) in Experiment 2. All cues were valid in predicting target location. Following array offset, participants made unspeeded responses about the presence of the target digit. Accuracy of target response was used as the dependent measure. Results and Conclusions: The ability to split the focus of attention was modulated with involuntary but not voluntary orienting. These results indicate that involuntary orienting of attention uses both suppressive and excitatory mechanisms, while voluntary orienting of attention uses only a suppressive mechanism.

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36.402

Effects of cholinergic enhancement on voluntary and involuntary visuospatial attention in humans

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Allocation and orienting of visuospatial attention are modulated by release of acetylcholine in cortex. In this study we measured the effects of pharmacological enhancement of the cholinergic system on voluntary and involuntary attention in healthy human participants.

Subjects performed a visual discrimination task in which they reported the tilt of a grating that appeared in one of four spatial locations in the visual display, arranged around the fixation point. An anti-cueing paradigm was used to manipulate attention. Each trial began with presentation of a salient cue in one of the four locations. For 20% of the trials, the target then appeared in the cued location, and for the remaining 80% of trials, the target appeared in the location diametrically opposite the cue.

Trials were blocked based on stimulus onset asynchrony (SOA) between cue and target presentation: long (600 msec) or short (40 msec). For long SOA trials, allocation of voluntary attention to the expected target location resulted in shorter response times (RTs) when the target appeared in the location opposite the cue. However, when the SOA was short, the involuntary capture of attention resulted in the opposite pattern: In these blocks, RTs were significantly shorter when the target appeared in the same location as the cue.

Participants performed the task in a double-blind, placebo-controlled, crossover design. The cholinesterase inhibitor donepezil (trade name: Aricept) was administered to increase synaptic acetylcholine levels. This enhanced the effect of cueing (difference in RT for valid and invalid trials) for long SOA but not short SOA blocks.

This result demonstrates cholinergic modulation of voluntary but not involuntary visuospatial attention.

Acknowledgement: We would like to thank Jon Kelvey for his help in collecting and analyzing the data. This work was supported by NIH grant R21-EY017926 and the Hellman Family Faculty Fund

36.403

Visuospatial neglect: Reflexive but not volitional orienting contributes to a disengage deficit

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Patients with visuospatial neglect and/or extinction respond much more slowly to a stimulus presented to their impaired, contralesional side of space when it is preceded by a stimulus presented to the intact, ipsilesional side of space. This response pattern is referred to as a disengage deficit, indicating that attention is slow to be disengaged from ipsilesional stimuli. Past studies have measured the disengage deficit for reflexive orienting (nonpredictive peripheral onsets) and volitional orienting (predictive central arrows). Recent evidence that nonpredictive arrows engage reflexive attention, however, implies that past studies using predictive arrows confounded reflexive and volitional attention. We therefore examined the disengage deficit in the same participants for when an attention cue engages only reflexive attention (nonpredictive peripheral onsets and arrow cues), reflexive and volitional attention (predictive peripheral onsets and arrow cues), and only volitional attention (predictive number cues). Results indicate that the significant disengage deficit for reflexive orienting (nonpredictive onsets and arrows) was unmoved when volitional attention was also engaged (predictive onsets and arrows), suggesting that volitional orienting does not contribute to disengage difficulties. This interpretation was confirmed when only volitional attention was manipulated by predictive number cues: significant cuing effects for contra- and ipsilesional fields were observed but there was no disengage deficit. The results are discussed with respect to their implications for understanding the attentional mechanisms underlying the disengage deficit as well as its assessment and rehabilitation in patient populations.

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36.404

Co-determination of attentional allocation by endogenous and exogenous factors

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Spatial attention is driven by both endogenous and exogenous factors. Here we report results from a cueing experiment that explores the interplay between these factors in determining the allocation of spatial attention in a visual search task.

Observers searched for a 2-deg circular target patch of one-dimensional oriented 1/f noise in a large circular field of isotropic 1/f noise of equal contrast. 10 possible random target sites within the 1/f background were indicated by 2-deg circles. Cued sites were indicated by red circles, non-cued sites by light grey circles. Between 0 and 10 sites were cued on every trial. The reliability of the cue was varied, but cueing was usually informative and at worst neutral. Targets appeared in half the trials. Observers were told that the target might appear in either red or grey circles, but the red circles were generally more reliable. Observers were asked to indicate presence/absence of the target with one of two keys, and to respond as quickly as possible, while minimizing errors.

We recorded the reaction time for target detection as a function of the number of cued locations and considered two models of search. The first is a standard serial search model that accounts only for the endogenous component of attention. The second model combines both endogenous and exogenous components, where the exogenous cue is based upon novelty: salience of cued sites is inversely proportional to the number of cued sites, and likewise for non-cued sites.

For 10 out of 10 subjects, we found that the second model combining both endogenous and exogenous factors provided a closer account of the data. These results suggest that the exogenous cue of novelty is a strong determinant of attentional allocation even in the face of salient exogenous competition and countervailing endogenous factors.

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36.405

Auditory Effects on the Timing of Exogenous and Endogenous Visual Attention

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The authors explored the effect of sound on the timing of exogenous and endogenous visual attention. Twelve clocks arranged in a circle around central fixation revolved in clockwise direction with randomly determined initial positions (Carlson et al., 2006, Journal of Vision). The participant's task was to report the hand position of a target clock at the time that an exogenous cue (one clock turning red for 100 ms) or an endogenous cue (a line pointing from fixation towards one of the clocks) was presented. An auditory click was presented either 100 ms before, simultaneously, or 100 ms after the cue. In a silent control condition, endogenous cues resulted in a larger lag of the clock's hand from actual position (> 200 ms) than exogenous cues (~80 ms). A simultaneous sound improved accuracy for both cues, and a click before or after the cues shifted the lag in that direction. Sounds thus affected the timing of exogenous and endogenous visual attention.

36.406

Individual Differences in Voluntary and Involuntary Attention

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The present study examined whether voluntary and involuntary attention manifest differently in people with differences in impulsivity (measured with the Barratts Impulsivity Survey). We proposed that high and low impulsive participants would display different amounts of voluntary and involuntary attention. We used the spatial-cueing paradigm to assess attention. In each trial a peripheral cue (the thickening of a rectangle) was displayed, followed by a letter target. Participants were required to identify the target (F or T). Targets could either appear in the cued location (valid trials) or in the uncued location (invalid trials). We used two different manipulations to probe voluntary and involuntary attention. The first was the time elapsing between the cue onset and the target onset (SOA). Targets were separated from cues by either 40 or 400 ms. This manipulation was motivated by the finding that involuntary attention is typically transient while voluntary attention takes longer to build up. In addition, the peripheral cues were either predictive of cue location (i.e., mostly valid trials) or non predictive of cue location (i.e., equal probability for valid and invalid trials). While predictive trials probe voluntary and involuntary attention, non predictive trials summon only involuntary attention, since target location is random with respect to cue location. The different SOAs and predictability manipulations were performed in separate blocks within subjects. We found that participants with high impulsivity scores exhibited larger involuntary attention effects whereas participants with low impulsivity scores, exhibited larger voluntary attention effects. This finding reveals cognitive processes underlying the measure of impulsivity. In addition, this finding suggests that voluntary and involuntary can be modulated independently contributing to the theoretical distinction between these systems.

36.407

Differential effects of transient attention on adaptation to different spatial frequencies

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This study explores the effects of transient attention –the stimulus-driven component of spatial attention– on adaptation to different spatial frequencies: Can transient attention affect adaptation? If so, does it have a similar effect on adaptation to different frequencies? Previous studies demonstrated that sustained attention –the goal-directed component of spatial attention– increases adaptation effects, but does transient attention have a similar effect on adaptation?

To answer these questions, Gabor patches of high or low spatial frequency were employed as targets in two paradigms. In the adaptation trials of one paradigm, four targets are continuously presented. A peripheral attentional cue indicates the location of one of these targets, but only two locations may be indicated. The test trials require the detection of a single target appearing in one of the 4 locations. The other paradigm involves adaptation that accumulates over successive presentations. It required the detection of a single target appearing in one of 4 possible locations. The adaptation trials include a high-contrast target that is preceded by either a peripheral cue indicating one of 2 predefined locations, or a neutral cue indicating all 4 locations. The test trials include a low-contrast target that is always preceded by a neutral cue. These various trials are randomly intermixed. For both paradigms, the test-target orientation is either identical or orthogonal to that of the adaptation-targets, and the adaptation effect is the difference between detection of 'identical' and 'orthogonal' test-targets.

Adaptation effects were found for both frequency conditions in both paradigms, but they were differentially modulated by transient attention. Like sustained attention, transient attention amplified the high-frequency adaptation, yet no amplification was found for the low-frequency adaptation, and it even reversed in some cases. These findings will be discussed in relation to previous studies suggesting that transient attention favors parvocellular over magnocellular activity.

36.408

Effects of faces as exogenous cues are dependent on visual field and handedness

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Background and Goal. Faces are unlike other visual objects we encounter on a daily basis. They openly display the mental states of others and are thus effective cues to potentially relevant information. The right hemisphere of the human brain has a dominant role in both face processing and spatial attention, a lateralization that has proven to be stronger in right- than left-handers. Here we demonstrate behavioral evidence for an effect of handedness in tasks requiring face processing and attention.

Method. We used non-predictive, peripheral cues to direct exogenous (involuntary) attention to a visual task stimulus. Cues were either faces (Experiment 1) or dots (Experiment 2), and were presented to the upper-left, -right, or both upper quadrants of the visual field. Observers performed an orientation discrimination task with contrast-varying stimuli (3-56% contrast, 4-cpd Gabor patches presented at 5° eccentricity) appearing 125ms after cue onset in either the lower-left or -right visual field. Attention was thus cued to the location of a tilted target (valid cue), a vertical distracter (invalid cue), or distributed over both locations.

Results and Conclusion. We found that for face-cues, contrast sensitivity (CS) modulation depended on the attention condition in right- but not left-handers. Right-hander CS was greatest on valid trials, and lowest on invalid trials, but there was no left-hander CS difference. Furthermore, an interaction between target visual field and handedness was observed for both CS and reaction time. For dot cues, however, CS depended on attention across both visual fields and handedness conditions. These results demonstrate that the use of social stimuli such as faces alters the effects of attention, likely due to the visual system's asymmetric treatment of such stimuli. The handedness-dependent face-processing asymmetry may explain the presence of attention effects in right-handers and its absence in left-handers.

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36.409

What does a short-SOA exogenous cue do in a so-called simple-RT task?

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Since first reporting negative effects of short-SOA exogenous cues on a luminance-detection task, we have found that this phenomenon might be limited to situations with low levels of background illumination. Under bright florescent lighting, the uninformative cues produced a positive cuing effect (i.e., valid-cue trials produce faster responses); under dim halogen lighting, the same cues produced a negative effect (i.e., invalid-cue trials produce faster responses). These data suggest that perceptual factors play a critical role in what is purported to be an attentional paradigm. We hypothesize that participants opt for different strategies under different lighting conditions, given that a variety of percepts are available across trials. We further hypothesize that different levels of background illumination make some percepts more salient than the others. For example, under bright lighting, local "hot-spots" in illumination may dominate, which favors valid-cue trials; under dim lighting, apparent motion may be more salient, which favors invalid-cue trials. To test these ideas, we reduced the possible percepts that were available under both types of background lighting.

36.410

Endogenous attention alters the appearance of spatial frequency

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Goal: Exogenous, involuntary attention alters the appearance of many visual features including contrast and spatial frequency. Whereas endogenous, voluntary attention also alters contrast appearance, it is unknown whether it alters other basic visual dimensions. Given that endogenous attention flexibly adjusts spatial resolution, whereas exogenous attention always increases spatial resolution, it is unclear whether these two types of attention will have the same effects on the appearance of spatial frequency.

Methods: A central cue prompted observers to attend to one of two peripheral locations or to both locations (focused vs. distributed attention). RSVP letter streams were shown at each location for 1.2 s, followed by two independently tilted Gabors. In focused-attention trials, observers directed attention to the cued stream, while in distributed-attention trials observers monitored both streams for the target letter. A target (letter X) was presented on 20% of trials, and observers indicated target detection by pressing a key. Observers were instructed to report the orientation (left vs. right) of the higher spatial frequency Gabor when they did not detect the target letter. One Gabor was the Standard, whose spatial frequency was fixed, while the other was the Test, whose spatial frequency was randomly chosen from nine levels around the Standard.

Results and Conclusion: RSVP detection performance was better for focused than distributed trials, indicating that attention was effectively deployed. Attentional deployment caused a systematic shift in the psychometric functions for appearance: stimuli at the cued location were perceived as having higher spatial frequency than stimuli at the uncued location. Concurrently, attention improved orientation discrimination performance. A control experiment ruled out a cue-bias explanation of the effect. These results indicate that endogenous attention increases apparent or perceived spatial frequency.

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36.411

Endogenous attention can reduce the tilt illusion, but not crowding

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Outside the fovea, the visual system both accentuates and obscures the differences between adjacent visual stimuli. We adapted Freeman, Sagi & Driver's (2001) dual-task paradigm to determine whether these complementary effects were similarly modifiable with endogenous attention. Left or right of fixation, the slight tilt of an almost horizontal Gabor pattern becomes hard to classify (as clockwise or counter-clockwise of horizontal) when horizontal Gabors appear above and below it. Classification is even more difficult when the tilted target is instead flanked on its left and right. We wondered whether this crowding could be alleviated if observers were required, not only to classify the target's tilt, but also to determine whether the flanks above and below it had the same spatial frequencies. The result was a clear "No." Acuity for tilt did not increase when attention was thus directed to the vertically aligned flanks. We even found a slight decrease in orientation acuity when attention was similarly directed to the horizontally aligned flanks. When, instead of being horizontal, the flanks are tilted at 20 degrees with respect to the horizontal axis, a physically horizontal target will appear tilted in the other direction. The results show a significant decrease in this tilt illusion when attention was directed to either to the flanks above and below the target or to the flanks on its left and right. Crowding's greater resistance to manipulations of endogenous attention suggest that it reflects a process that is different from and probably earlier than the one responsible for the tilt illusion.

36.412

On the exploration of surface-based attention with cuing task

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In this study, we compared the dynamic characteristics of surface-based attention (SBA), either triggered by exogenous or endogenous orienting. Two dynamic properties were concerned: inclusive of the time-course of same-surface advantages and the facilitation/inhibition mechanisms behind SBA. To approach these questions, we designed new surface materials and then conducted cuing tasks. First, SBA in cuing task must be verified. In experiment 1A, we used a direct cue to trigger exogenous orienting toward the cued surface at SOA 120 ms. Participants had to discriminate the color of the target which was located on cued surface (in valid condition) or uncued surface (in invalid condition). The result showed that reaction time (RT) was shorter in valid condition than in invalid condition. This was called the same-surface advantage. In experiment 1B, we used an indirect cue to trigger endogenous orienting at SOA 300 ms. The result also revealed the same-surface advantage. Further, we manipulated the cue type (valid, invalid and neutral) and SOA (120, 300, 500 and 1000 ms) to explore the time-course and mechanism of SBA. In experiment 2A, under exogenous orienting, we found the same-surface advantage at 120, 300 and 1000 ms SOA. RT in valid condition was shorter than neutral condition at 120 and 300 ms, but it was longer in invalid than neutral condition at 1000 ms. It meant that facilitation effect contributed to SBA at 120 and 300 ms, but the effect was reversed at 1000 ms. In experiment 2B, under endogenous orienting, RT in invalid condition was longer than neutral condition at all SOA situations, but RT in valid condition was not different from neutral condition. It meant that ignoring uncued surface played an important role in endogenous SBA. In conclusion, SBA triggered by either exogenous or endogenous orienting seemed to have different time-courses and mechanisms.

Object Recognition: Objects and Categories

Sunday, May 10, 2:45 – 6:45 pm
Poster Session, Orchid Ballroom

36.413

Is There an Object-Centered Coordinate Map in LOC?

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In an event-related fMRI-A paradigm, switching the relative positions of two separated objects, so that an elephant above a bus is followed by the bus above the elephant, results in a much greater release from adaptation in LOC than a translation of equal extent of the original scene (Hayworth et al, 2008).

Could this greater sensitivity to relative rather than absolute position be evident in the kinds of rotation paradigms that have been used to assess retinotopic organization in V1-V4? Because the wedges used in common retinotopic mapping can be perceived as highlighted portions of a larger object (the screen), common retinotopy techniques do not discriminate between object-centered and retinotopic coding. We devised a new paradigm to test whether LOC might contain an object-centered coordinate map, which would be consistent with the possibility that relative position is derived from an object-centered coordinate system.

While maintaining central fixation, subjects viewed an object which rotated around fixation at a constant eccentricity of approximately 3˚. As the object rotated around the screen, subjects performed one of two shape judgments (one-back matching or a fit-to-gap similarity judgment) on a region at the perimeter of the object that changed shape at a frequency of 2 hz. The task location rotated around the object faster than the object itself rotated around fixation (24s vs. 32s). In the posterior fusiform gyrus (which evidences the strongest relative-position effects) no BOLD signal modulation was observed at either frequency of rotation. The signal in LO was modulated more strongly at the frequency of rotation around the screen than at the frequency of rotation around the object, indicating that LO cannot be characterized by an object-centered map at the scale measurable by fMRI. Any effects of relative position must come from sub-MRI-voxel neural circuits or interactions with other visual areas.

36.414

Evidence for Object File Encoding in the Posterior Fusiform Gyrus (pFs) and the Intraparietal Sulcus (IPS)

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When viewing an elephant above a bus, pFs represents both objects simultaneously and is far more sensitive (evidenced by greater release of BOLD adaptation) to a change in the relative positions of the objects (bus now depicted above the elephant) than to a scene translation with equal object displacements. Global features, eye movements, and task difficulty were ruled out as possible explanations of this effect (Hayworth et al., 2008). If the relation changes could be tracked, would they still produce a release from adaptation?

Subjects viewed a 200ms S1 consisting of two separated objects each enclosed by a box outline, followed by a 300ms dynamic rearrangement in which the objects disappeared but the empty boxes remained and moved smoothly to new screen positions, followed by a 200ms S2 where objects reappeared within the stationary boxes. Objects always appeared at constant eccentricity. Box movement and the congruency of their contents defined four trial types: SameDirCongruent: boxes moved in same direction, S2 objects reappeared in the same boxes they did in S1, (e.g., elephant above bus -> elephant above bus); SameDirIncongruent: boxes moved in the same direction, but objects swapped boxes between S1 and S2 (e.g. elephant above bus -> bus above elephant); OppDirCongruent: boxes moved in opposite directions, with the S2 objects remaining in the same boxes as S1 (e.g. elephant above bus -> elephant side-of bus), OppDirIncongruent: boxes moved in opposite directions, objects swapped boxes (e.g. elephant above bus -> elephant side-of bus). In both pFs and IPS only incongruence resulted in a sizable release from adaptation over SameDirCongruent; OppDirCongruent gave only minimal release even though objects changed relative positions (e.g. above to side-of) between S1 and S2. These results are consistent with Kahneman and Treisman's (1984) Object File model but pose a challenge to simple stimulus-driven interpretations of adaptation.

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36.415

The visual system ignores outliers when extracting a summary representation

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There has been a recent surge in the study of ensemble coding, the phenomenon in which the visual system represents a set of similar objects using summary statistics (Alvarez & Oliva, 2008; Ariely, 2001; Chong & Triesman, 2003; Haberman & Whitney, 2007; 2008). These studies have revealed that humans are sensitive to scene statistics across multiple levels of visual analysis, including high-level objects such as faces. However, the limits of ensemble coding remain undefined. Here we use the method-of adjustment to explore this issue, allowing observers to adjust a test face to match the mean expression of a set of faces. In Experiment 1, observers viewed sets of 12 faces that contained 2 emotional outliers (i.e. expressions that deviated substantially from the mean expression of the other 10 faces) for 250 ms. When adjusting the subsequent test face to the mean expression, all observers preferentially adjusted to the local mean of the set (mean expression with outliers excluded) rather than the global mean (mean expression with outliers included). In Experiment 2, we modeled the performance of an observer who implemented a 'sampling' strategy; that is, an observer who picked N faces from the set and perfectly averaged them. The sampling hypothesis was first put forth by Myczek and Simons (2008) as a potentially more parsimonious explanation for ensemble coding. However, our sets contained outliers, the presence of which would be a detriment to a model that sampled. The results show that a sampling model could not explain human performance. Thus, observers effectively filtered the outliers, extracting the local mean from the set in only 250 ms.

36.416

Discovering the Structure of Object Representation through fMRI Clustering

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A striking and robust property of the ventral visual pathway in humans is the existence of regions selective for faces, places, and bodies. However, efforts to understand the functional organization of the rest of the pathway have encountered several nontrivial methodological challenges. First, the space of possible visual categories that might produce selective response profiles is large and we lack a theory of how to sensibly sample this space. Second, responses may be selective not just to a single object type, but rather to some set of object classes, a set that might fit our intuitions (e.g. all living things), or might not. Thus, the number of hypotheses to consider is not simply equal to the number of possible object types N, but is instead xN (where x is the number of resolvable response magnitudes). Third, standard brain-mapping methods that search for "blobs" of selective responses in the brain, that is, spatially contiguous regions with a similar functional profile, would miss functionally robust response patterns that are not spatially clustered at the grain of multiple adjacent voxels. Here we present a clustering method that overcomes all three of these problems by searching for functional structure in the ventral visual pathway without assuming either selectivity for single object types or spatial clustering of functional profiles beyond the scale of individual voxels. In positive controls, the method has robustly discovered selectivity for face, places, and bodies, as expected. Importantly, with this method the result was discovered without making any assumptions about spatial clustering of voxels with the same response profile, and without presuming that response profiles should reflect selectivity for a single object class. More ambitious efforts to apply the method to the discovery of new functional structure in the visual pathway are ongoing and will be reported.

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36.417

Subliminal Priming effect of Word and Object on Object Recognition: an ERP Study

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This study addresses the issues of the subliminal priming effects of word and object on the object recognition and their underlying neural correlates. We investigate the priming effect by combining the masked repetition priming technique with the recording of event-related potentials (ERPs). ERPs were recorded to repeated target (R) and unrelated target (UR) pictures of common objects that were immediately preceded by briefly presented pattern- masked prime word or prime object while participants conducted a semantic categorization task. Only the above threshold prime object elicited a P150 effect (at occipital sites) that was suggested to reflect early visual processing. Subliminal object prime elicited a marginally significant P300 while above threshold word prime elicited an N300 effect. Both above and subliminal word prime, and above threshold object prime elicited a widely distributed negativity (N400) that was argued to reflect more general semantic processing. It is suggested that subliminal words were processed to the semantic level but the subliminal objects can only be processed to object specific structural descriptive level. The results differentiate the subliminal priming effects between word and object to different levels of processing. Whether or not, the results were limited to the subliminal repetition priming paradigm will be discussed.

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36.418

Reading pictures

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Identifying an object requires matching it with a name stored in memory, much like looking up a word in a dictionary. We have previously shown that reading can be modeled surprisingly well as serial object recognition, where each word is an object (Pelli & Tillman, 2007). If words are identified like objects, are objects read like words? Here, we create hybrid word-picture narratives, where nouns are replaced by drawings of basic-level objects. We printed these stories on paper and asked subjects to read them silently as fast as they could without skipping any words. We find that, relative to unmodified (all-word) narratives, readers suffer no loss in comprehension when reading these hybrid stories. Most subjects read the hybrid stories slightly more slowly than all-word texts (15% slower on average). Additional tests compared word-only, picture-only, and hybrid sets of the same nouns in random order. Though words were read faster, there was no additional speed loss associated with switching back and forth from words to pictures. This suggests that reading and object recognition are not fundamentally different tasks. Thus, we can read pictures, and reading and object recognition really aren't so different after all.

36.420

The penetration of visual representations by conceptual categories

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Does knowing what an object is change its visual representation? Recent behavioral and neuroimaging work has begun to provide important insights into the effects of conceptual categories on visual processing (Puri & Wojciulik, 2008; Lupyan & Spivey, 2008; Esterman & Yantis, 2008 http://journalofvision.org/8/6/555/) showing that performance on tasks traditionally thought to be purely visual (e.g., visual search and physical identity judgments) can be affected by conceptual factors. For example, Lupyan (Cognition; 2008) reported the existence of conceptual grouping: performance in a visual search task was facilitated through grouping of items from the same conceptual category. Controlling for visual similarity, searching for a target among conceptually homogeneous distractors was faster than among conceptually heterogeneous distractors. Rather than resulting from long-term perceptual warping (e.g.,. Goldstone, 1998), the conceptual grouping effect appeared to emerge on-line.

Here, we report a series of experiments that (1) provide the strongest evidence yet for an on-line effect of categories on visual processing and (2) outline a robust methodology for studying such effects.

Participants were required to respond "same" to pairs of identical pictures and "different" to pairs of different pictures. On "different" trials, the stimuli could either be in the same conceptual category (e.g., two different chairs: C+ trials) or in different conceptual categories (e.g., a chair and a lamp: C- trials). Importantly, on some trials the two pictures appeared simultaneously while on others the second picture appeared after a delay. The two pictures were always visible when the response was made.

When visual similarity between/within categories was controlled, C+ responding was slower than C- responding only at SOAs>0. Thus, category membership automatically affects visual judgments but the effect takes time to emerge.

Subsequent experiments showed that such effects are modulated by item typicality. Category information affects RTs for typical items but not atypical items.

36.421

EEG signals of rapid visual categorization in monkeys, in V4 area

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Recent experiments showed that macaque monkeys are able to perform accurately visual categorization of natural scenes with extremely fast saccadic reaction times, from 100ms (Girard, Jouffrais & Kirchner, 2008). Considering this time constraint and the neuronal response latencies in the inferotemporal cortex, it is hypothesized that mid-complexity visual cortical regions like V4 area could play a crucial role in the extraction of visual cues that could be sufficient for task performance. We recorded intracranial EEG on two head-free monkeys during natural scenes categorization, in which they had to respond by a button release and a screen touch to the presence of an animal in gray-scaled pictures flashed for 50ms. Corticograms were recorded using several electrodes placed in the neighborhood of V4 area; electrode locations were assessed using X-ray and MRI scans. Results showed that event-related potentials on correct trials (ERPs) recorded on V4 area exhibited significant higher amplitudes in response to target stimuli from 80ms after stimulus onset, during a regional recruitment that picked at 96ms. No effect of picture familiarity was observed at these latencies. At low stimulus contrasts, the differential activity between target and distractor ERPs remained of equal amplitude but was slightly delayed. Further experiments showed that this differential activity and its latency were robust to spectral amplitude equalization of the stimuli. These results likely indicate that feature shape could be the main visual cue supporting these fast visual processes. We conclude that relatively simple shape analyses performed by mid-complexity visual areas could be sufficient to perform rapidly object categorization in natural scenes.

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36.422

Cortical Dynamics of Invariant Category Learning and Recognition of Realistic Objects

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Learning in the ventral cortical stream leads to recognition categories that tend to be increasingly independent of object size and position at higher cortical levels. The anterior inferotemporal cortex (ITa) exhibits such invariance, which helps to prevent a combinatorial explosion in memory of object representations at every size and position. Zoccolan, Kouth, Poggio, & Dicarlo (2007, Journal of Neuroscience) showed that ITa cells demonstrate a tradeoff between object selectivity and position tolerance. A neural model is presented of how perceptual and attentive learned categorization processes in the visual cortex together generate robust quantitative simulations of these data using a combination of well-known cortical mechanisms. The model was tested using the same training and testing procedure as in Zoccolan et al. (2007) and the same realistic natural stimuli from the Cal Tech 101 dataset. The Zoccolan et al. (2007) data and our simulations thereof are contrary to recent models of IT (e.g. Riesenhuber & Poggio, 2000, Nature Neuroscience; Wallis & Rolls, 1997, Progress in Neurobiology), which propose that ITa cells have object selective and position tolerant response

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profiles. The current model clarifies how the Zoccolan et al. tradeoff found in ITa cells may be the natural result of basic mechanisms of the ventral cortical stream.

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36.423

Quantifying the Role of Context in Visual Object Recognition

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Most studies of the role of context in object recognition have focused on conditions in which the target object is fully identifiable when viewed in isolation, and the role of context is in 'facilitating' the recognition process. The current study was aimed at identifying and quantifying the role of context in performing recognition of ambiguous stimuli; objects that cannot be identified successfully on the basis of their local properties alone. Subjects had to identify 'mosaic' photographs of objects—images divided up into grids of equally sized, square checks composed of the average values of the constituent image pixels. The number of checks making up each image—i.e. the 'resolution'— was manipulated for each object (starting with fewer, large checks and progressing to more, smaller checks) and was taken as a measurement of the information in that particular object image. We compared the amount of image information needed to perform accurate identification of the 'mosaic' object images with and without context. In the context conditions, the object image was shown within a larger scene (unlike the target object, the scene image was unaltered) while in the no-context conditions the mosaic object was shown in isolation. There were two context conditions: 'Generic Context'—in which the stimulus photograph consisted of an unfamiliar environment whose category was identifiable (e.g. 'a kitchen') and 'Expert Context'—in which the stimulus photograph consisted of an environment highly familiar to the subject (e.g. his or her own kitchen). The average reduction in image information needed to perform the task in the different contextual conditions, relative to the no-context condition, was calculated as an estimate of the 'top-down' information available from the context.

36.424

Experience can determine category selectivity in the visual system

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Category selectivity in the visual system is frequently observed with fMRI, either as local or distributed patterns of activity for specific object categories like faces, tools, body parts, or letters. Experience can modify activity in object processing areas, as demonstrated by the engagement of face-selective areas after subordinate-level individuation training with novel objects. However, the specific role of experience per se in determining any given pattern of category selectivity is weak because little empirical work has been concerned with measuring the neural changes resulting from different types of experience. Here, we trained two groups of participants in two different learning regimens that required either subordinate-level individuation or basic-level categorization of a set of novel objects (Ziggerins). Individuation training involved learning to categorize the Ziggerins at a subordinate level quickly, similar to how people discriminate faces during person identification. Categorization training involved learning to rapidly recognize at the basic level Ziggerins that were presented in spatially organized arrays with coherent styles, similar to how people process letters when reading a text. The two regimens resulted in different patterns of changes in fMRI responses. Local activity in the fusiform gyrus increased after individuation training and was correlated with the magnitude of configural processing for Ziggerins measured behaviorally. In contrast, categorization training caused more distributed changes, with increased recruitment of the medial portion of the ventral occipito-temporal cortex relative to more lateral areas. These results demonstrate that objects with the same geometry can be processed in qualitatively different ways (e.g., focal vs. distributed patterns of specialization) because of the different recognition demands of the different training regimens using the same set of objects. We suggest that the role of prior experience in determining responses in the visual system may have been underestimated because training experience is rarely manipulated explicitly in other studies.

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36.425

Learned Reorganization of Invariant Object Category Selectivity in Inferotemporal Cortex during Eye Movement Search

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It has been a long-standing puzzle how brains achieve invariant object learning and recognition in both the biological and computational research communities. Invariant object recognition is computationally challenging, since any individual object can produce a huge number of different views due to variations in object position, scale, pose, and illumination. How does brain solve this problem effortlessly? Li & DiCarlo (2008, Science) have shown how unsupervised natural experience rapidly alters invariant object representations in the inferior temporal cortex. They did this exploiting the fact that, during natural visual experience, objects tend to remain present while object or viewer motion changes their retinal image. In their study, two objects consistently swapped identity across temporally continuous changes in retinal position. A neural model is proposed that quantitatively simulates the Li & DiCarlo data as an expression of how spatial and object attention interact with invariant category learning processes during eye movement search of a scene. This model builds on the recent ARTSCAN model of this process (Fazl, Grossberg, & Mingolla, 2008, Cognitive Psychology), which also simulated reaction time data showing an object advantage during spatial attention shifts (Egly, Driver, & Rafal, 1994, JEP: General; Brown & Denney, 2007, Perception & Psychophysics). The current work clarifies and refines the predicted role of form-fitting spatial attentional shrouds (Tyler & Kontsevich, 1995, Perception) and related mechanisms that regulate persistence of object representations across eye movements during view-invariant object learning.

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36.426

Processing two visual categories at once: "OR" is easy, but "AND" takes time

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Rapid categorization of natural scenes is often thought to involve high-level presetting of the visual system for diagnostic features. But real world situations often require extracting and processing specific physical features of multiple objects often belonging to different superordinate categories. Is the human visual system able to perform parallel object categorization, or does it use serial processing? Extracting feature conjunctions has generally been studied within single objects. Here we tested the ability of the visual system to detect in parallel everyday objects spatially distributed within photographs and belonging to different categories.

Human subjects performed a go/no-go visual categorization of natural scenes flashed for 26 ms. In a series of four successive tasks, subjects had to respond manually as fast and accurately as possible to the presence of (1) an animal, (2) a vehicle, (3) an animal AND a vehicle, (4) an animal OR a vehicle (not exclusive). Distractor stimuli were also complex natural scenes containing other object categories and, according to the task, animals or vehicles.

Accuracy (% correct) and reaction times analysis were performed on photographs that contained both an animal and a vehicle because they are seen as target in all tasks. Performance in single animal/vehicle categorization tasks was similar (79/80% correct; median RT: 452/477ms). The "OR" task was performed with a higher accuracy (90%) at no temporal cost implying that the visual system can indeed pre-activate and detect in parallel multiple features diagnostic to different object categories. In contrast, longer reaction times were observed in the "AND" task (523ms) with no accuracy cost, suggesting the need for additional decision processing possibly involving "visual search-like" serial mechanisms.

Additional interference effects between animal and vehicle processing considering their respective sizes and location in depth are also discussed within a neuronal competition framework.

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36.427

Visually evoked EEG activity differentiates individuals during a perceptual categorization task but preparatory or late activity does not

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Introduction: There is a growing interest in differences in patterns of brain activity across individuals and their relation to cognitive strategies/performance (e.g., Mckay et al., 2003; Vogel et al. 2004). Here, we use multivariate pattern classifiers to quantitatively analyze individual differences in brain activity (electroencephalography, EEG) during a perceptual categorization task (Philiastides et al., 2006). We sought to compare the discriminant information across observers in preparatory, visually evoked and late-post stimulus temporal epochs of the EEG activity. Method: Twenty naive observers perceptually categorized briefly (40 ms) presented images of cars and faces embedded in filtered noise while their EEG activity was recorded from 64 electrodes. Each observer participated in 1000 trials and indicated their decision using a confidence rating. Results: Classifier performance (area under the ROC) identifying an individual from single trial EEG activity during pre-stimulus time intervals (preparatory) was close to chance (7.13%; chance = 5%) but then systematically increased to 65.21% during the time-interval of 200-250 ms post-stimulus presentation (visually evoked epoch). Classifier accuracy then monotonically decreased for late post stimulus intervals (>=250 ms). The temporally localized nature of the neural activity differentiating individuals stands in contrast to the neural activity differentiating face vs. car trials which has a similar onset (120-200 ms) but persists until 500 ms post-stimulus. Conclusion: Our findings suggest that the primary source of individual differences in EEG activity during a perceptual categorization task is restricted to visually evoked neural activity.

36.428

Influences of Contextual Information on Rapid Object Categorization in Natural Scenes

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Human visual system is very fast and efficient at extracting information about objects present in complex natural scenes. For example, event-related potential studies have shown that the underlying processing required to decide whether a briefly flashed natural scene contains an animal can be achieved in 150 ms (Thorpe, Fize, & Marlot, 1996). The results implied that a great deal of visual processing must have been completed before this time so that complex processing of visual categorization in natural scenes can be achieved. An interesting question is what makes such rapid object recognition possible. Here we carried out two experiments to investigate whether the contextual information provided by the scene contributes to rapid object categorization. In Experiment 1, participants were asked to view briefly flashed scenes and performed a go/no-go animal/nonanimal categorization task. In Experiment 2, participants performed a two-alternative forced choice task in which they had to decide whether a flashed scene contained an animal or not. In both experiments, we examined the influence of contextual information either by retaining or deleting the original scene background. The results of the two experiments showed that the reaction times were significantly faster for animals appearing with a scene background. The current findings demonstrate that scene context bolsters rapid object categorization in natural scenes.

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Color and Light: Color Apearance

Sunday, May 10, 2:45 – 6:45 pm
Poster Session, Orchid Ballroom

36.430

Color appearance and compensation in the near periphery

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Spectral sensitivity varies markedly between the fovea and near periphery due to cone sampling density changes and the rapid fall off in macular pigment density with eccentricity. Neutral white settings show complete compensation for these sensitivity differences (Beer et al. JOV 2005), while perceived hues have instead been found to vary and have been attributed to a partial compensation for macular pigment along the blue-yellow dimension (BY) of color appearance (Hibino, Vision Research 1992) or to relative losses in signal strength along the red-green dimension (RG) (Parry et al JOSA 2006). We measured both achromatic points and unique and binary hue loci to explore the extent and form of color appearance changes in the periphery. Stimuli were 25 cd/m2 2-deg circles displayed on a black background or an isoluminant gray adapting background equivalent to equal-energy white. The stimuli were shown for 0.5 sec at 4 sec intervals and were viewed directly or at an eccentricity of 8 deg. White settings were measured with a method of adjustment and were similar and thus effectively compensated at the two locations. Hue loci were measured with a 2AFC staircase that adjusted the stimulus angle at a fixed contrast relative to the nominal white. Hue loci differed across location and observers but were not clearly more variable for RG than BY or for unique vs. binary hues. We compare the pattern of these hue changes to the variations predicted from measures of each observer's macular pigment density difference between locations, and also examine the role of the common gray adapting background in normalizing hue settings and how this influences interobserver variations in color perception. These results are important for understanding the ways and extent to which color percepts can be calibrated to reflect consistent properties of the stimulus or are limited by physiological constraints.

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36.431

Transitions from negative to switch color afterimages

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VanHorn and Francis (VSS 2007 & 2008) described a switch color afterimage, where, the colors in an inducing image grating switch positions in the afterimage. For example, a blue and black bar inducer grating produces a black and blue bar grating afterimage. Similar reports of color contrast afterimages have previously been reported (Anstis, Rogers, and Henry, 1978; Ferree & Rand, 1912; King & Wertheimer, 1963; Poppel, 1986; Shively, 1973), but have received little systematic investigation. In this study we varied the number of bars in the inducing grating to observe the transition between negative color afterimages and switch color afterimages. Observers reported perceived colors with a color matching technique. We find that an individual blue bar stimulus and an individual black bar stimulus produce negative afterimages (yellow and white afterimages respectively). As flanking black and blue bars are alternately added to the blue bar stimulus (transitioning it to a blue and black bar grating) the afterimage of the blue bar darkens and is reported as having little to no yellow. As flanking blue and black bars are alternately added to the black bar stimulus (transitioning it to a black and blue bar grating) the afterimage of the black bar is reported as blue. The transition from a negative afterimage to a switch afterimage is almost complete after the addition of one flanking bar on each side of the individual bar stimulus.

Sunday Sessions

36.432

Simultaneous Color Contrast Pulls Out the Color Common to the Background and Test Patch or Bleaches the Test Patch If There Is No Common Color

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As known for centuries, if a small grey test patch is placed on a colored background, the test patch will be perceived as the color complementary to the color of the background—simultaneous color contrast. However, this same color is perceived for test patches if the background is acting upon the test patch by "pulling out" or removing from the test patch the color of the background. Interestingly, if the test patch itself is colored these two possible actions of the background on the test patch no longer produce the same perceived color for the test patch. We present a most compelling display in which the test patch is a long and relatively narrow color "gradient strip" moving from an intense solid color at one end with increasing amounts of white added until the other end is pure white. When this test patch is placed on a background of the same color as the gradient—e.g., a red to pink to white gradient strip on a red background—the entire strip is "bleached" in that the pure color appears whitened and the place at which the strip appears white comes far before where it is perceived as being when the strip is on a white background. There is no evidence in the perception of the test strip for the color complementary to the background. More remarkably, we have found that when a gradient test strip is placed on a background of a different color, the strip is still bleached, and there is still no appearance on the test strip of the color complementary to the background (there is mild uniformspreading or assimilation of the background color onto the test patch). These effects demonstrate there must be some mechanism "removing" color from one area upon contrast with a background area.

36.433

Effect of chromatic surround variance on color appearance in a real environment

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Color distribution largely varies among different indoor environments as well as outdoor. For example, some rooms are decorated with very colorful colors and the others are with black and white. It is not well understood how much these color variation influences to appearances of objects under those environments. It has shown that color appearance depends on chromatic surround variance, known as "Gamut expansion effect" (Brown & Macleod, 1997). They, however, used relatively small patterns on a display. It has not investigated if there is the same effect in an actual room environment. We examined if the apparent saturation of an object was influenced by the saturation of surroundings in a normal environment such as a room with furniture and objects inside.

In the experiment, two miniature rooms with gray and with colorful furniture were placed side by side and used as a reference and a test room, respectively. The colors in the test room were chosen to cover various hues. Observers compared the saturation of a small square patch in the reference and the test room and answered which was more saturated. Patches with various hues, and with low and high chroma were tested.

Our results show that the apparent saturation of patches in the test room is generally lower. This suggests that color appearance is changed slightly by the influence of saturated objects in the room. The effect is almost the same whether the test patch is immediately surrounded by colored background or not, which is consistent with pervious researches showing Gamut expansion effect is not a totally local effect. However, the shift of color appearances is very small, implying that the effect of chromatic surround variance on color appearance may be masked by other visual factors and smaller in an actual environment.

36.434

Reversing the watercolor effect

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In Pinna's watercolor effect, a boundary line is drawn on a white field to enclose a central region. When the line is colored purple on the outside and yellow on the inside, an illusory yellow color wash is propogated throughout the enclosed region, which then appears figure-like. Naïve observers rated the strength of this illusion as a function of the number of frames the boundary line was displayed; pre- and post- frames were a uniform white of the same mean illuminance (80 cd/m2). The illusion grew steadily until 10 frames (100 ms) were presented, after which no further increase was noted. We wonderd whether the illusion developed before, or after, the boundary signal created a figure. The bounding contour colors were reversed. The illusory yellow now spread into the background, not into the interior. The amplitude and time course of the illusion were hardly affected. We speculate that the watercolor illusion develops at a stage of color processing which occurs before that which distinguishes foreground from background.

36.435

SHAME: A new spatial hue angle metric for perceptual image difference

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Recently many different color image difference metrics have been proposed, to quantify visual differences between an original image and a modified version of it; some in the context of overall image quality and some to quantify specific image distortions. However, none of the proposed metrics have been able to demonstrate good and stable performance for various image distortions, that is, the metric values do not correspond well to the actual perceived differences.

A notable image difference metric, S-CIELAB, was defined by Zhang and Wandell (1996) as a spatial extension to the well-known CIE 1976 color difference equation. It introduced a spatial pre-processing in an opponent-color space, to simulate the properties of the human visual system. After filtering, the images are transformed into CIELAB color space, where a conventional CIE 1976 color difference is calculated, pixelwise.

Another recent image difference metric is defined by the hue angle algorithm, proposed by Hong and Luo (2002). This metric, which is about to be recommended in a report by the International Commission on Illumination (CIE), does not take into account the spatial properties of the human visual system, and for this and other reasons, we show that it miscalculates the perceptual difference between an original image and a modified version of it.

Based on this we propose a new color image difference metric, as an extension to the hue angle algorithm, taking into account the spatial properties of the human visual system. We have subjected the proposed metric to extensive testing on various image databases containing different image distortion types. The results show significantly improved performance compared to the metric proposed by Hong and Luo, and also good performance compared to other state of the art image different metrics.

36.436

The situated laptop: a tangible interface for computer-based studies of surface appearance

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In recent years, the study of surface appearance has been greatly facilitated by computer graphics and electronic display technologies that enable experiments in which images of surfaces with complex geometric, reflectance and illumination properties can be rendered and displayed with great fidelity. However, a significant limitation of current methods is that these images are typically presented statically or in pre-calculated motion

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sequences that are passively viewed by experiment observers. Under real-world conditions, to understand surface properties, observers often engage in complex behaviors that involve active manipulation and dynamic viewpoint changes. To support these kinds of interactions, we have developed a novel display system that supports both active manipulation and dynamic viewing of computer graphics simulations. The system is based on an off-the-shelf laptop computer that contains an accelerometer and a webcam as standard components. Through custom software that integrates these devices, we are able to actively sense the 3d orientation of the laptop's display and dynamically track the observer's viewpoint. We use this information to drive a physically-based illumination-map rendering algorithm that generates an accurately oriented and realistically shaded view of a surface to the laptop's display. The user experience is akin to holding a physical surface in one's hands and being able to actively tilt it and observe it from different directions to see the changing patterns and properties of environmental surface reflections. The system provides a powerful research tool that allows anyone with a compatible laptop computer to use more natural modes of interaction in their surface appearance studies.

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36.437

Preferred greyscale versions of coloured images: human vs machine

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Each year millions of greyscale reproductions of colour images are made. The majority of these are produced by removing the chromatic information, which leaves a greyscale made by just the achromatic colour variable. One problem with this approach is how to make a greyscales for images that contain equilumiant edges and/or borders in a way that preserves the image content.

In our experiment we evaluated some of the more recent algorithmic attempts to tackle the colour-to-greyscale problem, and compared the performance of these methods against greyscale images created manually by human observers. We used an image preference experiment where 10 participants carried out pair-wise comparisons of greyscales produced by 5 different mathematical algorithms and 1 human. Overall, we employed 10 different test images with varying amounts of equiluminant detail, and included images with different levels of content complexity (ranging from outdoor scenes to pie charts).

We find that two algorithms significantly outperform the other computational techniques (including luminance), and that these algorithms both attempt to preserve local colour contrast in the greyscale algorithms. Furthermore, we find that neither of these techniques is significantly preferred over human greyscales. Finally, the interactions between images and algorithm are strong, indicating that image content is important in deciding which is the best greyscale version. These results support the motivation for this research area: there are better ways to convert colour to greyscale than simply using luminance and that images created by human observers are comparable to those produced by algorithms.

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36.438

Color difference scaling at the blue-green color category boundary as a test of the Sapir-Whorf Hypothesis

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The effects of color on visual performance have critically tested the Sapir-Whorf Hypothesis that language controls many aspects of cognition, including perception. Kay & Kempton (1984) investigated the salience of small color differences near the boundary between "green" and "blue" English color categories. Here, we examined the perceptual scaling of color differences in this boundary region: Is scaling monotonic at the boundary? Are there visual field differences? If so, effects restricted to the right visual field might suggest a Whorfian effect of language, as proposed by Gilbert et al. (2006).

In the first experiment, we used maximum likelihood difference scaling (MDLS; Maloney and Yang, 2003) to perceptually scale the angular interval (140o - 160o) spanned by isoluminant greens and blues falling on an arc (radius=43 ΔE) in CIELAB. If the blue-to-green boundary produced especially salient color differences, MLDS should reveal them. If the salience were related to language, the differences should be greater in the right visual field. We found neither of these predicted effects. Left and right visual field difference-scaling functions (difference-scale vs. CIELAB color angle) were monotonic and indicated that perceptual differences among "greens" were always significantly greater than differences among "blues". There was usually a clear-cut discontinuity in these functions, indicating a transition between "green" and "blue" color appearance. But there was no violation of monotonicity at the discontinuity.

In a second series of experiments, we examined the transition region more closely by measuring the point of subjective equality (PSE) in color difference between a standard blue-green pair straddling each subject's blue-green boundary and variable-difference same-category color pairs. PSEs were consistent with the MLDS studies, indicating that difference scaling across the blue-green boundary is in no way enhanced relative to same-category differences.

Thus, we find no evidence for the cross-category privilege suggested by the Sapir-Whorf hypothesis.

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36.439

How color might look to others – adapting images to simulate color appearance across different environments

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Basic color categories show strong shared tendencies among linguistic groups, yet the focal stimuli chosen as best examples of these basic colors vary significantly across both individuals and populations. The causes of these differences are not known. We examined the extent to which variations in color appearance could be attributed to variations in the individual's color environment, by modeling how color appearance should change when observers are adapted to different environments. The adaptation was modeled as gain changes in the cones and in multiple post-receptoral channels tuned to different combinations of luminance and chromatic contrast. Channel responses were tabulated for images sampled from different environments and then rescaled so that the average response within each channel was equal across two environments. Shifts in perceived hue were assessed by determining the different stimuli required to produce the same response ratios in the different adaptation states. Rendering images with these adapted responses simulates how the world might appear to the same "observer" when they are under theoretically complete adaptation to different environments, and these effects are illustrated with images of the Munsell palette used in the World Color Survey. Adaptation to different natural color contexts significantly shifts color foci, yet these are primarily confined to changes within rather than between categories. We compare these predicted variations to the population differences actually observed in the World Color Survey, which similarly exhibit primarily within-category shifts in mean foci. Our analysis shows that even observers with a completely shared biology may experience color in significantly different ways because of adaptation to different environments, and provides both a measure of the theoretical extent of environmental influences on color naming and a novel way of simulating how the world might look to others.

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36.440

Representation of color naming category boundaries on dichromats along their confusion loci using a chromatic-opponent channel model

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Protanopia and deuteranopia are color vision types that cause difficulties of discrimination between red and green hue combinations along the specific directions, that are called confusion loci. Nevertheless, Jameson and Hurvich (1978) found that some dichromats used reddish or greenish color terms despite their impoverished red-green hue discrimination ability. Montag and Boynton (1987) investigated dichromats' color naming categories and dichromatic subjects showed color naming categories that are fairly in agreement with trichromats. They predicted the contribution of rods to dichromats' naming ability. In his following study, Montag (1994) suspected the contribution of an anomalous third cone pigment. Bonnardel (2006) used multidimensional scaling (MDS) techniques to analyze dichromatic color naming categories and concluded that categorizations of dichromats depend on learning factors. However, it is still unclear how dichromats perform the trichromatic color naming.In this study, we tested dichromats' color naming categories along their confusion loci that go through the equal energy white point. Subjects named 203 kinds of test stimuli with 11 basic color terms (Berlin and Kay, 1969). Test stimuli were presented as a circular aperture (2 degrees in diameter) on the illuminated background (x,y,L: 0.31, 0.32, 20.82cd/m2). In addition, we represented dichromats' naming category boundaries along outputs of Boynton's color vision model (1979). In the case of protanope, the boundaries were fairly represented by constant M-cone output lines. On the other hand, in the case of deuteranope, it could not be represented by constant L-cone output lines. When we assumed the r-g chromatic-opponent mechanism includes signals from L and Hybrid-cone (Merbs and Nathans, 1992), the constant outputs of the model could represent naming category boundaries of deuteranope. This suggests that the color naming categories of dichromats are reorganized by acquiring color terms and some dichromats rely on the presence of Hybrid-cone pigment to show trichromatic color naming categories.

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36.441

Color Naming Ability in Monochromats and Dichromats

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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 monochromat and dichromat subjects 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: Monochromat (n=4) and dichromat (n=4) subjects with best-corrected visual acuities of 20/100 to 20/600 in both eyes were tested. Color vision deficiencies were detected with Ishihara Color Plates and D-15 color tests. Subjects and controls 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..

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 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 are complementary. These data suggest a good degree of color constancy for our subjects.

36.442

Color constancy in 4- to 5- month old infants

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Previous study studies have demonstrated 4-month-old infants have color constancy. However, these studies did not control the luminance contrasts precisely. To solve this problem, we presented stimuli in which luminance cues are eliminated, and tested the infant's color constancy more precisely.

In the study of color constancy, it is important to exclude the possible luminance artifacts. We first obtained subjective isoluminance in each infant by using the minimum motion paradigm (Maurer, Lewis, Cavanagh & Anstis, 1989), and used these data to control the luminance in the stimuli.

We used a familiarization paradigm in the present study. In the familiarization phase, two identical face-like patterns were presented side by side. They were surrounded by small patches of various colors. Such a Mondrian-like pattern is expected to improve the performance of color constancy. The colors of face-like pattern and patches were simulating OSA color chips, based on spectrophotometric data. In the test phase, the chromaticity of the whole pattern changed to simulate illuminant-color changes, except either of the face-like pattern, which was presented with the same chromaticity as in the familiarization phase. If infants have color constancy, they would attribute it to changes in illumination, and the face-like pattern with chromaticity change may appear as a novel object surface. We controlled the intensity of illuminant to prevent changes in luminance of the two face-like patterns, so that the infants could not use the luminance contrast as a clue to discriminate two face-like patterns. If color constancy is present in infants, they will show a preference to the non-change pattern, which seemed to appear as a novel object surface under a novel illumination.

Current results suggested that the 4-5-month-old infants had a significant preference for the non-change face-like pattern. This result suggests that the 4-5-month-old infants have the color constancy.

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36.443

Surface Discrimination of Natural Objects: When is a Blue Kiwi Off-Colour?

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Natural objects typically possess polychromatic surface textures. In cone-contrast space, the chromaticity distributions of natural objects form distinctive signatures which may enhance colour constancy and object recognition (Hurlbert et al., VSS 2007). Whether the human visual system exploits this information may depend on its ability to discriminate between polychromatic textures, and to integrate colour and texture information. Here we measure the discriminability of chromatic textures in a surface classification task.

Observers performed a 2AFC task, answering 'yes' or 'no' to: 'Do the two patches arise from the same object's surface?' Images of natural objects were obtained using a tristimulus-calibrated digital camera system under

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controlled illumination. Reference surface patches were taken from different locations on single objects. Alternative patches were created by rotating the reference chromaticity distribution from its starting angle in cone-contrast space around the origin, maintaining luminance values and the overall shape of the distribution. Two starting angles were used for each reference surface patch: 'normal' (the mean angle of the natural object texture) and 'abnormal' (rotated significantly away from 'normal'). Stimuli were displayed on a calibrated CRT monitor.

Discrimination thresholds vary across objects but are generally below that necessary to detect changes in the chromaticity distribution caused by illumination changes. ANOVA revealed significant main effects of 'normality' and chromaticity distribution size, as well as significant interaction effects between 'normality' and starting angle in cone-contrast space, as follows. Discrimination thresholds were significantly higher for 'abnormal' starting angles; e.g. discriminating between 'blue' kiwis is harder than for natural 'green' kiwis. Thresholds were higher for smaller distribution ranges. For 'normal' starting angles only, thresholds varied systematically with angle, being lowest for 'yellowish' hues.

The results suggest that texture is linked to colour in object representation, and that the human visual system is able to exploit polychromaticity of familiar objects in recognition tasks.

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36.444

Categorization of surface colors during natural twilight: A field study

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Twilight presents a challenging visual environment for the perception of surface color. Color signals are highly variable during this semidiurnal transition between photopic and scotopic vision. This variability stems from rapidly changing light level, shifts in spectral illumination, and changes in sensory processing due to rod involvement. Research on surface color perception at low light levels is typically conducted in a laboratory setting that simulates twilight illumination but does not duplicate it (e.g., Middleton & Mayo, 1952; Porkorny, Lutze, Cao, & Zele, 2006). The present study investigates surface color perception under natural illumination in the absence of anthropogenic light sources. Observers used eleven basic color terms (Boynton & Olson, 1987) to categorize the color of spectrally calibrated Munsell color chips that were representative of the Munsell color space. The color chips, selected from three constant lightness planes (V4, V6, V8), were presented in randomly ordered arrays. Judgments were made in the spring and summer months under clear skies at specified time intervals during civil and early nautical twilight. For the majority of the chips, surface color was perceived over the duration of civil twilight for all lightness planes and light levels. Two general shifts in color categorization were observed as light level decreased: 1) the number of chips categorized as red, brown, and gray increased, and 2) the number of chips categorized as blue, green, yellow, purple, pink, and orange decreased. These shifts occurred for all lightness planes and are not accounted for by changes in spectral illumination. Rapid loss of surface color began at nautical twilight making reliable color judgments impossible. Although color categorization shifted, most surface colors could still be categorized into one of the eleven basic colors during civil twilight. This finding suggests that surface color perception is maintained at low light levels in a natural environment.

36.445

Categorical color constancy for rendered and real surfaces

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Color constancy supports object recognition by allowing the identification of a particular surface independently of illumination. We studied the stability of the color appearance of rendered and real Munsell surfaces under changing illumination with a color naming method. In the first experiment, subjects named the colors of surfaces rendered under different artificial illuminants and displayed on a CRT monitor embedded in a lighting chamber. In the full-field viewing condition, the monitor background and the surrounding walls had the chromaticity of the illuminant. In the reduced cue viewing condition, the monitor background was set to black to remove local contrast between the stimulus and the illuminant. In the second experiment, subjects named the colors of real Munsell chips placed on a gray cloth in a room illuminated by natural or filtered daylight. In the reduced cue viewing condition, the cloth under the chips was changed to black. Color constancy was quantified as the consistency of color naming across illuminants within each observer. We also analyzed naming consistency between observers for any given illuminant by counting the occurrence of same color names across observers.

Naming consistency for real surfaces was overall better and less affected by manipulations of illuminant cues than consistency for rendered surfaces. However, the pattern of naming consistency over stimulus hue, saturation and lightness was very similar for both stimulus types. Consistency was highest around most of the prototypical hues and increased with stimulus saturation. Naming consistency across observers followed the same pattern, indicating that observers might be more likely to agree on colors that remain perceptually more constant under illuminant changes.

We conclude that measurements with real and rendered stimuli under natural and artificial illuminants, respectively, give qualitatively similar results: categorical color constancy is not uniform across color space, but generally reaches its maxima around prototypical hues.

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36.446

Working Memory Predicts Individual Differences In Color Constancy

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The influence of cognitive processes on low-level perception is a classical question. This study tested whether individual differences in working memory (the ability to hold information in mind during distraction) are related to differences in color memory and/or color constancy. High- and low-working-memory participants were identified using the Aospan and Arspan tasks (Unsworth, Heitz, Schrock, & Engle, 2005). Participants studied a test color for one minute for later recall (paradigm modeled after Jin & Shevell, 1996). In the uniform background condition, the test color was surrounded by a uniform achromatic background that reflected all wavelengths nonselectively; in the complex background condition, the achromatic background had eight different colored sectors embedded within it. The two conditions manipulated context: a complex background typically improves color constancy. During study, each participant saw the simulated (CRT) display under one illuminant (A or C). After study, participants generated random numbers for two minutes (long-delay condition) or ten seconds (short-delay condition) in the dark, to prevent rehearsal of the test color while taxing working memory. A second display was then presented that had either the same illuminant used during study or the other illuminant. Participants adjusted the color of a test patch to appear like the color they had studied (a memory match). The paradigm allowed measurement of both color memory (no illuminant change between study and test) and color constancy (illuminant change between study and test). No significant difference was found for high- and low-working-memory participants for color memory, which depended on only remembering the test stimulus chromaticity. Better color constancy, however, was found for high- than low-working-memory participants in the long-delay condition. This suggests that working memory is involved in the development and/or delayed recall of a color-constant neural representation, but not in simple color memory for a chromaticity always viewed under the same illuminant.

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36.447

Memory colours of polychromatic objects

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Memory colours of familiar objects may assist in colour constancy and object recognition, as suggested by Hering (1874). Natural objects are polychromatic (Hurlbert et. al., VSS 2007); therefore memory colours may be intrinsically variable, influencing their role in constancy. Here we study the effect of shape and natural chromatic texture on the accuracy and variability of memory colours for natural objects.

We use a novel set-up that allows us to manipulate the non-uniform surface reflectance properties of solid objects under controlled illumination. Using a tristimulus-calibrated camera, we obtain images of real fruits and vegetables under characterized illuminations, eliminating shading and highlights. We morph the flattened tristimulus image to fit the visible surface of matching solid objects (painted white), maintaining the geometry, surface chromaticity and luminance values of the real objects.

Under controlled adaptation conditions, observers freely viewed individual objects. Their task was to adjust the 'colour' of the object until it appeared 'natural' for the depicted or stated object, using a joystick. We varied object shape (2D filled natural outline, 3D natural shape, or generic rhomboid shape (2D or 3D)), chromatic texture (natural polychromatic texture or single uniform chromaticity), and illumination. In adjusting the 'colour', observers freely rotated the mean angle of the chromaticity distribution (polychromatic textures) or the single chromaticity (chosen as the mean or maximally saturated of the natural distribution).

The mean accuracy memory colour tends to be higher, and the error range is significantly smaller, for surface colours attached to their natural 3D shapes, in comparison with other shape conditions, for both polychromatic and uniform conditions. Polychromaticity (vs. uniform chromaticity) improves accuracy for natural 3D shapes, but the effect depends on object type and illumination. We conclude that memory colour is linked to shape in object representation, and that polychromaticity does not influence its variability.

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36.448

Preference for Color-pairs within Finely Sampled Color Space

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In previous research we found that preference for color pairs increased as a function of color similarity (Schloss & Palmer, VSS07). The 37 colors we used were, however, only coarsely sampled within color space: 8 hues (red, orange, yellow, chartreuse, green, cyan, blue and purple) x 4 brightness/saturation levels (saturated, light, muted and dark) plus five grays. In this experiment, we tested whether preferences for color pairs remained monotonic when sampled more finely between the colors previously examined. Four equally spaced colors were interpolated between (a) adjacent saturated hues (hue change), (b) saturated and muted colors of the same hue (saturation change), (c) light and muted colors of the same hue (lightness change), and (d) muted and dark colors of the same hue (darkness change). We used checkerboard displays rather than figure-ground pairs with a central square on a larger ground square to avoid potential artifacts due to relative depth. Half of the displays contained narrow gaps between the squares of the checkerboard and half did not. If preference were simply a function of color similarity, then there should be a monotonic increase in preference as color similarity increased. This was not the case: preference increased as similarity in saturation and lightness decreased ($p < .001$), and it was not significantly affected by similarity in hue ($p > .05$). In addition, checkerboards with differences in lightness/darkness were always more preferred than those with differences in hue or saturation ($p < .001$), regardless color similarity. These findings support the hypothesis that very similar colors "clash" more than less similar colors within a finely sampled color space, especially for differences in saturation and lightness. Further experiments will examine the relation between color discriminability and color preference.

URL: http://socrates.berkeley.edu/~plab/color.html

36.449

Preference for Three-Color Combinations in Varying Proportions

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Previous research on preference for color combinations investigated pairs of colors (Schloss & Palmer, VSS-07; Ou & Luo, 2006). The current project investigated preference for combinations of three colors in varying proportions. The full set of 37 colors included eight hues (red, orange, yellow, chartreuse, green, cyan, blue and purple) at four saturation/lightness cuts through color space (high-saturation, medium-saturation, light, and dark), as well as five grays. In Experiment 1, displays were 45º-rotated checkerboards whose two colors were always adjacent high-saturation hues. When a third color of any of the remaining six hues was present, it formed squares of three different sizes (large, medium, small) at the intersections of the checkerboard. There were also control displays with no checkerboard. Observers rated their preferences for each display. Later they also rated their preferences for the individual colors in isolation. The results showed that displays containing no third color were most preferred, and preference decreased as the area of the third color increased ($p < .05$). When the third color was present, the display was most preferred when the third color was closest in hue to the other two colors, consistent with prior studies of color harmony (Schloss & Palmer, VSS-07). A regression model accounted for 62% of the variance with the following predictors: size of the third color square, average preference for the two individual checkerboard colors, distance in hue between the third color and the checkerboard colors, and redness/greenness of the checkerboard colors. Further experiments examined cases in which adding the third color increased the harmony of the two-color combination, and in which combinations of colors in other cuts of the color space were investigated.

URL: http://socrates.berkeley.edu/~plab/color.html

36.450

The Role of Spatial Composition in Preference for Color Pairs

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In this project we investigated the role of spatial composition in preference for color pairs. Our 37 colors included: 8 hues (red, orange, yellow, chartreuse, green, cyan, blue, purple) x 4 brightness/saturation levels (saturated, desaturated, light, dark) plus five grays. In the first experiment, displays contained two figure-ground pairs (small square on larger squares), side-by-side. Both pairs contained the same two colors in opposite spatial locations (e.g., yellow figure on blue ground and blue figure on yellow ground). Participants were asked whether they preferred the left, right or neither pair. A regression model showed that 32% of the variance was explainable by difference in preference for figure and ground colors when rated in isolation: pairs in which the ground color was more preferred than the figure color were more preferred overall. An additional 33% of the variance, however, was explainable by yellowness/blueness and lightness darkness: pairs with yellower, lighter figures and bluer, darker grounds were more preferred. In the second experiment we tested whether relative area, surroundedness or shared perimeter size influenced how spatial composition affected pair preference. In figure-ground displays we varied the area (and perimeter) of the figure; in bipartite displays we varied the relative size of the left and right regions; and in "plus sign" displays we varied the perimeter of the figure and held area constant. Results show that relative area was the most important factor influencing preference. For both figure-ground displays participants preferred color combinations in which the smaller region was yellower and the larger region was bluer. This was also true for bipartite displays, showing that surroundedness was not an important factor. Changes in perimeter when area was held constant had no effect on preference.

Acknowledgement: NSF grant BCS-0745820, Google

URL: http://socrates.berkeley.edu/~plab/color.html

36.451

Cross-Cultural Differences in Color Preference: Japan vs. the USA

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We studied cross-cultural color preferences for the 37 colors of the Berkeley Color Project: 8 hues (unique-red, orange, unique-yellow, chartreuse, unique-green, cyan, unique-blue, and purple) x 4 brightness/saturation levels (saturated, desaturation, light, and dark) plus five grays. Forty observers in Tokyo, Japan, and 48 observers in Berkeley, USA, rated aesthetic responses to all 37 colors using a line-mark ratings scale. The hue preference functions (averaged over brightness/saturation levels) were very similar for Japanese and American observers, with a broad peak around blue and a trough around yellow-chartreuse. Reliable differences were present in preferences for brightness/saturation levels, however. In particular, Japanese observers had a greater relative preference for light colors, rating light colors higher than Americans did and rating dark colors lower than Americans did. Japanese observers also liked desaturated (muted) colors less than American observers for warm colors (chartreuse, yellow, orange, red, and purple) but not for cool colors (green, cyan, and blue). Some gender effects were similar in the two cultures, but others were different. Males in both cultures tended to prefer saturated colors more than females, whereas females in both cultures tended to prefer desaturated colors more than males. Japanese females also preferred relatively lighter colors more than Japanese males, rating light colors more highly and dark colors less highly than their male counterparts. No similar interaction was present in the American observers, however. A colorimetric model based on yellowness/blueness, saturation, and brightness/darkness explained 79% of the Japanese group variance, versus 60% for the American data. An ecological-valence model, based on the assumption that people like colors that remind them of positive things (sky, trees) and dislike colors that remind them of negative things (vomit, feces), will also be fit to the data to determine whether the cultural differences we found can be predicted by this model.

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36.452

The Relationship between Color and Form in Judgments of Preference and Harmony

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In this study we investigated how the shapes and colors of lines influenced both preference and harmony ratings. We used two types of lines, irregularly jagged and smoothly curved, which were each presented in isolation as well as in side-by-side pairs: both jagged, both curved, and jagged + curved. Colors included eight saturated hues (unique-red, orange, unique-yellow, chartreuse, unique-green, cyan, unique-blue, and purple). Single lines appeared in each of the eight colors. Pairs of lines appeared in one of three color relationships: same hue (identity), adjacent hues (analogous), or opposite hues (complementary). Preference ratings were later obtained from the same participants for the eight individual colors presented as squares in isolation. Harmony ratings were strongly influenced by both line type and color relationship. Single curved lines were judged more harmonious than single jagged lines, curved pairs were more harmonious than jagged pairs, and pairs with different lines types were judged least harmonious. For all line pair types, harmony ratings increased as a function of hue similarity, consistent with Schloss and Palmer's (VSS-07) findings that color harmony is largely driven by hue similarity. In contrast, average preference ratings were only affected by line type: curved single lines were preferred to jagged single lines, and pairs containing same-shaped lines (both curved or both jagged) were preferred to pairs that contained one line of each type. A regression model predicted 55% of the variance in preference ratings with two predictors: harmony ratings of the corresponding displays and average preference for the line colors in the display.

Acknowledgement: NSF grant BCS-0745820, Google

URL: http://socrates.berkeley.edu/~plab/color.html

36.453

Color Harmony Increases the Capacity of Visual Short Term Memory

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Do color relations influence the ease and pleasure with which colors combine in mind? For almost two centuries, the hypothesis of color harmony has been supported by systematic explorations of subjective color pleasure (e.g., Chevreul, 1839/1991). Here, we replicate subjective pleasure while introducing methods for examining the consequences of color harmony for an objective measure of mind — the ease of holding colors in visual short term memory (VSTM).

We used the standard change detection method to measure capacity for holding colors in VSTM. Patterns of 9 to 15 contiguous color squares were presented to observers to hold in memory for 1 sec and compare against a same or different (one changed color square) test pattern. Pattern colors were randomly selected from palettes of 4 colors; harmony was defined as same or similar hue category within palette. Harmonious color palettes were much more pleasant than the disharmonious palettes, as confirmed by observer ratings.

In two experiments with differing sets of colors, VSTM accuracy was reliably higher for harmonious patterns than for disharmonious patterns. Estimated capacities, in terms of number of color squares, were reliably higher with harmonious palettes. Furthermore, as pattern size increased (increasing the load on memory), the advantage for harmony increased. The results indicate that color harmony increases both subjective pleasure and objective capacity for holding colors in mind.

Controls. Actual color changes were the same between harmony conditions. The harmony advantage cannot be explained by luminance heterogeneity because harmonious and disharmonious were similar on that in Experiment 1. Number of color categories per palette was equated in Experiment 2. In a separate experiment, harmonious contexts interfered somewhat with discriminating the critical color changes, consistent with the conclusion that harmony influences memory capacity rather than color discrimination.

M.E. Chevreul (1839/1991). Harmony and contrast.

URL: http://shell.cas.usf.edu/~sanocki/publicationspage.html

Motion: Depth and Optic Flow

Sunday, May 10, 2:45 – 6:45 pm
Poster Session, Vista Ballroom

36.501

Selective adaptation of 3D motion mechanisms

Thaddeus B. Czuba[1] (thad@mail.utexas.edu), Kyle R. Guillet[2], Lawrence K. Cormack[1], Alexander C. Huk[2], Bas Rokers[2]; [1]Psychology, Center for Perceptual Systems, The University of Texas at Austin, [2]Neurobiology, Center for Perceptual Systems, The University of Texas at Austin

Motion aftereffects are generally considered evidence for cell populations tuned to specific directions of motion. Despite some early reports, there is scant recent physiological or psychophysical evidence for neurons in visual cortex selective for the direction of motion through depth (i.e., tuned to 3D motion). By comparing adaptation under dichoptic and monocular conditions, we found large 3D motion aftereffects that could not be explained by a simple combination of monocular aftereffects.

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Subjects viewed random dot stereograms containing corresponding dots moving in opposite horizontal directions in the two eyes, thus producing 3D motion percepts. Following adaptation to this 3D motion (30 sec, towards or away), subjects performed a series of direction discrimination trials composed of a 3 sec top-up adaptation and 0.5 sec test stimulus. On each trial, the test stimulus contained a variable proportion of signal dots moving through depth, and the remainder of the dots followed random walks through depth (i.e. motion coherence was varied, akin to many 2D motion studies). On each trial, subjects reported the perceived global motion direction (towards or away).

We observed a very strong 3D motion aftereffect. Prolonged viewing of unidirectional 3D motion biased subsequent percepts of noisy 3D motion displays in the direction opposite adaptation. The contribution of 2D monocular adaptation was dissociated by measuring monocular aftereffects after identical 3D adaptation. Surprisingly, these aftereffects were much weaker (~4x) than the corresponding binocular aftereffects. This suggests that the effects of adapting to 3D motion cannot simply be accounted for by the summation of monocular 2D aftereffects; mechanisms tuned to 3D motion must be involved.

These results provide clear evidence for the existence of cell populations tuned to 3D direction, and suggest that 3D motion aftereffects (e.g. Sakano et al., 2005) can be used to further characterize these mechanisms.

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36.502

Slant stereomotion: A new kind of depth motion from modulation of interocular spatial frequency difference

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When observers view vertical gratings drifting in the opposite directions in the two eyes, they report a percept of whole-field cyclic motion in depth that is attributable to either the local disparity change (LDC) or local interocular velocity difference (LIOVD) cues as the bars drift past each other. Tyler & Sutter (1979) showed that, at velocities where the stereomotion from LDC/LIOVD fails completely due to motion rivalry, introduction of an interocular spatial-frequency difference still supports disparity slant percepts. We modify this paradigm in two ways to show that whole-field depth motion is not supported by either the LDC or LIOVD cue under binocular orientation rivalry conditions and to reveal the existence of a new kind of depth motion from the rivalrous slant conditions.

Experiment 1. Vertical sinusoidal gratings in a circular 5° aperture were drifted in opposite horizontal directions in the two eyes to determine the optimal velocity for perceiving cyclic depth motion from LDC/LIOVD cues.

Experiment 2. Introducing an interocular orientation difference of ± 45° (and increasing spatial frequency by Ö2) provided a condition of continuous orientation rivalry. Although both the LDC and LIOVD cues remained the same along any one horizontal line, cyclic depth motion was no longer perceived, implying that the interocular orientation difference blocked the ability to process either cue to depth motion.

Experiment 3. Implementing temporal modulation of the interocular spatial-frequency difference, under the orientation rivalry conditions, generated strong percepts of slant stereomotion around a vertical axis despite the blocked ability to process LDC or LIOVD cues.

The results establish the existence of slant stereomotion and imply that the processing mechanism of this new kind of depth motion is separate from that for whole-field stereomotion based on either LDC or LIOVD cues.

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36.503

Comparing Binocular, Biocular and Monocular Cues for Time-To-Contact

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Judgements of time-to-contact (TTC) have been shown to be influenced by both monocular cues, such as looming, and binocular cues, such as changing disparity (Gray & Regan, 1998, Vision Research, 38: 499-512). We investigated the contribution of binocular motion information when presented in conjunction with monocular motion cues in a TTC task. We compared TTC judgements in three conditions, a) combined cue - consistent looming and changing disparity, b) monocular - looming showed to one eye only, c) biocular - both eyes presented with a looming stimulus but no change in disparity. Observers were shown a circular patch of dots which appeared to move directly toward them for 588ms at a constant speed, simulating one of three TTCs (1.8s, 2.5s or 3.2s). The stimulus was then replaced with a blank screen for a variable interval before the screen flashed. Observers were asked whether the stimulus would have contacted them before or after the flash, had it continued in its trajectory. This data was used to determine whether observers could perform a TTC judgement in the present task. Analysis suggested that four of eight observers' responses did not in fact reflect TTC judgements, but were based on other stimulus parameters. For those who based their responses on TTC information, we derived approximations of TTC estimates for each condition. Three of these four observers gave more accurate TTC estimates under the combined cue condition than monocular and biocular. No observer's responses differed between monocular and biocular conditions, suggesting that judgements in these conditions were based on monocular information only. The results lead us to conclude that under present conditions, binocular cues can aid TTC estimation when present and consistent with monocular cues, but no influence occurs when binocular information indicating zero motion is presented alongside monocular motion cues.

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36.504

Discriminating curved from straight motion trajectories in 3D scenes

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Our previous research (VSS, 2008) found that observers use available velocity information when judging the trajectory of moving objects and making decisions about the relative curvature of an object's path. The present study examined whether the presence of a ground plane affects how projected velocity and size change information are used in judging the motion trajectory of an object. Observers were asked to discriminate between straight and curved motion paths of a ball. Half of the observers viewed the ball moving through a 3D scene, while the other half viewed the identical motion against a blank background of similar color and luminance. The motion path of the ball was either straight or arced upward at one of three different levels of curvature as it moved toward the observer's point of view. The curvature was indicated by the size change function only, by the velocity function only or by both types of information. The projected path of the ball was identical in all conditions. Observers were able to discriminate curved from straight trajectories more accurately from the velocity change information alone than from size change information alone. Performance using only size change information was near chance for all conditions. Accuracy was similar for velocity information alone and combined size and velocity information. When velocity information was available, observers performed more accurately with the ball moving against a background scene with a ground plane than with the ball moving against a blank background. These results indicate (1) that variations in projected velocity indicating path curvature are more important than variations in projected size in discriminating between straight and curved trajectories and (2) that a background including a ground plane increases the accuracy of curvature discrimination.

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URL: http://www.cogsci.uci.edu/~mlbrauns/lab/

36.505

Measuring azimuth and elevation of binocular 3D motion direction

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The vast majority of studies on motion in depth perception used horizontally moving dots as stimuli. Here we measure perceived azimuth and elevation angle of an oriented line moving in 3D. Although motion direction of an oriented line is highly ambiguous three observers gave similar and reliable estimates of 3D motion direction.

In two experiments we presented moving line stimuli to the left and right eye on calibrated flat CRT monitors with a refresh rate of 120 Hz in a two-screen Wheatstone configuration. On each trial observers verged on a fixation cross flanked by nonius lines at a viewing distance of 55 cm. An oriented line travelled back and forth on a 3D trajectory inside a circular aperture. Line orientation (±45 and 90 deg) and orientation disparity (-6 to +6 deg) was independently varied in randomly intermixed trials. In each open-loop trial the observer repeatedly viewed the line moving in depth before a string of dots was superimposed inside the aperture. The observer adjusted orientation and horizontal disparities of the string of dots until they matched perceived 3D motion direction of the oriented line.

The results indicate systematic effects of 3D line orientation on perceived azimuth and elevation angle. We discuss whether our findings are compatible with intrinsic/extrinsic borders and predictions from generalized motion-in-depth models (Lages & Heron, VSS 2009).

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36.506

Testing generalized models of binocular 3D motion perception

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When an oriented line moves in depth inside a circular aperture motion direction of this line is highly ambiguous. From a computational point of view both motion and stereo correspondence is under-determined yet somehow the visual system solves the inverse problem. Although observers reliably report azimuth and elevation angle of 3D motion direction (Heron & Lages, VSS 2009) existing models can only predict azimuth of horizontal motion in depth and face computational problems when trying to explain non-horizontal motion in depth.

The interocular velocity difference (IOVD) model detects local motion vectors in the left and right eye before it computes motion direction. It is shown that a standard IOVD model offers no general solution to the inverse problem of an oriented line moving in depth. If the model uses velocity constraints rather than motion vectors additional constraints, such as minimal displacement in 3D, have to be introduced to establish a 3D motion direction.

Changing disparity over time (CDOT) on the other hand suggests that horizontal disparities are extracted to build a depth map of the line stimulus that can be tracked over time. It is shown that the average of left and right eye motion vectors combined with corresponding horizontal disparity provides a suitable estimate of 3D motion direction in a binocular viewing geometry.

We compared predictions of a generalized IOVD and CDOT model with empirical data from two experiments. It is concluded that both generalized models still have difficulties to predict perceived motion direction of an oriented line. Additional geometric constraints are discussed that may be able to explain binocular 3D motion perception.

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36.507

Contributions of vergence, looming, and relative disparity to the perception of motion in depth

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It is known that modulations of absolute binocular disparity of a textured surface do not create a sensation of motion in depth (MID) when the image does not change size (loom). We reported previously that modulations of disparity do create some MID in a surface containing a radial pattern that lacks a looming signal when it moves in depth. We have built an instrument that allows us to independently control looming, changing absolute disparity (vergence), and changing relative disparity of surfaces actually moving in depth. A textured surface and a surface with a radial pattern moved back and forth in depth between 40 cm and 70 cm. With monocular viewing, looming created MID of the textured display but not of the radial display. Modulation of absolute disparity (vergence) produced no MID of the textured display but some MID of the radial display. When modulation of absolute disparity was increased relative to looming, MID was increased for both displays. When disparity modulation and looming were in conflict, MID decreased for both stimuli. These results indicate cue summation. Superimposition of a stationary reference stimulus that provided changing relative disparity, generally increased MID for both stimuli. Addition of the reference stimulus to the radial display with reversed vergence produced MID in accordance with the vergence signal. Addition of the reference stimulus to the patterned display with vergence reversed relative to looming, produced a paradoxical effect. The textured display appeared to move simultaneously in opposite directions. When it appeared to move forward relative to the observer, it appeared to move backward relative to the stationary reference stimulus. This indicates strong cue dissociation. We will demonstrate this unique paradoxical effect.

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36.508

Individual differences reveal two independent motion-in-depth mechanisms

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We found large differences in people's abilities to see motion in depth. Binocular motion in depth perception can theoretically be derived in two different ways: namely, based on changing disparity over time (CDOT), or based on inter-ocular velocity differences (IOVD). In the former, disparity is calculated first and then a change over time is monitored. In the latter, velocity is measured in each eye first and then the difference is taken. In three experiments we measured the abilities of 63 participants to see motion in depth from these two cues, both in isolation and in combination. Thirteen people could not see motion in depth in IOVD stimuli, but who were able to see motion in depth from CDOT stimuli; twelve participants were able to see motion in depth from IOVD stimuli, but not from CDOT. Thirteen people did not see motion in depth at all, and 21 people could see motion in depth from all stimuli. There were significant correlations in detection thresholds between CDOT stimuli and stimuli containing both cues, and between CDOT and IOVD, but not between IOVD and both cues. We performed a range of vision tests to control for possible effects of visual or motivational factors in the study. We also did a texture discrimination experiment with a similar design and stimulus as in the main experiments. Texture discrimination thresholds for those who could see motion in depth were not different from those who could not. The frequent double dissociation leads us to conclude that CDOT and IOVD mechanisms can exist independently of each other. Furthermore, motion in depth perception is achieved in fundamentally different ways in different people. The latter finding has widespread implications for our understanding of perception in general.

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36.509

Does the motion/pursuit law accurately characterize the perception of depth from motion parallax?

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Perception of unambiguous (Nawrot, 2003, Vision Research; Naji & Freeman, 2004, Vision Research) scaled (Nawrot, 2003, Journal of Vision) depth from motion parallax relies on an extra-retinal signal (Nadler et al, 2008, Nature) derived from the pursuit eye movement system (Nawrot & Joyce, 2006, Vision Research). Underlying our experiments is a mathematical motion/pursuit law (Stroyan, 2008, VSS Abst. 23.304) that uses the ratio of retinal image motion and pursuit eye movement to exactly determine the

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relative depth of an object to the point of fixation. Unlike prior work starting with Nakayama and Loomis (1974, Perception), the motion/pursuit law does not rely on observer speed as a visual input, but does use an extra-retinal pursuit signal. If the motion/pursuit law accurately describes the visual system's function, then changes in perceived depth from motion parallax should be best explained by change in the motion/pursuit ratio, rather than changes in either retinal image motion or pursuit eye movement. Observers were presented two random-dot motion parallax stimuli that could differ in retinal image motion (0.42, 0.625, 0.833, 1.25, or 2.5 deg/sec), pursuit speed (5, 7.5, or 10 deg/sec), and motion/pursuit ratio (0.25, 0.167, 0.125, or 0.083). In each trial the motion parallax stimulus window translated across the monitor, in either direction alternately, changing between the two stimuli at mid-screen. Observers performed a 3AFC task by indicating which of the two stimuli had greater depth magnitude (left, right, or same). Pursuit was monitored with an eye tracker. Multiple regression indicates that one independent variable, change in motion/pursuit ratio, best explains change in perceived depth. While a change in retinal image motion or in pursuit may produce a change in perceived depth, it is due to change in the motion/pursuit ratio. If motion and pursuit change but their ratio remains constant, there is no change in perceived depth.

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36.510

A Bayesian ideal observer for perceiving heading and rotation from optic flow

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Retinal optic flow produced by self-motion is a function of both the linear translation of the observer and the rotation of viewpoint due to eye and head movements. A challenge in analyzing optic flow is identifying the translational and rotational components. Previous psychophysical work has found that extra-retinal input from eye movements helps the human visual system extract observer translation direction (heading) from optic flow with a rotational component. However, heading can also be accurately perceived in the absence of extra-retinal feedback when optic flow is sufficiently rich. We developed a Bayesian ideal observer model to account for such results. Given an input velocity field, the model computes the likelihoods of different combinations of heading and rotation, assuming a rigid environment and noise in velocity measurements. The likelihood function from optic flow is combined with a likelihood function representing extra-retinal information about eye movements, and the maximum of the resulting function is interpreted as the observer's perceived heading and rotation. With plausible noise assumptions, the model can simulate human heading perception across a range of conditions, including: simulated vs actual eye rotations, environments with various depth structures, and the presence of independently moving objects.

36.511

A comparison of motion integration for optic flow components

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In order to perceive optic flow from moving objects and/or scenes, the visual system integrates local motion signals over space and time to form a globally coherent motion percept. Our previous study revealed greater sensitivity in perceiving circular/radial motion than for translational motion (Lee et al., 2008), suggesting the existence of specialized motion integration mechanisms for analyzing complex "optic flow" motion. The current study examined the properties of integration mechanisms tuned to different motion patterns, comparing their spatial and temporal extent.

Stimulus consisted of 728 drifting Gabor elements, each with randomly assigned orientation. For signal Gabor elements, drifting velocities were manipulated to generate translational, circular or radial motion. For noise Gabor elements, velocities were random. Sensitivity was measured by proportion of signal elements yielding a performance level of 75% correct in a discrimination task.

In Experiment 1, we found greater sensitivity for circular motion than for translation over a range of speeds, 0.8, 1.6 and 2.4 deg/s. The difference in sensitivities between translational and radial motions diminished with increase in speed. Furthermore, for circular motion, but not translational and radial motion, sensitivity remained fairly constant across different speeds, suggesting that an integration mechanism specialized for circular motion may be tuned for a broader range of speeds. In Experiment 2, we found near invariance of human sensitivity with element density (different numbers of Gabor elements within a 12°circular visual field) for all three motion patterns, suggesting linear pooling of local motion guided by specialized integration mechanisms for translation, circular and radial motion. In Experiment 3, we found that human sensitivity increased linearly with stimulus duration, up to about 80~150ms, for all the three motion patterns. This result reflects a temporal integration limit in the early stage of local-motion analysis with a time constant of about 100ms.

36.512

Cortical distribution of asymmetric responses to radial expansion/contraction in human adults and infants

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Previous behavioural studies indicated that the ability to detect radial motion pattern, one of the main cues for motion-in-depth perception, emerges in the first few months of life (e.g., Brosseau-Lachaine et al., 2008; Gilmore & Rettke, 2003; Gilmore et al., 2004; Shirai et al., 2004a, 2004b, 2008). Cortical activity related to radial motion detection has also been found at that age (Shirai et al., in press). The common onsets of the behavioral sensitivity and cortical responses to radial motion imply that the emergence of radial motion perception is elicited by the maturation of particular cortical mechanisms. It would be important to investigate any difference in the distribution of cortical radial motion responses between infants and adults, for understanding the development of radial motion processing. However, no study has identified the cortical area(s) related to the radial motion sensitivity in infancy.

In the present study, we examined the distributions of cortical activities to radial expansion/contraction motion with adults and infants (3-4 and 4-5 months of ages) by measuring steady-state visual evoked potentials with a high-density electrode array. We cyclically presented a radial (either expansion or contraction) and random motion pattern alternately and analyzed the mean amplitude of the fundamental harmonic component (F1) corresponding to the pattern alternation frequency. The results indicated that the adults showed greater activity to contraction than to expansion in the right parietal area (P6 and P8). Although the older infants also showed a bias toward contraction, this bias was spread over the whole occipitoparietal area. The younger infants showed no contraction bias in these measurements. We will discuss the early development of radial motion detection in the light of the present results and previous behavioural and VEP studies.

36.513

Motion-onset visual evoked potentials (m-VEPs) in children: similarities and differences between translational and radial motion

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Purpose: Although translational motion (t-motion) is often used in motion-onset VEP studies, other types of motion such as radial motion (r-motion) have been shown to be efficient stimuli as well. However, the motion-onset VEPs are not well known in children. The aim of this study was to characterize and compare VEP responses to t-motion and r-motion in a large homogenous paediatric sample.

Method: Motion-onset VEPs have been tested in a cohort of Inuit children (mean = 11,3 ±1 year) using left-right t-motion (n=125) and contraction-expansion radial motion (n=98). For both types of stimuli, motion-onset was evoked by an initial stationary period of 1120 ms follow by an abrupt and rapid motion (duration: 160 ms; velocity: 6,5 deg/s; contrast: 10%). Motion direction was unpredictable. Brain responses were recorded from 32 scalp electrodes according to the 10-20 system.

Results: The amplitude of the P1 and the N2 components to r-motion were significantly stronger compare to t-motion. In both cases, the topographic mapping of the electrical activity shows a lateralized right hemisphere distribution over the occipito-temporal region, which was more important for r-motion. No significant difference was found for latency.

Conclusion: This study shows in school-age children that VEP responses evoked by r-motion are clearly more robust than those evoked by t-motion. This finding is consistent with previous reports in adults. Because r-motion is associated with a better signal and minimize ocular artefacts, this type of stimulus might therefore be more appropriate for paediatric motion-onset VEP assessment.

36.514

Generating optic flow from illusory disk motion

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A range of motion illusions can be elicited by static images, such as Op art paintings, or similar geometric patterns designed by visual scientists. Many of these illusions require the observer to make eye movements that lead to image shifts generating local motion signals (Zanker and Walker, Naturwissenschaften 91, 2004). In an attempt to test the physiological mechanisms underlying motion illusions in the absence of eye movements, we developed the 'Spinning Disks Illusion': concentric rings of disks filled with greylevel gradients appear to spin around the centre when the background luminance is modulated, eliciting specific responses in area V5/MT (Williams et al, Perception 34, 2005). A two-dimensional implementation of a biologically plausible motion detector, the 2DMD model, was used to account for the perceived shift of an isolated greylevel disk under these conditions (Zanker, Perception 36, S64, 2007). This basic phenomenon was used in the present work to generate more complex motion patterns. When randomly distributed sets of disks with radial or tangential orientation of the greylevel gradient are presented in front of a background with modulated luminance, a strong percept of translational and rotational optic flow is perceived by human observers. We used the 2DMD model to assess the strength of the flowfield information as function of a variety of stimulus parameters such as the number and the size of the disks, or the slope of the greylevel gradient. We found that the saliency of optic flow is highest for fine-grain motion detectors, and that it increases with the number of disks and decreases with the size of the disks. Following from the results of such computer simulations, the discrimination of flowfield patterns can be used in psychophysical experiments to study the influence of these stimulus parameters on the strength of the perceived motion illusion.

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36.515

Use of speed differences for detection of moving objects by moving observers

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A person moving through the world must be able to detect moving objects to avoid collisions. In previous studies, we examined human ability to find an object moving at a different angle from the radial optic flow field generated by observer motion. In this study, we examined whether differences in image speed could be used to detect moving objects within a radial flow field. Observers viewed a radial flow field simulating observer motion of 200 cm/sec in a straight line toward a set of 25 circular objects initially at a distance of 800 cm from the observer. In half the trials a randomly chosen target circle moved at an increased or decreased image speed. The target speed was computed by multiplying the image speed calculated for an object at the target's image position by a given factor. Each trial lasted 1 sec. In every trial, observers pressed a key to indicate whether or not the target circle was present. We measured the percentage of correct responses for speed factors of 0.3 to 0.9 for slower moving objects and 1.1 to 1.5 for faster moving objects. Thresholds were computed by fitting the data with a sigmoidal curve and determining the speed factor at which the observers performed with 75% accuracy. The results for 10 observers show that for slower moving objects (speed factor <1) accuracy increases as the speed factor decreases, with an average threshold factor of 0.5. For faster moving objects (speed factor > 1), accuracy increased with increasing speed factor, with an average threshold factor of 1.4. Thus, observers can detect a moving object within a radial flow field based on its image speed if its speed is sufficiently slower or faster than the image speeds of objects that are part of the stationary scene.

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36.516

Detecting object movement during self-movement: the importance of local motion contrast, position change and optic flow

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We have shown that observers can identify object movement within the complex pattern of retinal motion that arises during movement of the observer. We hypothesised (Rushton & Warren, 2005) that this process exploits the brain's well-documented sensitivity to optic flow (global patterns of motion that are characteristic of self-movement) and data collected in previous studies is compatible with this hypothesis. Here we report strong direct tests of alternative solutions. We first remove the retinal disparities within the scene that are necessary for object movement to be identified by local (within disparity plane) motion contrast; we do this by presenting the scene to a single eye, whilst presenting the probe object (which varies in depth) to both eyes. We find the observers still demonstrate behaviour compatible with the identification of object movement. In a second study, we investigate the effect of removing motion (flow) from the display. We do this by presenting either a natural continuous change in (simulated) observer viewpoint, or an unnatural step change. We find that in the latter case, despite local motion and position change information being preserved, performance is significantly impaired. Taken together these results point to a central role for optic flow processing in the identification of scene-relative object movement.

36.517

A physiologically based model for detection of moving objects by a moving observer

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A moving observer must determine her direction of motion and detect moving objects. Once heading is known, a moving object can be detected by examining local image motion differences and identifying those that have large angular differences from the radial optic flow pattern or that have a larger than average magnitude. A physiologically based model for computing heading (Royden, 1997) performs a motion subtraction using operators based on physiological properties of cells in the Middle Temporal visual area (MT). This model computes heading well. Here, we tested the model's ability to detect moving objects in the scene. The model was modified to detect potential moving object borders based on an increased response magnitude compared to the average response across the scene or a preferred direction of motion that differs significantly from the radial pattern expected for the computed heading. We simulated observer translational motion of 200 cm/sec toward the center of two frontoparallel planes, 400 and 1000 cm from the observer. A 6x6 deg moving object moved leftward at a speed of 7.5 deg/sec. The horizontal and vertical positions of the object were varied between -7, 0 and 7 deg. Speed and angle thresholds for signaling a possible moving object were determined empirically, to give the maximum object detection with the minimum false positives. Once these thresholds were established, they were held constant for all conditions tested. We found that in most cases the model detected the borders of the moving object very well, with an average of 10.4 out of 12 of the operators located along the object edges signaling a moving object border and 2.4 of 157 operators outside the object edges giving false positives. The results were similar when tested with the addition of observer rotation of 5 deg/sec about the X, Y or Z axes.

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Vision and Action: Hand Movements

Sunday, May 10, 2:45 – 6:45 pm
Poster Session, Vista Ballroom

36.518

Response to Changes in Variability During Movement Under Risk

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Humans account optimally, or nearly so, for visuomotor variability (Trommershäuser et al., JOSA A 20, 2003) during movement under risk, even when variability is artificially increased (Trommershäuser et al., J Neurosci 25, 2005). How do humans estimate task-related variability in a dynamic, volatile environment in which variability changes? Methods: Subjects pointed rapidly at a target (a tall, green rectangle) on a visual touchscreen display. A small white circle indicated where the finger landed, and a blue circle was also displayed, randomly displaced horizontally from the white square. Displacements were drawn from a zero-mean normal distribution whose standard deviation remained constant for a sequence of trials (random epoch lengths: 75-150 trials) then suddenly changed to a new value (3.7-18.4 mm). Instructions indicated that outcome variability followed such a random sample-and-hold trajectory. On 2/3 of trials, an overlapping, horizontally displaced, red penalty rectangle was also displayed. Subjects won a point (4¢) if the blue square landed on the target, but lost 5 points if it landed on the penalty region. Observers should thus aim further from the penalty area when displacements are larger. Slow movements (> 400 ms) were penalized 10 points. Results: 5 of 6 subjects took changing variability into account in planning movement. Actual movement endpoints (where the finger landed) were significantly correlated ($p < .01$) with the endpoints that maximized expected gain. The local dynamics of estimation were investigated by regressing the observed movement endpoint against the previous few trials' squared displacements. These account for significant endpoint variance for these same 5 subjects, with displacements from more recent trials weighted more heavily. There are notable individual differences, e.g. in the time span over which movement variability was estimated to influence the current trial's movement strategy. Conclusion: Subjects dynamically estimate movement outcome variability over a windowed running average of previous outcomes.

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36.519

Comparison of distortions of probability information in three stochastic tasks: visual, visuo-motor and decision making under risk

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In decision making under risk (DMR), subjects deviate from Expected Utility Theory (EUT) by distorting probability information (Allais, 1953). We compare performance in DMR, a visual task equivalent to DMR and a visuo-motor task equivalent to DMR. In the visual and visuo-motor task, subjects shot at rectangular targets on a screen with a stochastic shooter. During a training phase (600 trials) subjects could learn how the probabilities of hitting a target varied with width. Following training, subjects were presented with pairs of targets. The widths of the targets were adjusted so that the subject could win points Oi with probability pi (i = 1,2) by choosing to aim at zone i. In 4 conditions, we varied the probability p2 of incurring outcome O2 between 0.8, 0.6, 0.4 and 0.2 by varying the size of one of the targets. The larger target always had value 1, the smaller, 2. We measured subjects' preferences by using an adaptive staircase procedure to estimate the probability p1 that corresponded to the point of indifference for choosing between the targets. In the visual task the subject selected a target by key press. In the visuo-motor task, the subject selected a target by touching it. The subject's own motor variance was effectively added to the shooter's variance in the motor task, decreasing the chances of hitting the target. In the third task (DMR) we displayed numbers representing probabilities and assigned outcomes of the two lotteries. Three subjects completed the experiment. The prediction of EUT is that p1/p2 at PSE should be constant, independent of p2 (Allais, 1953). We found that subject's preferences violated EUT in the DMR task, but not in the visual and visuo-motor task. In the latter two conditions we could not distinguish subjects' performance from optimal.

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36.520

Dissociations between Perceived and Actual Success in Goal-Directed Movements

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Purpose. Last year, we developed an experiment intended as a very simple model of injury or stroke in which the subject, after first practicing a speeded touching movement, was required to perform the movement but with their elbow physically constrained. We found that subjects' objective performance suffered little and recovered quickly after constraint but that their predictions of success decreased markedly and remained depressed. Moreover, when the constraint was removed, subjects continued to underestimate their actual success. Typical explanations for this "dissociation" between performance and perceived performance emphasize the awkwardness of the constrained movement. Here we examine if similar effects occur after moving with the non-dominant hand. Methods. Participants (n=8) made fast reaches (35 cm, 250ms) with their index finger to touch a target (circular, 0.4 cm) on a horizontal touchscreen. Before each trial, participants estimated their chances (0-100%) of hitting the target. Participants performed three blocks: B1) 40 trials with dominant hand, B2) 30 trials, non-dominant hand, and B3) 30 trials, dominant hand. Analysis. We calculated within-subject averages of 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 and S1›S2‹S3 : participants showed lower accuracy and lower estimates for the non-dominant hand. Unlike the estimates following the joint constraint, participants' estimates for the dominant hand rapidly recovered after moving with the non-dominant hand. Conclusions. Restraining the arm's degrees of freedom leads to a pronounced, erroneous decrease in perceived motor performance that persists after constraint removal. However, an aftereffect was not found after moving with the non-dominant hand, so it cannot be a simple residual effect of perceiving one's performance on non-routine movements as awkward.

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36.521

Exploring the limits of optimal motor-planning

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Performance in cognitive- and perceptuo-motor decision making tasks is known to dissociate (Trommershäuser, Maloney, & Landy, 2008). A potential explanation for this dissociation is the explicit nature of cognitive tasks and the implicit nature of motor tasks (Seydell, McCann, Trommershäuser, & Knill, 2008). However, there is evidence that performance remains optimal, or nearly optimal, for motor tasks requiring explicit choice (Trommershäuser, Landy, & Maloney, 2006; Seydell et al., 2008) – seemingly eliminating the implicit/explicit factor as an explanation. Here the explanatory value of the implicit/explicit dimension was re-evaluated. A speeded reaching task for targets in the fronto-parallel plane was undertaken. The task involved two components – target choice (explicit) and aim point choice (implicit). On each trial, two targets varied in size (small/large), and distance (far, medium, near) and elevation (up/down), relative to a central dock. Target hits were rewarded (with the value depending on target size) and misses were penalized. Some evidence was found that participants' target choice behaviour suffered while aim point choice remained close to optimal. Furthermore, there is some evidence that participants' under-utilise the available response time for some target configurations – a potential further source of sub-optimality. Interestingly, estimation of overall optimality of observers appeared to be dependent on the analysis method used (e.g., non-parametric vs. parametric bootstrapping). Taking these findings into account, there may thus be reason to re-evaluate the optimality of participants' behaviour in perceptuo-motor tasks involving both target- and aim point choice.

36.522

A neural model of the visual tuning properties of action-selective neurons in STS and area F5

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The visual recognition of goal-directed movements is crucial for the understanding of intentions and goals of others as well as for imitation learning. So far, it is largely unknown how visual information about effectors and goal objects of actions is integrated in the brain. Specifically, it is unclear whether a robust recognition of goal-directed actions can be accomplished by purely visual processing or if it requires a reconstruction of the three-dimensional structure of object and effector geometry. We present a neurophysiologically inspired model for the recognition of goal-directed grasping movements. The model reproduces fundamental properties of action-selective neurons in STS and area F5. The model is based on a hierarchical architecture with neural detectors that reproduce the properties of cells in visual cortex. It contains a novel physiologically plausible mechanism that combines information on object shape and effector (hand) shape and movement, implementing the necessary coordinate transformations from retinal to an object centered frame of reference. The model was evaluated with real video sequences of human grasping movements, using a separate training and test set. The model reproduces a variety of tuning properties that have been observed in electrophysiological experiments for action-selective neurons in STS and area F5. The model shows that the integration of effector and object information can be accomplished by well-established physiologically plausible principles. Specifically, the proposed model does not compute explicit 3D representations of objects and the action. Instead, it realizes predictions over time based on learned view-dependent representations for sequences of hand shapes. Our results complement those of existing models for the recognition of goal-directed actions 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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36.523

The effects of stimulus ambiguity and trial order on the selection of goal-directed actions

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We recorded reaction times (RT) of participants who were asked to pick up an elongated object at various orientations with a precision grip. Although most of these orientations consistently elicited one of two grip postures, there was a region of orientations that, due to biomechanical constraints, elicited both grip postures to varying degrees. In the first experiment, we found a clear increase in RT as object orientations reached this 'ambiguous' region. Also, we found that randomizing the order of orientations—instead of presenting them in a clockwise or counterclockwise fashion—significantly lengthened RTs. To determine whether the difference in RT across different trial orders reflected explicit knowledge or simply trial history, we conducted a second experiment in which we presented the object at only two unambiguous orientations (each affording a different grip posture), in three different trial orders: blocked, alternated, and randomized. We found that the blocked and alternated trials led to significantly faster RTs than the randomized trials, suggesting that when switching between two unambiguous orientations, participants used their explicit knowledge about upcoming trial types. In a third experiment, we presented the object within the ambiguous region or within an unambiguous region, with the same trial order conditions that were used in the second experiment. As expected, RTs during blocked unambiguous trials were shorter than those during blocked ambiguous trials. Also, there was slight but significant difference between randomized ambiguous and unambiguous trials, probably reflecting trial history effects. Most surprisingly, we were unable to detect a difference in reaction time between the alternated ambiguous and unambiguous trials. Thus, while explicit knowledge of upcoming trial type provided an advantage when participants switched between two unambiguous grip postures, it failed to provide such an advantage when participants switched between ambiguous and unambiguous orientations, suggesting an interaction between explicit knowledge and ambiguity.

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36.524

The anti-pointing task: vector inversion is mediated by a perceptual representation of reaching space

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The anti-pointing task entails reaching mirror-symmetrical to a presented target. A previous study by our group (Heath et al. 2008: Exp Brain Res) showed that anti-pointing movements in left and right space exhibit a respective under- and overshooting bias: a finding consistent with perceptual asymmetries of target extent (e.g., Elias et al. 2002: Brain Cogn). Unlike earlier work in which pro- and anti-pointing movements were completed in separate blocks of trials, the present investigation entailed a situation wherein the aforementioned response contexts were randomly interleaved on a trial-by-trial basis. In particular, a discriminant stimulus change (i.e., change in colour of fixation cross) occurring in time with response cuing signaled the appropriate movement context – a situation requiring visuomotor inhibition for both pro- and anti-pointing movements. We reasoned that premovement inhibition of direct stimulus-response relations would provide a framework for determining whether top-down visuomotor inhibition and/or the visual remapping of target location (i.e., vector inversion) mediates the visual field-specific bias of anti-pointing. As expected, pro-pointing reaction times were faster than anti-pointing counterparts ($F=42.64$, $p < 0.001$) indicating increased computational load for movement planning in the latter condition. Most notably, pro-pointing in left and right space exhibited a comparable and a robust level of accuracy whereas left and right space anti-pointing respectively under- and overshot veridical target extent ($F=135.68$, $p < 0.001$). Thus, the present results indicate that

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top-down visuomotor inhibition does not contribute to the endpoint bias of anti-pointing. Rather, results indicate that the remapping of target coordinates to a mirror-symmetrical location in space is mediated by a perception-based representation of target extent.

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36.525

The effect of gaze shifts, pointing, and saccadic adaptation on the relative position judgments of a remembered object

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Henriques et al. (1998) showed that people re-map the location of an object with respect to gaze when pointing to its remembered location. In this study, we wanted to see if people's representation of the relative location of a remembered object also re-maps with respect to gaze. We also investigated the effect of pointing and saccadic adaption on relative location judgments following a gaze shift. METHOD: Head-fixed subjects in a dark room indicated the location of a previously displayed object (a vertical bar) relative to a second bar. This was done with gaze fixed 5o-15o horizontally from the first bar, or after the first bar was foveated followed by a 5o-15o horizontal gaze shift. In the pointing conditions, subjects pointed to the first bar following the gaze shift, and then judged its remembered location relative to a second bar. In the saccadic adaption condition, following a training session subjects performed saccades that were approximately 25% hypometric. RESULTS: When gaze was fixed, people judged the remembered bar as being closer to the fovea. When subjects shift their gaze after viewing the first bar, however, there was no such bias, i.e., they were accurate. Pointing affected the relative position judgment in the gaze-shifted condition by introducing a similar bias to the fovea. Saccadic adaptation did not significantly alter localization, but there was a trend in the direction of adaptation. CONCLUSIONS: Our results suggest that the brain does not update with respect to gaze for perceptual judgments following an eye movement. Likewise, saccadic adaptation does not significantly affect perceptual localization. However, pointing did affect perceptual localization following an eye movement, suggesting that perception of the object's relative location may have been re-mapped when accompanied by a simultaneous action.

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36.526

A window into behavioural strategies used in visuomotor adaptation

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Our lab has previously demonstrated that the computer-based Viewing Window task is useful for investigating the interactions between action and perception (Baugh and Marotta, 2007). During the task participants identify blurred images by controlling a small window through which they can see part of the image clearly. Past research has used manipulation of the relationship between the participant's action and resulting viewing window movement to investigate visuomotor adaptation. However, only large distortions apparent to the participant have been used. In daily life, we frequently make subtle adjustments that are performed without our awareness. We hypothesized that by altering viewing window control with subtle, gradual changes we could also elicit non-conscious adaptation. In the present study the first 10 trials (pre-measures) of the Viewing Window task were performed using normal control followed by 61 experimental trials during which control changed by either: 1. large jumps to -22.5° and -45° (sudden condition), or 2. small changes of -0.73° during each trial to a maximum of -45° (gradual condition). The Viewing Window then returned to normal control for 10 trials (post measures). Scan paths of movement revealed more complex pathways during the sudden condition compared to the gradual condition. Additionally, a significant interaction between the rotation condition and the time spent on/off the object during the pre- and post-distortion trials was found. Both groups demonstrated greater time spent scanning areas off of the object once viewing window control returned to normal. However, this effect was larger in the gradual rotation group indicating larger after-effects. The results of this study demonstrate that the Viewing Window task can be used to elicit two common strategies of visual motor adaptation and can therefore provide a tool to investigate neural networks underlying conscious and non-conscious visual motor adaptation.

36.527

Visual-haptic disparity of target will modulate action-guidance strategy

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The contribution of vision to action guidance is flexible. For example, Wolpert (2007) has demonstrated that humans integrate sensory information as a function of sensory reliability. Modalities that are more reliable are used more extensively to make a perceptual judgment than those that are less reliable (e.g. Ernst & Banks, 2002). The present study was performed to test how different visual-haptic mappings influenced grasping actions. We presented a Müller-Lyer figure (MLF) on a half-silvered mirror, such that the image mapped onto a physical object located below the mirror. This set-up gave participants the feeling that they were physically grasping the shaft of the MLF. The physical object did not always match the size of the image, which created a visual-haptic disparity. Participants performed two counterbalanced blocks of trials. In block A, the physical object was adjusted opposite to the size of the illusory percept (constant disparity block) and in block B, the visual-haptic mapping was random (variable disparity block). Participants were instructed to reach out and grasp the shaft of the MLF (kinematic variables were derived using an Optotrak Certus). It was hypothesized that grip scaling would be proportional to the size of the physical object in the constant disparity block, but would reflect the size of the illusory percept in the variable disparity block. Contrary to our hypothesis, participants' grasping behaviors were influenced by the illusion regardless of the mapping condition. That is, peak grip aperture (pGA) was smaller for the fins-in compared to the fins-out MLF configuration. Additionally, pGA decreased over the first several trials. This adaptation in pGA required fewer trials in the constant disparity condition. Thus, haptic feedback uncertainty in the variable block delayed pGA adaptations. These results suggest that visual guidance strategies are altered by inter-modal mapping certainty.

36.528

Reduction of the flash-lag effect in terms of active control of visual stimulus and size of hand movement

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In our previous study, we found that observe's active control of the stimulus movement would reduce the illusory flash-lag effect (Ichikawa & Masakura, 2006 Vision Research). In this study, in order to examine whether the size of hand movement affect the extent of the flash-lag effect in active observation, we measured the extent of the flash-lag effects for different size conditions for the hand movement. In the active condition, the position of the moving stimulus (19.1 x 19.0 arc min) was determined by the position of computer-mouse which was controlled by observer's right hand; 28.8 arc deg of vertical movement of the stimulus on the display corresponded to three size conditions (about 30.0, 10, or 2 cm) for the hand movement on the desk. In the automatic condition, the stimulus moved automatically without observers mouse control. The velocity of the stimulus movement on the display in the automatic condition was determined by the average of the stimulus movement in the active condition. In each trial, the flash stimulus (19.1 x 19.0 arc min) was presented beside the moving stimulus when the stimulus was at seven tenth of the moving distance. The vertical position lag between the moving and flash stimuli ranged from -76.0 to 76.0 arc min by 19.0 arc min step (negative value indicates that the position of the flash stimulus was behind of the moving stimulus). Observers judged whether the moving stimulus was below or above the flash stimulus. The extents of the flash-lag effect in the active condition could be significantly smaller than that of the automatic condition in any size condition for the hand movement. This result suggests that the proprioceptive signal for the hand movement to control the visual stimulus would be effective to reduce the flash-lag effect regardless of the size of hand movement.

36.529

Differences between action and perception in learning object categories

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“Understanding is grasping” in many languages. The universality of this metaphor suggests that humans rely on representations of body movements when they think about concepts or categories. Given this, learning to sort objects into categories might improve if the objects are grasped. But the neural control of visually guided grasps involves areas in the parietal cortex, whereas areas in the occipito-temporal cortex are associated with recognizing objects and assigning them to categories. Therefore, learning object categories might be impaired if objects are grasped. As a third possibility, learning categories might involve ‘amodal’ neural mechanisms remote from perception and motor control. So then learning with or without grasps should not differ. To test these predictions, we asked participants to learn to sort objects into categories depending in the combination of two object chracteristics. People learned less well when they grasped the objects in different ways to indicate categories than when they pressed buttons, even when we varied button locations to manipulate processing load for button reaches. These results suggest that the language intuition is false, as sensoriotor control of grasps hinders category learning. It suggests that the functional specialization of action and perception permeates high-level functions of human concept knowledge.

36.530

Large Perspective Changes (>45°) Allow Metric Shape Perception Used to Guide Grasping

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Background. Lee, et al. (2008a) found that binocular viewing (wtih head movement) of cylinders (5 aspect ratios) did not yield accurate metric shape perception used to guide reaches-to-grasp. Metric shape perception was not calibrated by grasp feedback. However, Bingham & Lind (2008) found large perspective changes (≥45°) allowed accurate metric shape perception. Lee, et al. (2008b) investigated judgments of SFM and stereo displays and found metric shape only became accurate with changes ≥45°. We now investigated whether such information allows accurate reaches-to-grasp.

Methods. A different group of 10 Ss performed in each of 3 experiments. Elliptical cylinders (5 aspect ratios) were viewed in a mirror while rotated 50°. Feedforward reaches-to-grasp actual and virtual cylinders behind the mirror were measured using Mini-Bird markers on index and thumb nails and wrist. Major and minor axes of each target were grasped and measured apertures (at MGA and TGA) were used to compute aspect ratios. Exp 1 entailed no delay between viewed perspective change and reaches-to-grasp. In Exp 2, there was a 5s delay. In Exp 3, three different targets were viewed and rotated simultaneously and then grasped in sequence with a delay for the third object of ≈25 s.

Results. Aspect ratios, as reflected in grasping, were now accurate at both MGA and TGA in all three experiments. In previous studies, regression of produced versus actual aspect ratios had yielded low slopes of ≈0.6. Now slopes were 0.8-0.9.

Conclusions. Large perspective changes (as generated during approach to a workspace) yield accurate perception of the metric shape of multiple objects in a scene, that remains stable with continued viewing from a single perspective, and that allows accurate control of subsequent feedforward reaches-to-grasp. Future study of space perception used to guide actions requires consideration of nested actions at different spatial-temporal scales.

36.531

Gaze strategies and grasping: Complex shapes

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At last year’s VSS meeting (journalofvision.org/8/6/299/) we demonstrated that during a natural grasp, gaze fixations cluster towards the top edge of an object. These fixation locations were tightly coupled to index finger grasp position, which fell across the object’s center of mass (COM). The tight link between grasp position and fixation locations has also been shown in situations where participants are instructed to grasp an object at a specific location (de Grave et al., 2008; Johansson et al., 2001). However, these studies have explored fixations while grasping symmetrical objects – whose COM also corresponds to the object’s midline. While previous studies have highlighted the importance of an object’s COM while grasping, showing that people grasp an object across this point regardless of where the midline of the object is (for example Kleinholdermann et al., 2007), it is still not clear whether such dissociations are present in gaze fixation locations.

The purpose of the present study was to explore whether it is an object’s midline or an object’s COM that is the main focus of fixations while grasping. Participants were presented with complex asymmetrical shapes whose COM was oriented on either the left or right side of the object’s midline. In support of previous research, participants grasped the objects across the COM. Likewise, gaze fixations were concentrated towards the top edge of the objects, corresponding to index finger location. Additionally, first fixations were found to be significantly shorter in duration then final fixations, indicating that participants were spending more time looking at the shapes while positioning their fingers on the object. Despite the complexity of the shapes, however, participants did not explore the object area in more detail. This study highlights the importance of an object’s COM rather than its midline for the programming of both grasp and gaze fixations.

Acknowledgement: This work was supported by grants from the Natural Sciences and Engineering Research Council of Canada to JM and the Manitoba Health Research Council to LD.

36.532

A model on human grasp point selection

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We present a model of where humans place index finger and thumb when grasping arbitrary objects with a precision grip. The model incorporates three weighted rules to (a) maximize force-closure, (b) optimize the position of the object’s gravicenter relative to the fingers, and (c) minimize deviations from ones natural grasp angle. We determined the parameters of the model in two experiments (N=18 and N=19) with objects of simple geometry. In a third experiment (N=18) we predicted the grasp points for a set of objects with complex geometries. The results show that our simple model can surprisingly well predict human grasp point selection.

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36.533

The Role of Audition in the Scaling of Grasping

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Sunday Sessions

Although there is some work that has investigated the role of haptic and olfactory cues in the control of grasping, there has been little investigation of the role of natural auditory cues. The aim of our study therefore was to investigate how natural auditory cues about object size and location affect grip aperture in normal right-handed participants. The experiment required participants to pick up two objects of different sizes but in the same position (task 1) or to pick up the same object located near or far from subject's hand (task 2). In both tasks, participants were tested with and without vision – and with and without hearing the sound of the object being placed on the table. Hand and finger movements were tracked at 100 Hz using OPTOTRAK©. In task 1, hearing the sound of the object being placed on the table improved performance when vision was not available; that is, participants showed evidence of grip scaling for object size (which did not occur without vision and auditory cues). With vision, of course, grip scaling was always better, but even here auditory information improved performance. In task 2, the sound of objects being placed at different distances on the table did not improve localization when vision was blocked; participants simply 'guessed' the distance at which the object had been placed. Taken together these results suggest that auditory cues can be used to estimate the size of objects in a grasping task, but not the distance of those objects in peripersonal space. Vision contributes a great deal more to accurate scaling, but audition still plays a small role even when vision is available. Future experiments will address how these visual and natural auditory cues are weighted and integrated in the scaling of grip aperture.

Sunday Sessions

36.534

So close and yet so far away: An effect of disgust on distance perception and graspability

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Previous research has shown that fear and arousal can influence the perception of spatial layout (Stefanucci & Proffitt, in press; Stefanucci & Storbeck, in press). In a series of studies, we examined the relationship between disgust and perception, particularly the perception of tools. In Study 1, we tested whether placing a disgusting substance on a tool would alter the way in which people grasped the tool. Using Creem & Proffitt's (2001) paradigm, which showed that people picked up tools by their handle even when the handle was oriented away from them, we showed that people will not grasp the handle when the tool has a disgusting substance on the handle. In Study 2, we assessed whether disgust would influence grasping behavior and the perceived distance to the object before the grasp. Participants were placed into a disgust or neutral condition. The tools in the disgust condition were entirely covered in a disgusting substance. In both conditions, participants estimated the distance to and picked up tools at three different distances: 20, 30, and 40 cm. Participants in the disgust condition estimated the tools to be significantly farther away than participants in the neutral condition and that difference was larger at the closer distances. The differences in perceived distance found in this study suggest that disgusting tools may activate a different motor plan than clean tools (as evidenced by Study 1 and 2) and, as a result, participants overestimate the distance to the tool (Study 2). The data suggest that emotion, particularly disgust, influences grasping behavior and the perceived distance to graspable objects in the environment. Follow-up studies are examining estimates of reachability to tools that are disgusting as well as the perceived distance to tools for which the location of the disgusting substance is varied.

36.535

Distractor Valence Affects Action

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Significant neurobehavioural evidence suggests a discrete segregation between the pathways associated visual perception (i.e. ventral projections) and those ascribed visuomotor functions (i.e. dorsal projections; see Milner & Goodale 2008 for a recent review). In general, the dorsal stream appears specialized for processing veridical egocentrically coded cues in a fashion that is independent of conscious awareness (e.g., Binsted et al., 2007). Conversely, the ventral stream considers the relational characteristics of visual objects and scenes to arise at a rich percept. However, demonstrations of dorsal insensitivity to perceptually driven object features have failed to address valence as an evolutionarily viable action moderator. In the current investigation we utilize a variant of a Tipper attention paradigm (e.g., Tipper et al 2001; Welsh et al., 1999) to present distractor cues at offset, non-target locations; importantly, the non-target cues varied in perceived valence (i.e. positive, neutral, negative). Participants were to reach to a target image presented either alone or concurrently with non-target images of (a) a spider, (b) a flower or (c) scrambled pixels. In response to these manipulations, 12 participants demonstrated reliable distractor effects for reaction time, movement time and movement trajectory formation. Recorded movements were slower in the presence of all distractors in both the planning and control phases (see Keulen et al., 2002). Importantly however, and contrary to a view of the perceptual isolation of action, participants demonstrated significant influence of distractor valence. Pointing movements were faster and more variable when made in the presence of a spider cue. Further, both the positive (flower) and the negative (spider) valenced cues demonstrated a reliable attraction effect on the movement trajectory. Thus, it appears that the visuomotor system is does not restrict its visual set, instead it appears to rapidly integrate perceptual interpretations of abstract scene cues (here line-drawings) for movement adaptation.

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36.536

Posterior Cortical Atrophy: The effects on Perception and Action

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Posterior cortical atrophy (PCA) is a rare progressive neurodegenerative disorder that can target the occipital, temporal and parietal lobes. In early stages, PCA is characterized by impairments in higher level visual processing, while memory, language, and reasoning remain relatively intact. Symptoms can include problems in colour perception, face and object recognition, visually guided action, reading, writing, and problems seeing multiple objects in an array – depending on the location of atrophy. Here we present data from a 74-year-old woman, RB, who has been experiencing progressively worsening visual disturbances over the last 3 years.

RB shows severe deficits in recognizing faces (including gender and race) and line drawings of common objects and, despite being a talented artist, she now has difficulty reproducing even simple line drawings. In particular, her deficits involve problems with integrating factors into a concept of the whole – she focuses her attention on one aspect or one detail of the visual form and then is unable to use additional features to form a holistic representation. RB has also experienced colour "hallucinations" where, for example, she has seen walls as different colours after closing and reopening her eyes, or sees colour in black and white pictures.

Combined with MRI cortical analysis, these behavioural results suggest atrophy to the inferior temporal cortex, extending to the angular gyrus in the right hemisphere. Despite these severe perceptual difficulties, RB shows a relatively preserved ability in her visually guided action – properly scaling her grasp for object size and selecting stable grasp points on objects she is impaired at distinguishing perceptually. This case of "ventral" PCA reinforces the findings that there are separate visual pathways for visual perception and the visual control of action.

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36.537

Changes in Visuomotor Performance of Concussed Individuals

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Recently, researchers have found evidence that after a concussion, residual visuo-motor control deficits may linger longer than working memory or psychomotor speed deficits. All of the major computer administered test batteries currently in use for concussion rehabilitation rely on examination of the latter kinds of tasks, and lack any measures of visuomotor control. The present research set out to develop a range of tasks which measure integrated visuomotor performance. Using a touch-screen computer, the first task required participants to point towards or away from (i.e., anti-pointing) a target. A second task required participants to intercept moving targets, and a third had participant's pointing to targets which moved in an unpredictable manner. All three required participants to use visual information to execute controlled movements, but ranged in the degree to which movement planning, early, or late guidance depended on visual information. The three tasks were delivered to 124 individuals from a healthy population to develop normative data for each of the measures. A self-report questionnaire was used to identify individuals from the normative population who had a prior history of concussion. Eighteen individuals were identified, and their performance was directly contrasted with the healthy individuals. While only a few reported moderate or severe concussions, and information about recency and number of occurrences were unavailable, performance differences were observed which provided evidence of residual deficits. In particular, while concussed individuals were not slower, or less accurate than the healthy population on the "pointing-antipointing" task, they demonstrated greater variability of performance. Future research will compare recently concussed individuals with the normative set developed here, and make direct comparisons with an existing computer administered test battery.

Spatial Vision: Adaptation and Masking

Sunday, May 10, 2:45 – 6:45 pm
Poster Session, Vista Ballroom

36.538

Dividing the legs of sheep: Does Burr's Australian stockman strategy work?

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Whereas Durgin (1995; 2008) has proposed that aftereffects of visual number are due to texture density aftereffects, Burr and Ross (20080 have responded that using texture density to estimate visual numerosity is like an "Australian stockman" enumerating a herd of cattle "by counting the legs and dividing by four". To test this hypothesis (with sheep), subjects first compared collections of sheep legs (black and white lines) and collections of black and white sheep with splayed legs. For our naïve observers, approximately 165 legs corresponded to 100 sheep in apparent numerosity. Whereas fast numerosity judgments between collections of like items can compare total texture "energy," those of unlike elements must construct some unit of division. Establishing apparent numerosity between the collections permitted exploring whether adaptation to subjectively similar quantities of legs and sheep could still produce an adaptation effect due to the differing densities of legs. To be safe, we adapted subjects to 100 sheep and 200 legs on opposite sides of fixation. The total texture energy of the sheep was still, of course, much greater. Test stimuli were either sheep or legs. In both cases adaptation was greater in the region adapted to sheep, consistent with Durgin and Huk's (1998) finding of greater transfer of adaptation from low to high spatial-frequency elements, rather than Burr and Ross (2008) who proposed that visual numerosity adaptation is immune to element type. Much as early vision has access to texture information that is no longer available to higher vision, the modified Australian Cattleman strategy of measuring something akin to global texture energy and normalizing by local element energy is among the simplest models of numerosity estimation in homogenous textures. It is almost certainly wrong in detail, but it is probably less wrong than theories that suppose vision represents large multitudes independently of magnitudes.

36.539

Aftereffect of spatial offset between Gabor patches

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The mechanisms underlying detection of second-order information such as contrast modulation have often been modeled as two filtering stages intervened by a nonlinearity, or filter-rectify-filter (FRF) mechanisms. Previous studies have suggested that oriented second-stage filters may mediate the detection of spatial offset between Gabor patches (Keeble & Nishida, 2001). However, the details of FRF mechanisms, especially orientation connectivity between first- and second-stage filters, remain unclear. In this study, we examined whether a negative aftereffect was elicited after adaptation to spatial offset between Gabor patches. Subjects were adapted to 36 pairs of vertically pseudo-aligned Gabor patches (inter-patch distance 75 min) with vertically-oriented carriers. For all such pairs, there was a horizontal spatial offset (25 min) between the patches in the same direction. The initial adaptation lasted 90 s, followed by a 6-s top-up adaptation after each trial. To prevent any adaptation to luminance-defined attributes, the position of each pair as well as the carrier phase of each patch were changed randomly every 100 ms. The test stimulus, a pair of vertically pseudo-aligned Gabor patches with horizontally-oriented carriers, was shown for 500 ms after adaptation. Subjects reported whether the lower patch was to the right or left of the upper patch of the test pair, and the point of subjective alignment (PSA) was determined by the method of constant stimuli. We found a negative aftereffect: the PSA was shifted significantly in the same direction as the spatial offset applied to the adaptor. This aftereffect can be interpreted as a change in the response of oriented second-stage filters. Moreover, in a separate experiment we also noticed that the magnitude of the aftereffect differed as a function of the carrier orientation of the adaptor, from which we will discuss the nature of orientation connectivity between first- and second-stage filters.

36.540

Identifying the mechanism of adaptation to prolonged contrast reduction

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We have previously reported that following four hours of natural viewing with a 3-fold reduction of input contrast, subjects' contrast discrimination improves in the adapted range (psychophysics) and cortical response increases (fMRI) (Kwon et al., VSS 2007). Here, we ask whether the adaptation is best characterized as "response gain" (steepening of the underlying contrast response function, CRF) or "contrast gain" (shift in the midpoint of the CRF without a change in shape). We present a theoretical rationale for predicting adaptation to long-term contrast reduction should result in response gain while short-term adaptation to changes in stimulus contrast should result in contrast gain. Three normally-sighted subjects contributed psychophysical contrast-discrimination data and fMRI BOLD responses for a range of contrasts (1 – 33 %) before and after four hours of reduced-contrast viewing. CRFs were fit with a four-parameter variant of the Naka-Rushton equation (Rmax, C50, n, m), using both psychophysical and fMRI data and a standard linking hypothesis. We examined the parameter changes between pre- and post-adaptation and interpreted these changes to distinguish between contrast gain and response gain: an increase of Rmax in the post-test signifies response gain; a decrease of C50 signifies contrast gain. The mechanisms of the adaptation were tested with the F-test designed to identify the model that best accounts for the given data with the fewest parameters. Our results showed that the best-fitting model is response gain ($F(2,20) = 30.64$, $p < 0.01$; $F(2,20) = 28.90$, $p < 0.01$ for cortical areas V1 and V2 respectively). The adaptation increased the Rmax value by a factor of approximately 1.30 for V1 and V2. Our results indicate that long-term contrast adaptation (on the scale of four hours) is better described as "response gain" than "contrast gain."

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36.541

Isolating the Angular Harmonic of the Indirect Tilt After-Effect

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The Angular Harmonic (AH) at which Indirect Tilt After-Effects (TAEs) oscillate provides an important cue in revealing the underlying mechanism(s) responsible for the bias. Assuming that Direct but not Indirect TAEs are tuned for spatial frequency, we estimated the AH for Indirect TAEs using adapt and test gratings whose spatial frequency differed by 25% and whose temporal frequency (TF) was either 0 Hz or 18 Hz. The adapt and test contrasts were 60% and 30% respectively and their relative orientations were varied between 0° and 90°. Subjects reported whether the test grating's perceived orientation was rotated clockwise or anti-clockwise about vertical. At low adapt TFs, the AH of Indirect TAEs was estimated at 4 cycles per full circle, while at the higher adaptor TF, the AH was noisier but nearer to 2. Our results are consistent with the idea that Indirect TAEs arise from the adaptation of mechanisms preferentially selective for orthogonal orientations.

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36.542

Spatial and temporal integration in blur adaptation

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Because of factors such as the eye's limited depth of focus and accommodative lags, blur in the retinal image varies continuously over time and space. We examined how these variations are integrated in visual adaptation to image blur. Grayscale images were composed of a dense and random collage of rectangles and were filtered by varying the slope of the log amplitude spectrum over a range from -1 (strongly blurred) to +1 (strongly sharpened) relative to a focused slope of -1, with rms contrast held constant. The images subtended 4 deg and were varied in time to avoid local light adaptation. Subjects adapted for 60 sec to image sets drawn from a single slope or to a set of hybrid stimuli formed by combining pairs of images with different slopes. Test images were then interleaved with adaptation top-ups while the blur level was adjusted with a 2AFC staircase to determine the level of subjective best focus. Adaptation to blurred images caused physically focused images to appear too sharp and vice versa. These shifts were weaker in the hybrid images, suggesting that the adaptation is determined by the average image blur and not by the sharpest feature; but were biased toward sharper slopes, suggesting that this average is not linear with slope. In a second set of measurements, hybrid adapting sets were created by instead alternating in time between blurred and sharpened slopes. These again produced intermediate aftereffects relative to a single adapting slope. Measurements of the alternation rates at which the aftereffects become phase-dependent (ie dependent on the last presented slope) provide a measure of the integration time controlling blur adaptation, while combinations of different slopes within this time provide an estimate of how different blur levels are weighted to set the observer's state of adaptation to blur.

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36.543

Contrast-modulated noise shows an adaptable, rectifying, contrast-comparison process ("Buffy adaptation")

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For several years we have been studying an adaptable, rectifying, contrast-comparison process (nicknamed "Buffy adaptation") that dramatically increases visibility for some patterns and decreases it for others. We have been using patterns composed of evenly-spaced Gabor patches. Such patterns seem rather different from continuous texture patterns like contrast-modulated noise. Here we investigate whether the adaptable rectifying contrast-comparison process can also be demonstrated with contrast-modulated noise. And we ask whether a simple model can account quantitatively for the results.

The adapt pattern (1 sec in duration) is binary noise: an array of 512x512 checks in which each check is randomly chosen with probability 0.5 to be one of two luminances. The contrast of the binary noise adapt pattern is 50%. The test pattern (~90 ms in duration) has stripes defined by binary noise of two different contrasts C1 and C2 (with a square-wave modulation frequency of approximately 0.5 c/deg). The observer's task is to identify the orientation of the contrast-defined stripes, which can be either horizontal or vertical. To measure an observer's threshold, we hold the average test contrast constant and vary the difference between the contrasts (|C2-C1|). When one of the test contrasts is less than the adapt contrast and one is greater, it is called a straddle test pattern. We find the same results as with the Gabor-patch patterns: Performance is substantially worse on straddle test patterns than on test patterns in which both C1 and C2 are on one side of the adapt contrast (as long as they are not too far above or below the adapt contrast, in which case performance is again poor).

A simple model containing the adaptable rectifying contrast-comparison process in conjunction with a conventional gain-control process (e.g. a normalization network) can account well for the results.

36.544

Distortion in perceived object size accompanies saccadic adaptation

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Introduction and Motivation. The considerable evidence of the saccadic system's plastic nature has led some researchers to investigate the subsequent effects of saccadic adaptation on the conscious perception of visual stimuli. These studies found perceptual misjudgments of stimulus location after the amplitude of a saccadic eye movement had been adapted to compensate for an artificially induced, post-saccadic visual error. However, the overall effect on perception remains unclear, as only one saccade vector was adapted, the perceptually judged stimuli were flashed only briefly, and misjudgments were usually found only in the presence of a saccadic eye movement - a situation where perceptual illusions have also been demonstrated in the absence of saccadic adaptation. Here, we studied the effect of saccadic adaptation on the perception of a persistent object during fixation.

Methods. Three adaptation blocks (75 trials) were interleaved with four perceptual judgment blocks (60 trials). During adaptation trials, participants freely scanned a search display for a pre-specified target item. To reduce the amplitude of participants' saccades in only one dimension (horizontal or vertical), the search display was continuously shifted along that dimension during every saccade using a novel, whole-field saccadic adaptation paradigm (Garaas, Nieuwenhuis & Pomplun, 2008). Participants' perception of object size was measured by having them fixate a cross figure and indicate which bar (horizontal or vertical) they perceived to be longer. Cross figures of varying aspect ratios were presented using a staircase procedure which 'narrowed in' on participants' perceptual bias.

Results. The adapted component of participants' saccades was reduced by an average of 31%, while the unadapted component remained precise. Perceptual judgments were progressively biased toward perceiving greater relative height or width during the reduction of horizontal or vertical saccade components, respectively, $r = 0.61$, $p < 0.0001$.

Conclusion. Saccadic adaptation is accompanied by changes in perceived object size.

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Sunday Sessions

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36.545

A negative adaptation after-effect of mean size

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Recently, Burr and Ross (2008) reported a negative adaptation after-effect on the perceived numerosity of dot displays. Based on these findings, they proposed that numerosity is encoded as a basic property of scenes, like color, orientation, and other visual dimensions susceptible to adaption. Given mounting evidence that the visual system rapidly represents the mean size of sets of objects without representing individual items (e.g. Ariely, 2001), here we investigated whether a similar mean size adaptation after-effect occurs. On each trial, observers adapted to two displays of 16 dots with various mean sizes, presented simultaneously in opposite visual fields. After adaptation, two single circles replaced the dot displays, and participants judged which dot appeared larger. On average, observers perceived the test dot that appeared in the same location as the adapting display with the larger mean size as being smaller than the test dot that replaced the adapting display with the smaller mean size. This negative after-effect suggests that mean size is also represented as a basic dimension of visual scenes.

36.546

Visual Replay Effect: Objective Evidence from a Masking Paradigm

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Transcranial magnetic stimulation (TMS) is a non-invasive method employing a magnetic coil to generate an electrical signal in the human brain. When applied directly to the visual cortex, TMS induces either scotomas (blind spots) or phosphenes (flashes of light) depending on coil type and stimulation conditions. Interestingly, if TMS is applied at a particular timing after a visual stimulus, an "instant replay" of the original stimulus is perceived, typically within the phosphene area (Halelamien, et al, VSS 2007). This replay effect potentially offers unique insight into the formation and storage of mental representations. To obtain objective evidence of replay's perception and determine if replay shares the same early perceptual circuit as retinally-triggered stimuli, we use a masking paradigm to examine replay's spatial and temporal specificity. Subjects were presented a physical mask followed by a letter, which they were asked to report. In the TMS condition, a double pulse of TMS was administered after mask presentation to facilitate "replay" of the mask, obscuring letter detection. The timing was carefully selected such that there was no direct forward masking by the physical mask but a potential masking effect by the replayed mask. Three conditions were tested with and without TMS: 1) no physical mask presented, 2) physical mask and letter in different positions, and 3) physical mask and letter in the same position. We found that the replay effect was most pronounced when the delay between mask and TMS pulse was 150-250 ms. Further, our data shows statistically significant performance degradation with the addition of TMS only when the physical mask and letter are presented in the same visual location, suggesting a replay induced masking effect. These results provide evidence for the ability of TMS induced replay to interact with the same perceptual circuits as retinal input in a spatiotopically organized manner.

36.547

Detection mechanisms selective to combinations of luminance- and contrast-modulations

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First, we evaluated cross-attribute interactions by measuring detection thresholds for luminance- (LM) and contrast-modulated (CM) Gabor signals embedded in either LM or CM noise. As previously found (Allard and Faubert, VR 2007), masking was attribute-specific: detection thresholds for LM signal were greater in LM than CM noise and vice versa. This suggests independent mechanisms for these two attributes at the detection stage. We then investigated whether there are additional mechanisms that detect specific combinations of the two attributes by measuring detection thresholds when the two were combined in phase (LM+CM) or in counter-phase (LM-CM) and embedded in either LM+CM or LM-CM noise. When the signal and noise were defined by the same combination (both in phase, or both in counter-phase), detection thresholds were greater than when the signal and noise were defined by orthogonal combinations (e.g. in-phase signal, counter-phase noise). Furthermore, when the signal and noise were defined by orthogonal combinations, the detection thresholds were lower than the single attribute detection thresholds (e.g. LM signal, LM noise). Consequently, the combination of LM and CM attributes was detected even though both of the component attributes were subthreshold. This result implies that in addition to the independent LM and CM detection mechanisms, there must be others that respond to specific combinations of these attributes.

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36.548

Critical-Band Masking Estimation of 2nd-Order Filter Orientation Bandwidth

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Standard models of texture segregation comprise (i) a linear filter (to enhance a constituent texture), (ii) a nonlinearity (to compute 'texture energy'), (iii) a second linear filter (to enhance the texture modulation), and (iv) a decision stage. We estimated the orientation tuning of the 2nd-order filter using the critical-band masking technique. Methods: The task was 2-interval forced-choice detection. Target stimuli were 2nd-order vertical sine-wave gratings (0.5 cycle/deg) masked by 2nd-order noise. The noise had narrow spatial frequency bandwidth centered on the target frequency. The orientation bandwidth of the noise was varied across blocks, ranging from 0 (no noise) to 180 deg (all-pass in the orientation domain) in steps of 30 deg, by sweeping the cutoff angle from horizontal (at 0 deg bandwidth) through vertical (at 90) and back to horizontal (at 180 deg), both clockwise and counterclockwise. In the target interval, a grating plus noise mask was used to modulate between two carrier textures (sine-wave gratings, 4.0 cycle/deg, oriented at -45 and 45 deg). In the non-target interval, the modulator was a noise mask alone. Modulator and carrier grating phases were randomized. Noise spectral density was held constant, and signal contrast was controlled by interleaved staircases. Threshold contrast elevation was obtained for each noise-mask cutoff angle. A sigmoid was fit to clockwise and counterclockwise noise-orientation-cutoff sweeps to derive the 2nd-order channel's orientation tuning. Results: Estimated 2nd-order orientation tuning is broad relative to 1st-order channels. Simulations of the standard filter-rectify-filter texture-segregation model will be compared to our behavioral data.

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36.549

Spatial-frequency tuning develops over time

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Recent neurophysiological observations on the development of orientation and spatial-frequency tuning in the primary visual cortex are equivocal—some studies report that tuning is virtually complete as soon as it can be measured while others report significant sharpening of both aspects of tuning. The issue is important because it bears on the mechanisms that produce the tuning: is tuning acquired simply from careful combination of the weakly tuned lower mechanisms in the midbrain (LGN) or is intracortical or even cortico-thalamic interaction required to produce the much tighter tuning seen in cortical cells? Here we provide unequivocal behavioural evidence derived from psychophysical, 2-AFC critical band-masking

Sunday Sessions

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experiments with human observers, showing that spatial-frequency tuning develops over the first tens of milliseconds. We discuss the implications for the implementation of the characteristics we measure.

36.550

Surround suppression in visual cortex: Effects of spatial frequency

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Surround suppression, the phenomenon in which the perception and/or neural response to a target is reduced by the presence of a surrounding annulus, was previously demonstrated in early visual cortex with fMRI (e.g., Williams, Singh, & Smith, 2003). Here, we investigated whether the surround suppression of fMRI responses is influenced by stimulus spatial frequency, an effect that has been shown psychophysically (Betts, Sekuler, & Bennett, 2008). The central region of interest (ROI) was defined in four observers (mean age: 28.3 years) as the cortical area exhibiting greater responses to a 3 deg circular checkerboard than to an annulus (inner diameter = 3 deg, outer diameter = 9 deg). Activation of this central ROI was measured during two types of scans: 1) the Center-Alone (CA) scan, in which the presentation of a 3 deg circular grating alternated with a uniform field, and 2) the Center + Surround (CS) scan, in which the 3 deg circular grating was always present and a surrounding annulus grating alternated on and off. CA and CS scans used horizontal gratings with spatial frequencies of 0.33 and 1 c/deg that flickered at 5 Hz. As expected, ROI activation was positively correlated with the presence of the circular grating in the CA condition. ROI activation was negatively correlated with the presence of the annulus in the CS condition, even though the central stimulus was always present. This result is consistent with surround suppression. The ratio of CS to CA activation in the 25% most responsive voxels was significantly greater in the 0.33 c/deg condition in all observers. This result is consistent with psychophysical results showing greater surround suppression for 0.5 c/deg than for 1 c/deg. Future research will extend the paradigm to older adults to examine the hypothesis that aging reduces surround suppression in early visual cortex.

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Monday Sessions

Color and Light: Lightness and Color of Surfaces

Monday, May 11, 8:30 – 10:00 am
Talk Session, Royal Palm Ballroom 1-3
Moderator: James Schirillo

41.11, *8:30 am*

Grouping by illumination level: Surroundedness can substitute for adjacency in the coplanar depth effect

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Because reflectance is confounded with illuminance in the retinal image, illuminance must be somehow discounted. But the illumination level need not be known if the visual system can determine which surfaces share the same illumination level. Two surfaces that are coplanar, adjacent, and separated by a sharp boundary support a strong inference of common illumination. But the inference is weakened as the two surfaces are separated by a gap, even though coplanar, because an illumination boundary might fall within the gap. But if one surface completely surrounds the other, even if separated by a gap, their illumination will be the same except in the unlikely event that the illumination boundary just fits within the gap. We tested this idea using the perpendicular planes stimulus of Gilchrist (1977). First, each 4cm target was moved 2cm laterally within its plane so that it appeared to float in space. This destroyed most of the coplanar ratio effect. Next, the large square coplanar neighbor of each target was extended so that the target was surrounded by a 1.7 cm square border, with a 2 cm gap between target and border. This produced a coplanar ratio effect half as strong as that produced by adjacency, but only for the target in the highly-illuminated plane. A further experiment with articulated planes showed no difference whether the highest luminance in the plane was adjacent to the target or three or more patches removed from the target. Many studies have shown that target lightness depends on proximity to the highest luminance when these are separated by a gap. Our results and others show that proximity plays little or no role when the space between target and highest luminance is filled with other surfaces, presumably because any intervening illumination boundary would be revealed by these mediating surfaces.

Acknowledgement: NSF (BCS-0643827) NIH (5R25GM060826)

41.12, *8:45 pm*

An Edge-Based Account of Lightness Compression and Insulation in the Staircase Gelb Effect

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We know from classical demonstrations such as simultaneous contrast that the lightness of an image region can be strongly influenced by its local border contrast. More generally, though, lightness depends on a combination of the local border contrast with the contrasts of other borders within the region's extended surround. In previous work, my colleagues and I introduced a quantitative model of lightness computation based on the idea that lightness is computed from weighted sum across space of logarithms of luminance ratios at edges (edge integration). This model accounts with great quantitative precision for lightness judgments in simple stimuli such as disks surrounded by rings (Rudd & Zemach, 2004, 2005). Here I apply the most recent version of this model (Rudd & Popa, 2007)—which combines edge integration with a contrast gain control mechanism acting between borders—to the problem of predicting the lightness of the steps in a staircase Gelb display. Experiments by Gilchrist and his colleagues have revealed two interesting quantitative properties of lightness perception in the staircase Gelb display. First, the range of perceived reflectances of the staircase steps is strongly compressed relative to the actual physical reflectance range. Second, when the staircase is surrounded by a white frame the perceived reflectance range becomes much more veridical (less compressed), an effect known as "insulation" (Gilchrist et al., 1999). I will explain how the edge integration model accounts for both the compression and insulation effects. The results are consistent with a general neural scheme for computing lightness involving a weighted combination of edge-based filling-in signals whose gains are modulated by the surrounding spatial context.

References

Rudd, M. E. & Zemach, I. K. (2004). Vision Res., 44, 971-981; (2005). J. Vision, 5, 983-1003.

Rudd, M. E. & Popa, D. (2007). J. Opt. Soc. Am. A, 24, 2766-2782.

Gilchrist, A. et al. (1999). Psychol. Rev., 106, 795-834.

41.13, *9:00 am*

Shadows Control Microsaccades and Drift

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Are microsaccades simply random movements that return a drifting eye to a fixation point? Or do microsaccades and drift play a functional role in visual analysis?

Our work on lightness algorithms for computer vision suggests that movements on the temporal and spatial scale of microsaccades and drift might be extremely useful for measuring colorimetric phenomena that are critical for recognizing illumination flux. To test this hypothesis, we created a number of different stimuli that simulate the spatial distribution of color and intensity, i.e., the spatiospectral order, typically created by shadows or, more generically, illumination boundaries. As a control, we generated another set of stimuli constituted of exactly the same colors in the same quantities but that did not contain patterns plausibly created by illumination boundaries, and thus appeared to represent only material boundaries. We then monitored the microsaccades and drift of 40 subjects who were asked to free-view each of the stimuli for 20 seconds each.

Our experiments suggest that microsaccades and drift are indeed substantially controlled by the high-order spatiospectral differences between material and illumination boundaries, often thought to be accessible only at the cortical level. To a significant extent, microsaccades and drift are not random and may be tied to the functional detection of illumination flux and shadows.

41.14, *9:15 am*

Yellow papers under blue light vs. blue papers under yellow light: same or different?

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A yellow paper lit by a blue light reflects the same neutral light as a blue paper lit by a yellow light. However, they look rather different. Moreover, neither appears as a grey paper lit by a neutral light which reflects the same light. Using multidimensional scaling we analysed the dissimilarity structure produced by these papers.

Three normal trichromatic observers took part in the experiment. The stimulus display consisted of 3 identical sets of 7 Munsell papers (10B5/12, 10B5/8, 10B6/4, N6.5, 2.5Y7/6, 2.5Y8/10 and 2.5Y8/16) illuminated independently by 3 light sources. The lights were adjusted so that the CIE xy-chromaticity coordinates of the light reflected from yellow paper 2.5Y8/16 under blue light, blue paper 10B5/12 under yellow light, and grey paper under neutral light were close: (0.267, 0.316), (0.288, 0.345), and (0.267, 0.351), respectively. Dissimilarities between the Munsell papers for all the illuminations were evaluated by ranking (see further details of the method in Tokunaga, Logvinenko, & Maloney, Visual Neuroscience, 2008, 25, 395-

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398). In spite of the close proximity between chromaticity coordinates, the yellow paper under blue light and blue paper under yellow light were judged only slightly less dissimilar than these papers under neutral light by the three observers: 97, 92, and 90%. As all of the lights and papers were simultaneously present in the scene, such a colour constancy effect can hardly be accounted for by chromatic adaptation.

A phenomenon similar to the illumination contrast discounting (see Logvinenko & Tokunaga, VSS'09) was also observed in the chromatic domain. Specifically, the same difference in the CIE chromaticity was found to be judged as less dissimilar when it was produced by the paper difference than by the illumination difference. Hence, while both material and lighting colour difference contributed into dissimilarity judgements, the former was more effective.

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41.15, *9:30 am*

Surface material properties and color constancy of 3D objects

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Purpose: Most previous research on color constancy has studied matte flat surfaces. Very little is known about color constancy for three-dimensional objects. Such objects can be made of different materials. We investigated the effect of object material properties on color constancy. Methods: Stimuli were computer-rendered three-dimensional scenes viewed stereoscopically. Three simulated scene illuminants were used: Neutral, Blue and Yellow. On each trial, a test sphere appeared briefly in the scene. On red/green trials, observes judged whether the test sphere appeared reddish or greenish. On blue/yellow trials, observers judged whether the test sphere appeared bluish or yellowish. A staircase procedure controlled the body color of the test sphere, and over trials this converged so that the sphere appeared achromatic. In different blocks, the specular component of the test sphere was varied to simulate different materials. The achromatic chromaticities for each material were compared across simulated illuminant changes to compute a constancy index (CI). Results: We ran consistent-cue and reduced-cue conditions. In the consistent-cue condition only the illuminant was varied, while the contextual surfaces in the scene remained fixed. The CIs were similar for all materials. It is possible that constancy was near ceiling for all materials, thus masking an effect of material. In the reduced-cue condition, we co-varied the simulated reflectance of the background wall with the illuminant, so as to hold the light reflected from the wall constant. This eliminated local contrast as a cue to the illuminant change. For data from the three observers studied so far, CIs were still similar for all materials, although with a trend in the direction of more constancy for glossy tests. Conclusion: Constancy is robust across changes in object material properties. Specular highlights on the test object may lead to an increase of constancy, but this effect is small if it is real.

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41.16, *9:45 am*

An Ecological Valence Theory of Human Color Preferences

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We studied color preferences for 37 colors: 8 hues x 4 brightness/saturation levels plus five grays. Average color preference for saturated, desaturated, and light colors was a relatively smooth function of hue with a strong peak at blue and a trough at chartreuse. The hue function differed for dark colors: dark orange and yellow were much less preferred, and dark red and green were somewhat more preferred. Males preferred saturated colors to desaturated ones, whereas females preferred desaturated colors to saturated ones. Male-female differences were highly correlated with rated activeness/passiveness of colors (r=0.73), with males preferring active colors. People with greater color expertise preferred chromatic colors more than novices, but both preferred achromatic colors equally. Despite enormous individual differences, hue preference was relatively stable within observers across brightness/saturation levels (average r=0.35). Hue preference was also relatively stable across contextual objects: walls, trim, couches, pillows, shirts/blouses, ties/scarves (average r=0.65). A colorimetric model based on yellowness/blueness, saturation and brightness/darkness explained 60% of the group variance, whereas an emotional-association model based on calmness, courageousness, and frustratedness of colors explained 79%. We also tested an ecological-valence model, hypothesizing that people like colors that remind them of positive things (sky, trees) and dislike colors that remind them of negative things (vomit, feces). We asked participants to name all the objects that came to mind for each presented color and later obtained ratings of how positive/negative they felt about each object. We then weighted the average valence for each object by the frequency with which it was reported for each color. Color preference was strongly related to this weighted object valence measure (r=0.83), suggesting that color preference may be analogous to taste in food: a heuristic designed to help guide us toward potentially beneficial objects and situations and away from potentially harmful ones.

Acknowledgement: NSF grant BCS-0745820, Google

URL: http://socrates.berkeley.edu/~plab/color.html

Scene Perception: Mechanisms and Representations

Monday, May 11, 8:30 – 10:00 am
Talk Session, Royal Palm Ballroom 4-5
Moderator: Alice Albrecht

41.21, *8:30 am*

Rapid, global image processing: Powerful, but capacity-limited

Karla Evans[1,2] (kevans@search.bwh.harvard.edu), Jeremy Wolfe[1,2]; [1] Brigham & Women's Hospital, [2]Harvard Medical School

It has been well documented that people are able to get some semantic and/or statistical information out of a briefly presented image. They are able to report on the gist of a scene in 100 ms (Potter, 1975), detect the presence of an animal in an image presented for 20 ms (Thorpe et al., 1996) and determine the mean size of sets of objects (Ariely, 2001; Chong & Treisman, 2003). These findings suggest that some advanced scene processing is possible without attentional selection of specific objects. What are the limits on this non-selective processing? During natural viewing, do we have simultaneous access to multiple non-selective possibilities: mean orientation, scene gist, animal detection, etc? Alternatively, perhaps we only have access to currently task-relevant capability. If you are looking for animals, you might not automatically compute mean orientation. In a series of psychophysical experiments we tested whether there is a cost to non-selective processing and the nature of that cost.

We compared conditions where observers know the relevant global image property before seeing the stimulus to conditions where the relevant global property is specified after the stimulus has been presented. The results show that observers' post-cued performance was well beyond what could be achieved if that processing ability had to be set to one attribute at a time. However, performance was below what would be predicted if observers computed all non-selective properties without cost. In a second set of experiments, observers monitored RSVP streams for one target category (e.g. beach) in a block of trials where two others (e.g. person, vehicle) could be targets. Images containing a trial-relevant and a block-relevant item (car on beach) produced more errors as the presence of the car seemed to block encoding of the beach. Non-selective processing of semantic information cannot encode all available signals.

41.22, *0:45 am*

Perceptually averaging in a continuous visual world: Extracting statistical summary representations over time

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We typically think of perception in terms of processing individual features, objects, and scenes, but a great deal of information is also distributed over time and space. Recent work has emphasized how the mind extracts such information, as in the surprisingly efficient ability to perceive and report the average size of a set of objects. The extraction of such statistical summary representations (SSRs) is fast and accurate, but it remains unclear what types of populations these statistics can be computed over. Previous studies have always used discrete input — either spatial arrays of shapes, or temporal sequences of shapes presented one at a time. Real-world visual environments, in contrast, are intrinsically continuous and dynamic. To better understand how SSRs may operate in naturalistic environments, we investigated if and how the visual system averages continuous visual input. When faced with a single disc that continuously expanded and contracted over time — oscillating among nine 'anchor' sizes — observers were equally accurate at reporting the average disc size as when the nine anchors were presented in a single spatial array. We further demonstrated that the averaging process samples continuously (and not just over the 'anchor' sizes, for example) by manipulating the durations over which the objects expanded and contracted. When a disc expanded, for example, it could spend more time during either its initial expansion (when it was smaller) or its subsequent expansion (when it was larger) — and this manipulation greatly influenced the reported average sizes, even though the discs always oscillated between the same anchor sizes. These studies, along with additional manipulations, show that SSRs are continuously updated over time, and that the resulting averages are as accurate as with spatial arrays. As such, these results illustrate how SSRs may be well adapted to dynamically changing real-world environments.

URL: http://www.yale.edu/perception/

41.23, *9:00 am*

The bear before the forest, but the city before the cars: revealing early object/background processing

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Natural scene recognition can be seen as a process of decomposition (first the gist is extracted and then objects identities) or a progressive build up (spatial relationships between objects give rise to the global scene). Since the contribution of the background on object identification is still controversial, knowing the processing times for object and background recognition as well as their interactions could be crucial. Previous reaction time studies by our group using manual responses suggest parallel object and context processing with early interactions (from context on object categorization and from salient objects on context categorization, Joubert et al., 2007, 2008). In order to assess the very first step of this early interference, we used a choice saccade task where participants had to choose between pairs of natural scenes according to their global context or to the object they contained. Manipulating the nature of object (animal, vehicle, no object) and background (natural, man-made) relationships, we showed that choosing on the basis of the background can be done very quickly and efficiently (median RT = 217 ms and 72% correct for natural, 213 ms and 74% correct for man-made). Roughly comparable performance was observed in the object discrimination task, although we found a strong search asymmetry with an advantage for animals (181 ms, 81%) over vehicles (207 ms, 63%). Interestingly, and in contrast to previous manual response studies, we found no evidence for object/background interactions (in terms of congruency) at such extremely short processing times, suggesting that early interactions during the first feed-forward sweep do not take place in the first steps of cortical processing but rather in higher level cortical areas.

41.24, *9:15 am*

Natural scene categorization by global scene properties: Evidence from patterns of fMRI activity

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Human scene categorization is remarkably rapid and accurate, but little is known about the neural representation mediating this feat. While previous studies on neural representation of scenes have focused on basic level scene categories, here we examined whether the neural representation of scenes reflect global properties of scene structure, such as openness of a space, or properties of surfaces and contents within a space, such as naturalness. In an fMRI study, human participants performed a one-back task on blocks of images of four scene groups: Open Natural images, Closed Natural images, Open Urban images, Closed Urban images. Each image group included multiple basic level categories. For example, Open Natural images included open views of fields, oceans and deserts; while Open Urban images included open views of highways, parking lots, and airports. For each participant, we defined regions of interest (ROIs) of the parahippocampal place area (PPA), the fusiform face area (FFA), lateral occipital complex (LOC) and V1. Multivariate pattern analysis was applied to voxels within each ROIs, and split-half pattern correlation and Euclidian distances across voxel activations were calculated (Haxby et al., 2001). We observed high identification accuracy in the PPA and V1, but not in the FFA and LOC. Most interestingly, when the correct identification failed in the PPA, the confusion was between images with the same layout rather than between images with the same content. For example, Open Natural images were often highly correlated with Open Urban images, but rarely with Closed Natural images. These results suggest that a critical component of scene representation in the brain is the coding of global properties of spatial layout.

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41.25, *9:30 am*

Making Big Things Look Small: Blur Combined with Other Depth Cues Affects Perceived Size and Distance

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Blur is commonly considered a weak distance cue, but photographic techniques that manipulate blur cause significant and compelling changes in the perceived distance and size of objects. One such technique is "tilt-shift miniaturization," in which a camera's lens is translated and slanted relative to the film plane. The result is an exaggerated vertical blur gradient that makes scenes with a vertical distance gradient (e.g., bird's-eye view of landscape) appear significantly nearer and therefore smaller. We will begin by demonstrating this compelling effect, and then describe how we used it to examine the visual system's use of blur as a cue to distance and size. In a psychophysical experiment, we presented computer-generated, bird's-eye images of a highly realistic model of a city. Blur was manipulated in four ways: 1) sharp images with no blur; 2) horizontal blur gradients were applied to those images; 3) vertical gradients were applied; 4) a large aperture (diameter up to 60m) was used to create an image with an accurate correlation between blur and depth for realizable, small-scale scenes. Observers indicated the perceived distance to objects in the images. Technique 1 produced a convincing impression of a full-sized scene. Technique 2 produced no systematic miniaturization. Techniques 3 and 4 produced significant and similar miniaturization. Thus, the correlation between blur and the depth indicated by other cues affects perceived distance and size. The correlation must be only reasonably accurate to produce a significant and systematic effect. We developed a probabilistic model of the relationship between blur and distance. An interesting prediction of the model is that blur only affects perceived distance when coupled with other distance cues, which is manifested in the tilt-shift effect we observed in humans. Thus, blur is a useful cue to absolute distance when coupled with other depth information.

41.26, *9:45 am*

Representational Transparency in Aesthetic Judgments of Spatial Composition: Effects of Object Position and Size

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Previous research has shown robust, systematic aesthetic preferences for the horizontal position and facing direction of single objects within rectangular frames (Palmer, Gardner & Wickens, 2008; Gardner & Palmer, VSS-2006, VSS-2008). People prefer an object to be laterally positioned near the center (the "center bias") and to face into, rather than out of, the frame (the "inward bias"). Similar, but more complex, biases occur in the vertical dimension: a "lower bias" for objects supported from below and viewed from above (a bowl on a table), an "upper bias" for objects supported from above and viewed from below (a light fixture on a ceiling), and a "center bias" for symmetrical images of gravitationally unsupported objects (a flying eagle viewed from directly below or above). The object's characteristic ground-relative position in the world also affects people's preferences for vertical placement: eagles are preferred higher and stingrays lower in the frame. Real-world compatibility in the size domain also affects aesthetic judgments: a mouse picture is preferred when it is smaller within the frame and an elephant when it is larger (Konkle & Oliva VSS-2007). Canonical perspectives (Palmer, Rosch & Chase, 1981) also produce higher preference ratings for pictures of objects (Khalil & McBeath, VSS-2006). These effects can be unified by the "representational transparency" hypothesis: observers prefer images in which the spatial characteristics of depicted objects in the world are optimally reflected in analogous spatial properties of the image. This has both a real-world-position component (eagles higher, stingrays lower) and a viewer-relative component (objects viewed from below are preferred higher, objects viewed from above are preferred lower). Representational transparency provides a reasonable first-order approximation of default expectations for people's aesthetic responses, but greater aesthetic value often requires violating these expectations in meaningful ways that reflect the intentions of the artist.

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Spatial Vision: Crowding and Mechanisms

Monday, May 11, 11:00 am – 12:45 pm
Talk Session, Royal Palm Ballroom 1-3
Moderator: Bosco Tjan

42.11, *11:00 am*

Spatial interactions in crowding: effects of flankers' relations

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We examined local and global effects in crowding. Crowding anisotropy was tested varying flankers' local orientation, global relations, and location. A high-contrast horizontal Gabor target was placed on the horizontal meridian at 2.5º eccentricity, flanked by two Gabor patches of same contrast, at 0º, 45º, or 90º relative to the horizontal meridian (referred to as radial, diagonal and tangential conditions, respectively). In each condition flankers were either collinear or parallel relative to each other (local orientations of 0º/90º in the radial and tangential arrangement, and 45º/135º in the diagonal arrangement). Crowding was quantified as an increase in log orientation discrimination thresholds in the presence of flankers. Crowding was insignificant with the tangential pairs (<0.1), but was found with the diagonal (0.3 & 0.56), and the radial (0.55 & 0.12) pairs (collinear & parallel pairs, respectively). The difference between the collinear and parallel pairs' effects was independent of local orientations (0º & 45º). Thus, oriented Gabor stimuli show an ∞ shape interaction zone rather than the elliptical used to describe the results of Toet & Levi (1992) with T stimuli. Additional results indicate an interaction of flankers' location, local orientations, and global relations in crowding by two flankers. The effects of these pairs, however, were found to be non-indicative of crowding produced by a variety of circular arrangements of flankers (as in Livne & Sagi 2007). We will describe results from such configurations suggesting that flankers' grouping is an important factor in crowding. Flankers modulate the effects of each other – remote flankers may exert their effect on a target via intermediate flankers, showing in some cases separation-independent crowding. By applying a quantitative model of crowding, based on basic gestalt grouping rules (proximity, similarity, continuity), to the obtained experimental results we were able to rank specific local relations (collinearity, co-circularity, etc) in respect to their combined effect.

42.12, *11:15 am*

Crowding in peripheral vision: why bigger is not always better

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Crowding, the deleterious influence of nearby contours on visual discrimination, is ubiquitous in spatial vision. Crowding impairs recognition of objects in clutter, and is thought to reflect inappropriate integration of target and flankers in peripheral vision. One prediction of the faulty integration model is that increasing the size of the flankers should result in increased crowding. We tested this hypothesis using a simple orientation discrimination task. The target was a Gabor patch, and the flankers were comprised of N segments (N = 1 to 8) of an annular grating. Strong threshold elevation occurred when the inner edge of the annulus was closer than about 0.4 times the target eccentricity. Control experiments (e.g. target detection, and radial/tangential asymmetries) verified that this threshold elevation was due to crowding rather than masking or surround suppression. Fixing the position of the inner edge and increasing the size of the annulus resulted in a monotonic decrease in the magnitude of crowding – i.e., the bigger the flanks, the smaller the crowding. To characterize this surprising result we: 1) fixed the annulus size and varied the target-flank distance, 2) fixed the outer edge of the annulus and varied its size. All three data sets superimposed when plotted as a function of the center-to-center distance between target and flanks. Taken together our results provide an explanation for the unexpected effect of flank size – increasing the annulus size (with a fixed inner radius) increased the center-to-center distance between target and flankers. The faulty integration model is indeed faulty. The results are consistent with the notion that the visual system extracts the centroids of features (both targets and flankers) within ≈ 0.4 times the target eccentricity, and jumbles them up into a crowded percept, so bigger is not necessarily better.

Acknowledgement: NEI grant RO1EY01728

URL: http://levilab.berkeley.edu/

42.13, *11:30 am*

Crowding-induced changes in appearance: Bringing signal to the noise

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Crowding is a breakdown in object recognition that occurs in cluttered visual environments. Though often attributed to inhibitory or noisy processes that result in information loss, we show that crowding actually produces a systematic change in the appearance of target objects. In particular, patches of isotropic bandpass-filtered noise appear oriented when crowded by four identically oriented Gabor patches. This was assessed with a novel change-detection paradigm, where either the target or flanking stimuli (counterphasing at 2 Hz) could be changed midway through the 1-second presentation. Observers were required to detect changes in the target noise, positioned at 15º eccentricity. On trials in which a Gabor replaced the noise element, subjects' ability to detect change was directly related to the similarity between flanks and the replacement Gabor: while dissimilar substitutions were easy to detect, similar substitutions were rarely noticed. This indicates that the perceived orientation induced by crowding is indistinguishable from physically oriented stimuli. The strength of this induced orientation was also apparent on trials when flank orientation changed (leaving target noise unaltered), with observers frequently indicating an

erroneous rotation of the target. When this crowded noise was used as an adaptor, the perceived orientation of subsequently presented Gabor stimuli showed a strong tilt aftereffect (TAE), while contrast-detection thresholds were unaffected. This TAE cannot be solely attributed to spatially non-specific adaptation at the flank locations, as adaptation to the flanks in isolation induced a much smaller TAE. Rather, these results demonstrate that crowding arises from the superimposition of target and flank signals in the target location, via interactions that occur after the initial feature-detection stage. It is through these interactions that crowding exerts what amounts to an organisational influence, combining information from adjacent locations in the peripheral visual field.

Acknowledgement: Funded by the Wellcome Trust.

42.14, *11:45 am*

Modulation of the spatial extent of the crowding effect by shaping visual attention

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The visual crowding effect is a ubiquitous phenomenon in peripheral vision. However, the role of spatial attention on crowding remains controversial. Here we examined this issue by manipulating the spatial distribution of visual attention through a pre-cueing paradigm and measuring the strength as well as the critical spacing of the crowding effect. In an orientation discrimination task, a Gabor target was presented in the lower right visual field, and distractors (also Gabor patches) were presented either vertically (above and below the target) or horizontally (left and right of the target), with the distance between the target and distractors varied across trials and serving as one of the independent variables. Just before the appearance of the target and distractor stimuli, observers were asked to perform a Vernier discrimination task or a color discrimination task either in a vertical or horizontal orientation, with the purpose of shaping observers' spatial attention to be along or perpendicular to the axis of the subsequent target-distractor configuration. Results consistently showed a reduced crowding effect as well as a reduction in critical spacing of crowding when observers' spatial attention was pre-cued to be orthogonal to the target-distractor configuration, compared with when attention was pre-cued along the target-distractor configuration. These results provide strong support that both crowding strength and critical spacing of crowding can be modulated by shaping spatial attention and spatial attention plays a critical role in the crowding effect.

42.15, *12:00 pm*

Three essential ingredients of crowding

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Crowding refers to the marked inability to identify a target when it is flanked by other objects. Recent findings have linked crowding to many form-vision deficiencies in the periphery (Levi, 2008; Pelli and Tillman, 2008). Currently, no precisely specified computational model exists to satisfactorily explain the phenomenon. We used an ideal-observer model to examine the roles of three types of limitations that might lead to crowding in peripheral vision: low spatial resolution, large positional uncertainty, and a perceptual template with a limited field of view (FOV). Each combination of these limitations was examined. Given the assumed limitations, the ideal observer made the statistically optimal decision to identify a target letter ("a", "e", "o", "s") either presented alone or flanked by a letter on each side. We gauged the performance of the ideal-observer model by the stimulus signal-to-noise ratio (SNR) required to reach 75% correct identification. Low spatial resolution was simulated by low-pass filtering the stimulus with 1/e cut-off at 2.5 c/letter. Positional uncertainty, if present, was set to ± 0.5 letter width. FOV was either one letter width or unlimited. These conditions were chosen to mimic the condition of viewing a letter 2-3 times the acuity at 5^{o} eccentricity. We found that while adding one or more of these limitations elevated SNR threshold, thresholds for the flanked-letter condition were essentially identical to those for the single-letter condition except when all three limitations were present. In other words, crowding occurs for an observer that optimally utilizes stimulus information only when spatial resolution is low, positional uncertainty is high, and the field of view of the perceptual template covers only one object. These requirements explain the weak crowding in the fovea and why the internal features of an object cause less crowding than adjacent objects.

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42.16, *12:15 pm*

Adapting to astigmatism

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Adapting to blurred or sharpened images alters the perceived focus of subsequently viewed images. We examined whether these adaptation effects could arise from actual sphero-cylindrical refractive errors, and whether they can be selective for specific aberrations by testing different axes of second-order astigmatism. Arrays of images were generated by titrating the magnitude of astigmatism over +0.3 microns, with varying defocus added to maintain constant blur strength (0.35 microns). The two ends of the series thus contained images blurred by only astigmatism, while the center image in the series was isotropically blurred with spherical defocus. Images subtended 4 deg, and were spatially jittered in time to avoid local light adaptation. Subjects adapted for 1 min to full astigmatic blur along either axis and then to 5-sec top-ups interleaved with test images. A 2AFC staircase was used to estimate the stimulus that appeared isotropic. Adaptation to horizontally blurred images caused a stimulus with no astigmatic blur to appear vertically biased and vice versa, shifting the perceived isotropic point to images that were thus more blurred along the adapting axis. Similar orientation-selective aftereffects were found for images of filtered noise or natural scenes. Because astigmatic blur distorts perceived shapes in the images (in addition to perceived "fuzziness"), the observed effects could reflect figural aftereffects for shape rather than adaptation to blur per se. These figural changes are larger in smaller images, since the angular distortion from blur is constant while the object angle varies with size or distance. In further measurements we compared aftereffects in different-sized images that have equivalent blur but different shapes or vice versa. Our results suggest that at least for lower-order aberrations, spatial vision can selectively adapt to the blur introduced by the eye's optics, and that this adaptation may include meridionally specific adjustments to perceived defocus and shape.

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42.17, *12:30 pm*

The development of contrast sensitivity for gratings and natural images: revisiting the golden standard

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Our recent work suggests the children's sensitivity to changes in the spatial frequency content of natural images cannot be predicted by their spatial contrast sensitivity function (CSF) measured with sinusoidal gratings (VSS 07 & 08). The present study compared root-mean-square CS for natural images, phase-scrambled versions of the same images, and Gabors in children aged 6, 8, and 10 years (n = 16 per age) and in adults (mean age = 22). Natural and phase-scrambled images were band-pass filtered (1 octave) at one of five frequencies (0.33, 1, 3, 10, & 20 cpd). In this way, we were able to create an equivalent CS metric for natural and phase-scrambled images as that used with Gabors. Detection thresholds were measured using a temporal 2AFC task combined with a QUEST staircase. As expected, CS with Gabors was adult-like for 8-year-olds. However, our results raise three new

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issues regarding CS. First, for both adults and children, the shape of the CSF is different for natural images in comparison to gratings and phase-scrambled images. For natural images, peak sensitivity lies at higher spatial frequencies and the slope of the high spatial frequency turn-down is much shallower. Second, adult sensitivity is higher for natural images than for the two other stimulus types. Finally, CSF for natural images is still immature for 10-year-olds and the difference in threshold between children and adults is greater for natural images than for gratings or phase-scrambled images, indicating that sensitivity to natural images develops more slowly. Given the important developmental differences between traditional measures of CS using gratings and CS measured with natural images, the latter might be more relevant for the clinical assessment of visual development and visual pathology.

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Attention: Selection and Modulation

Monday, May 11, 11:00 am – 12:45 pm
Talk Session, Royal Palm Ballroom 4-5
Moderator: Leila Reddy

42.21, *11:00 am*

Capturing attention without perceptual awareness

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Visual images that convey threatening information can automatically capture attention. One example is an object looming in the direction of the observer—presumably because such a stimulus signals an impending collision. However, it is not known if conscious processes are required to drive this attentional prioritization. Instead, detecting threatening stimuli may rely on separate, unique neural processes that are independent of perception.

To test the hypothesis that threatening stimuli can be detected without conscious perception, we generated an image sequence on a flat monitor of a looming ball that moved either on a collision path with the subject's head or on a path nearly missing the head. Critically, observers were unable to distinguish a collision path from a near-miss path in a two alternative forced-choice control experiment. Following each looming stimulus, subjects were asked to search for and determine the orientation of an oval stimulus among a series of distracting circular stimuli. Search times increased with increasing number of distractors when the target oval appeared either at a location away from the looming stimulus, or at the location of the near-miss looming stimulus. However, when the target oval appeared at the same location as a looming stimulus on a collision path, search times were nearly independent of the number of distractors. This shows that the looming stimulus attracted attention only when it was on a collision path with the observer, even though the colliding and near-miss paths were perceptually indistinguishable.

This dissociation between behavior and perception suggests that conscious perception may not be necessary to trigger behaviorally relevant responses such as detection and evaluation of an impending colliding object. These results demonstrate that the visual system can automatically categorize threatening versus non-threatening images at a level of precision beyond our perceptual capabilities.

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42.22, *11:15 am*

Spatial attention reduces contrast adaptation

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Introduction: Directing voluntary covert attention to a location in the visual field enhances contrast sensitivity while adaptation to contrast decreases sensitivity. Does the enhancement in sensitivity brought about by attention interact with adaptation? In particular, might larger decreases in sensitivity with higher contrast adaptation be countered by larger increases in sensitivity with attention?

Methods: We measured contrast discrimination thresholds in a 2IFC task in focal-attention and distributed-attention conditions as a function of the adaptor contrast. Each block of 80 trials started with observers adapting for 70-s to either a blank field or to 4 isoeccentric, 5-Hz counterphase-modulated, 2-cpd gratings. On each trial, following 4-s top-up adaptation, four test gratings of different contrasts were presented at the adaptors' locations in two 600-ms intervals. Only one of the gratings (the target) changed contrast across temporal intervals. Observers reported the interval in which the target grating had higher contrast. We directed observers' attention either to a target location (cued by an arrow at fixation), or to 4 locations (4 arrows), 600-ms before presenting the test gratings. We measured contrast discrimination thresholds both when attention was directed to the target location (focal attention) and when attention was distributed across the four stimuli (distributed attention). Adaptor contrast varied from 0 to 100%.

Results: Discrimination thresholds increased with adaptor contrast. Thresholds were lower for focal- than distributed-attention for all adaptor contrasts, indicating that attention improved contrast discrimination. The effect of attention increased as a function of adaptor contrast, such that thresholds in the focal-attention condition approached those found without adaptation.

Conclusion: Attention counteracts the effect of adaptation; it restores visibility by bringing the adapted stimulus back to near pre-adaptation visibility levels. This is consistent with the idea that the effect of attention and adaptation might rely on common neural mechanisms.

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42.23, *11:30 am*

Attention and biased competition in multi-voxel object representations

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The biased-competition theory accounts for the effects of attention at the neuronal level. Two hallmarks of this model are 1) the neuronal response to simultaneously presented stimuli is a weighted average of the response to isolated stimuli, and 2) attention biases the corresponding weights in favor of the attended stimulus. However, perception is not a property of single neurons, but probably relies instead on the activity of larger populations of neurons, which could be reflected in fMRI patterns of activity. Because several non-linearities can influence the pooling of single-neuron responses into BOLD signals, the fMRI effects of attention need not exactly mirror those observed at the neuronal level. Here we ask 1) how simultaneous stimuli are combined in multi-voxel patterns of representation and 2) how this effect depends on stimulus category, the brain region under consideration, and the allocation of attention. We considered data from an fMRI study in which four object categories (faces, houses, shoes and cars) were presented in four conditions: in isolation, or in pairs such that each category was attended, unattended, or attention was divided equally between the two. Unlike traditional analyses that collapse the response across all voxels in a region of interest, the response in each condition was represented in a multi-dimensional space where each voxel defined a dimension. In this high-dimensional space, the BOLD response to two simultaneously presented categories was well described as a weighted average of the response to individual stimuli. The weights were biased towards the preferred category in category-selective regions (FFA and PPA for faces and houses, respectively). Independently of this category-specific effect, and consistent with the biased competition theory, attention shifted the weights in favor of the attended stimulus, and the magnitude of this shift (30%) was quantitatively consistent with previous reports in single neurons.

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42.24, *11:45 am*

Competition for Limited Capacity: Towards a Saliency Theory of Distractor Processing

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Characterizing the conditions under which irrelevant stimuli are efficiently filtered out has long been a central driving force in attention research. Although several factors, including load and local competition, have been identified to be important, a parsimonious and straightforward account has yet to be proposed. In a series of experiments using color-word flanker and Stroop paradigms, we show that the relative saliency of distractors determines the level of distractor processing. For each subject, we first measured the unique yellow point where yellow appears neither reddish nor greenish. We then devised three saliency conditions, with the color difference between red and green being large, medium, and small for the high, medium, and low saliency conditions, respectively. With the saliency of the target manipulated while the distractor held constant, the relative saliency of the distractor was directly manipulated. Subsequently, subjects were to categorize the color of each central patch (red/reddish yellow or green/greenish yellow). When the target and distractor were spatially separated (flanker task), increasing the relative saliency of the distractor also increased the interference effect from the distractor, regardless of whether the conflict came from sensory information, semantic information, or both. When the target and distractor were spatially overlapped (Stroop task), the same pattern persisted. An individual difference analysis of sensitivity to color difference further revealed that the relative saliency of the distractor as scaled by sensitivity correlated with the interference effect. However, precueing the distractor 80ms before the target increased the interference effect only in the low saliency condition but decreased the interference effect in the medium and high saliency conditions. Thus, these results demonstrate that the relative saliency of the distractor, with saliency defined by the strength of stimuli-response association, determines distractor processing. This saliency account can also parsimoniously explain a number of (sometimes puzzling) findings in selective attention.

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URL: http://zhichenglin.googlepages.com/

42.25, *12:00 pm*

Psychophysical evidence for the normalization model of attention

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Objective: The normalization model of attention (Reynolds & Heeger, SfN, 2008) has been proposed to reconcile disparate findings on the effects of attention on neuronal responses in visual cortex. According to the model, different forms of attentional modulation can occur depending on stimulus size and attention field size. We tested a key prediction of this model: a shift from response gain to contrast gain with smaller stimuli and larger attention field.

Methods: Observers performed a 2AFC orientation discrimination task on one of two slightly tilted Gabor stimuli, presented (30 ms) simultaneously in opposite hemifields (5° eccentricity). Exogenous attention was directed by a peripheral pre-cue, preceding stimulus onset by 100 ms. A response cue, at stimulus offset, indicated the target location. This yielded three cue conditions: valid (pre-cue matched to response cue), invalid (mismatched) and neutral (both locations pre-cued). Attention field size was enlarged by randomly varying stimulus locations (along arcs at 5° eccentricity), thus introducing spatial uncertainty. Stimulus size (σ=0.4° or 1.0°) and attention field size were yoked: smaller stimuli were combined with larger attention field and vice versa. Performance (d') was measured for each stimulus/attention field size, cue condition, and several contrasts.

Results: We assessed the effect of attention by fitting psychometric functions for the three cue conditions with two free parameters: asymptotic performance at high contrasts (max d') and the contrast yielding half-maximum performance (C50). For large stimuli and small attention field, attention altered only max d', as predicted by a change in response gain. For small stimuli and large attention field, attention altered only C50, as predicted by a change in contrast gain.

Conclusion: Exogenous attention has different effects on contrast response functions, depending on stimulus size and attention field size, supporting a key prediction of the normalization model of attention.

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42.26, *12:15 pm*

Attention improves response reliability by decreasing noise: Reduction in the amplitude of fluctuations of fMRI signal at non-stimulus frequencies using periodic retinotopic mapping stimuli

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Visual spatial attention could enhance the neural representation of a stimulus by amplifying the response to the stimulus and/or by suppressing sources of noise. In this study we show that attention improves the reliability of fMRI responses to a periodic rotating wedge checkerboard stimulus through both an increase in signal strength and a decrease in noise. On separate runs, attention was continuously directed either to the wedge stimulus or to the central fixation point. In both attention conditions, subjects performed a difficult contrast decrement detection task, and task difficulty and the physical stimuli were equated in the two conditions. Fourier analysis was performed on fMRI time series in retinotopic visual cortical areas (V1, V2, V3, V3A/B, V4, V7) as well as in intraparietal cortical areas that contain topographic maps of visual spatial attention (IPS1 and IPS2). Relative to the attention to fixation condition, attending to the wedge stimulus increased the amplitude of the response at the temporal frequency corresponding to the stimulus cycle (0.03 Hz). This enhancement of stimulus signal by attention was observed across all identified cortical areas. We also analyzed fluctuations in other temporal frequency bands that did not correspond to the stimulus cycle and therefore represent noise in the fMRI response. In cortical areas higher in the visual hierarchy, attending to the stimulus reduced the amplitude of fluctuations in these non-stimulus frequencies. In conclusion, attending to a stimulus can improve reliability of cortical fMRI responses by enhancing the stimulus signal and by decreasing noise.

Acknowledgement: We wish to thank Joanna Tung for her help in data analysis.

42.27, *12:30 pm*

Modulation of the direction of figure by feature-based attention

Nobuhiko Wagatsuma[1] (wagatsuma@cvs.cs.tsukuba.ac.jp), Megumi Oki[1], Ko Sakai[1]; [1]Department of Computer Science, University of Tsukuba

Computational and psychophysical studies have reported that spatial attention facilitates the perception of border ownership (BO) that tells the direction of figure with respect to the border so that attended location appears as figure (Wagatsuma, et al. 2008). To investigate whether feature-based attention facilitates BO perception, we carried out psychophysical experiments in which BO was determined for ambiguous stimuli with Moving Random Dot Pattern (MRDP) while attention was directed to a motion direction. The experiment comprised cue- and test-tasks with distinct stimuli: the motion discrimination task to control feature-based attention, and the BO determination task. In the motion discrimination task, subjects were instructed to judge the direction of MRDP with respect to a reference diagonal line. A test stimulus was presented immediately after the cue stimulus. Test stimulus consisted of two random-blocks adjacent to each other which were segregated by perpendicular motion directions. We asked subjects to report which region was in front of the other at the fixation point located on the

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border of the two blocks. The results showed that the region with attended motion direction was more perceived in front, suggesting that feature-based attention facilitates BO perception so that attended region appears as figure. Our modeling study has suggested that gain of V1 neurons that were tuned to the attended motion direction was modulated selectively so that motion contrast was increased. The modified contrast modulated the response of BO-selective neurons in V2 because BO was determined from surrounding contrast around its classical receptive field, although attention should also directly modulate the BO-selective neurons. These results suggest that the spatial- and feature-attention work, at least in part, in the same framework that attention modulation of contrast in early vision plays a crucial role in modulating higher-level perception.

URL: http://www.cvs.cs.tsukuba.ac.jp/

Perceptual Learning: Specificity and Transfer

Monday, May 11, 8:30 am – 12:30 pm
Poster Session, Royal Palm Ballroom 6-8

43.301

Perceptual learning transfers from luminance- to contrast-defined motion

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Distinct brain circuits detect luminance-defined motion (LDM) and contrast-defined motion (CDM). Patterns of transfer of perceptual learning are diagnostic of the amount of overlap between these circuits.

Method: The stimuli were mixtures of dynamic noise and moving texture carriers (speed 10°/sec, duration 400 msec). The textures were patches of static noise filtered with a bandpass filter centered on 1 cycle/deg. CDM stimuli were multiplicative mixtures that contained no net directional Fourier energy (Chubb & Sperling, 1989). LDM stimuli were additive mixtures, titrated to approximate the initial CDM difficulty in a pilot study. Each participant was pre-tested and post-tested on LDM and CDM in a direction discrimination task at two orthogonal directions (-45 vs. -65; 25 vs. 45 deg). Twenty-two participants trained on either LDM or CDM in a constant direction for four sessions, counterbalancing between subjects. To allow for estimation of the psychometric slope, training contained 10 and 6 degree discriminations.

Results: The average d' improved from 1.4 to 2.2 for the LDM group and from 1.2 to 1.8 for the CDM group on the trained direction of motion. There was full transfer to the orthogonal direction in both groups. Critically, there was full transfer from CDM to LDM, and partial transfer (65%) from LDM to CDM.

Conclusion: This substantial amount of transfer suggests substantial overlap between LDM and CDM circuits. Zanker (1999) studied perceptual learning of the global motion of a figure defined by local dot motion. He found very little transfer from primary (local collinear with global) motion to secondary (local orthogonal to global) motion. Our results suggest that the circuits for local LDM and CDM overlap more than the circuits for global primary and secondary motion.

43.302

The stimulus specificity of motion perceptual learning depends on the difficulty during post-test rather than training

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Psychophysical performance improves with practice but the improvement is often specific to the trained stimulus configuration. The improvement on easy tasks often transfers more than that on difficult tasks (Ahissar & Hochstein, 1997; Liu, 1999). These results were first established using experimental designs that confounded the difficulty during training and subsequent generalization tests. When these two factors were manipulated separately between subjects in an orientation discrimination task (Jeter et al., in press), the observed thresholds challenged the widespread notion that the training regimen determines the locus of learning. We replicate this surprising finding with d' measures of motion discrimination within subjects.

Method: The stimuli were moving filtered-noise textures (speed 10 deg/sec, duration 400 msec, bandpass filter centered on 3 cycles/deg). Each participant was pre-tested on two easy motion-direction discriminations (-59 vs -51; 31 vs 39) and two difficult ones (-57 vs -53; 33 vs 37 deg). The 20 participants then practiced one particular task for four sessions, counterbalancing between subjects. All four tasks were post-tested on Day 6.

Results: The group-averaged d' improved from 0.97 to 1.58 for the difficult task and from 1.78 to 3.12 for the easy task. The improvement was partially specific to the practiced direction: Post-test d' at the orthogonal direction was 1.22 for the difficult and 2.15 for the easy task. Importantly, the post-test performance in the easy-training group was identical to that in the difficult-training group.

Conclusion: Easy generalization tests yielded higher specificity indices (SI=70%) than did difficult tests (SI=40%), contradicting the Reverse Hierarchy Theory (Ahissar & Hochstein, 1997). Moreover, in agreement with Jeter et al. and contrary to the traditional interpretation, these indices did not depend on the training condition. Within a range of difficulty levels, practicing a given task seems to induce similar internal changes that produce different outcomes on different tests.

43.303

Perceptual learning of visual motion: The role of the spatial frequency of the carrier

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Motion-sensitive neurons in the middle temporal (MT) cortex inherit their basic spatial tuning from their inputs from earlier visual areas. In particular, the tuning for spatial frequency is not very different than that in areas V1 and V2, though MT neurons are somewhat more broadly tuned (Britten, 2004). We investigated how the spatial frequency of the motion carrier affected the d' of direction discrimination and the perceptual learning thereof.

Method: The stimuli were filtered-noise textures moving at 10 degrees/sec for 400 msec. Each patch was filtered with a radial bandpass filter with a peak frequency of either 1 (Low) or 4 (High) cycles/deg. Twenty-five observers discriminated motion directions that differed by either 7 degrees (Easy) or 4 degrees (Difficult) in a block. All observers were pre-tested on Day 1 and post-tested on Day 6 on all four combinations of frequency and difficulty. On Days 2 through 5, participants trained exclusively on one pair of features, counterbalanced across four groups.

Results: The average d' improved in all groups: EasyHigh from 1.67 to 2.91, EasyLow from 1.43 to 2.56, DifficultHigh from 1.11 to 1.81, and DifficultLow from 0.89 to 1.50. The learning effects transferred well across spatial frequencies. As expected, the Easy groups performed better than the Difficult groups. Additionally, the High frequency groups performed better than their Low frequency counterparts for both difficulties.

Conclusion: The transfer of learning across the spatial frequency of the carrier suggests plasticity site(s) broadly tuned for spatial frequency, such as areas LIP and/or MST. Area MT, which is relatively narrowly tuned, seems to remain unchanged. This agrees with recent physiological evidence of training-induced changes in LIP but not MT (Law & Gold, 2008). The MT involvement can account for the main effect of spatial frequency, which did not interact with the practice effects.

43.304

Enabling complete transfer of perceptual learning across orientations in foveal vision through double training

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Monday Sessions

Recently we reported that contrast and vernier learning transfers completely to a new location provided that the new location is primed by additional training with an irrelevant task/feature (Cur.Biol.2008), suggesting that learning may occur in non-retinotopic high brain areas. Here we demonstrate that perceptual learning also transfers across orientations in foveal vision with a similar double training paradigm.

Our results show that (1) Orientation discrimination learning for a foveal Gabor at ori_1 didn't transfer to orthogonal ori_2, replicating known orientation specificity. Neither did contrast discrimination learning at ori_2 transfer to orientation discrimination at the same ori_2. However, with simultaneous orientation training at ori_1 and contrast training at ori_2, orientation learning at ori_1 transferred to ori_2 completely; (2) Similarly, contrast learning at ori_1 didn't transfer to ori_2, and orientation learning at ori_2 didn't transfer to contrast discrimination at ori_2 either. But simultaneous double training resulted in complete transfer of contrast learning from ori_1 to ori_2; (3) Moreover, replacing contrast training in (1) with simple Gabor exposures at ori_2 for ~2800 trials (subjects judged whether the stimulus was a Gabor (80% trials) or a letter C (20% trials)) also enabled nearly complete transfer of orientation learning from ori_1 to ori_2.

These orientation transfer results, along with our previous findings of complete location transfer of perceptual learning, invalidate location and orientation specificities as distinct characteristics of perceptual learning and question the inferred involvement of retinotopic early visual cortex. Rather they are more consistent with the Mollon-Danilova hypothesis that learning occurs at a central site. We propose that perceptual learning involves training-induced improvement of task-specific, but feature and location non-specific, decision-making in high brain areas. Learning transfers to a new location or orientation after additional training that improves spatial attention to the new location or feature attention to the new orientation.

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43.305

The rate of perceptual learning at a fixed accuracy threshold is improved by feedback and by mixture with easier trials

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Performance improvement in perceptual learning may be measured as increases in accuracy for a constant stimulus, or as reductions in threshold contrast for a given threshold accuracy. Conditions that lead to better perceptual learning are of both theoretical and practical concern. Reviews of perceptual learning (Dosher & Lu, 2009) suggest that feedback is not necessary for learning, although it may be helpful under some circumstances. The rate of learning may also be influenced by the ease of the training regime, yielding higher or lower accuracy of response. The current experiment measured contrast thresholds in an orientation discrimination task as a function of feedback and of the presence of different accuracy trials during practice. Observers discriminated the orientation of a Gabor stimulus (+/- 12 deg from vertical at one of two precued locations 5 deg in the periphery). Performance was tested in zero external noise and in high external noise. Four groups of observers were tested. Feedback (on correct trials) was either provided or not, and training with a 75% accuracy adaptive staircase of contrast was mixed either with a 65% adaptive staircase or an 85% adaptive staircase. Learning in the 75% accuracy staircase condition thresholds was estimated through a power function model of perceptual learning. The 75% threshold showed larger and faster improvements when it was measured in the context of the higher accuracy 85% trials than when mixed with the lower accuracy 65% trials, and benefited from feedback in some cases. The results are consistent with the predictions of an augmented Hebbian reweighting model of perceptual learning (Petrov, Dosher, & Lu, 2005, 2006). The model predicts that perceptual learning can occur without feedback, but may be improved by it, and that mixing in practice trials at a higher accuracy level can also lead to better learning.

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43.306

The Less-Is-More principle in realistic visual statistical learning

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While in previous studies, a number of abstract characteristics of visual statistical learning have been clarified under various 2-dimesional settings, little effort was directed to understand how real visual dimensions in 3-dimensonal scenes interact during such learning. In a series of experiments using realistic 3D shapes and the dimensions of color, texture, and motion, we tested the Less-Is-More principle of learning, namely the proposal that information in independent dimensions do not interact in a simple additive manner to help learning. Following the original statistical learning paradigm, twelve arbitrary 3D shapes were used to compose scenes, where shape pairs followed particular co-occurrence pattern and scenes were composed of random combinations of such pairs. Similarly to the results with abstract 2D shapes, subjects automatically and implicitly learned the underlying structure of the scenes. However, there were notable differences in learning depending on the features of the stimuli. Humans performed well above chance in the baseline experiment with full colored and textured shapes (63% correct, $p<0.001$). When they received the same training but only with colors using a single type of shape and no texture, performance dropped to chance (51%, ns.), showing that providing the same color label information without "hooks" was not useful. However, removing color and texture or color and shape improved performance (both 68%, $p<0.001$) showing that reducing the richness of the representations is not always detrimental. Finally, adding characteristic motion pattern to each shape did not elevate performance (65%, $p<0.001$) demonstrating that even the most effective type of visual information does not necessarily speed up learning. These results support the Less-Is-More idea that the most effective learning requires the maximum amount of information that the system can reliably process based on its capacity limit and internal representation, which is not equivalent to having the most possible information.

43.307

The emergence of explicit knowledge with experience in visual statistical learning

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Visual statistical learning has been established as a paradigm for testing implicit knowledge that accumulates gradually with experience. Typically, subjects are presented with a stream of scenes composed of simple shapes arranged according to co-occurrence rules. Subjects observe the scenes without a defined task, and during the test subjects' familiarity with the building blocks of the scenes is measured. However, the test in this paradigm usually directly follows the practice, while long-term effects are usually considered to last for hours or days. In addition, while the learning is implicit, the underlying structure of scenes can be summarized by a few explicit rules, which when told to the subject, the task becomes trivial. It is not clear, however, whether the implicit learning leads to explicit knowledge of the rules, or if the two types of learning are unrelated. To address these issues, we ran a modified visual statistical learning study, where subjects were tested one hour after the practice session. In addition, we varied the length of practice from 144 to 216 to 288 scenes. At short length, subjects showed no learning (55%, $p>.05$), in strong contrast with earlier results (74.7%, $p<0.0001$) where the practice and test without intermission yielded strong implicit learning. As the length of practice increased to 216, implicit familiarity emerged (82%, $p<0.004$), whereas with 288 trials not only did performance improve further (85%, $p<0.0004$), but explicit knowledge of the rules was reported by a majority of the subjects. Thus, even though visual statistical learning contributes to immediate familiarity, it is also the basis of more prolonged representations in long term memory. Moreover, this type of learning gradually leads to the emergence of explicit knowledge of the rules observed in the scenes, thus questioning the idea that implicit statistical and explicit rule learning are two separate processes.

43.308

Versatile perceptual learning of textures after variable exposures

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Perceptual learning of 10AFC texture identification is stimulus-specific: After a fixed set of ten textures is learned, accuracy drops substantially when those textures are rotated 180 degrees, reversed in polarity, or when a novel set of textures is presented. Two questions arise: 1) Can perceptual learning occur without any repetition of items during training? 2) Does exposure to a more variable training set increase transfer of learning? We trained three groups of observers in a 10AFC texture identification task on two days (420 trials/day). Method of constant stimuli was used to present the textures at multiple contrasts and noise levels. The Fixed group viewed a fixed set of 10 textures throughout training (840 exposures per texture set). The Unlimited group viewed 840 novel sets of 10 textures (1 exposure per texture set). The Switch group viewed a fixed set of 10 textures on Day 1, and a different fixed set on Day 2 (420 exposures per texture set). In all groups, transfer of learning was tested on Days 3 and 4 by using a fixed set of textures in both sessions and having half the observers from each group switch to a novel set on Day 4. Response time and accuracy were measured. Results: 1) Gradual, but significant, learning occurred even when each trial comprised novel stimuli. 2) Greater transfer of learning from Day 3 to Day 4 was found in the Unlimited and Switch groups. Specifically, the Unlimited and Switch groups were affected less by, and recovered faster from, a change in textures viewed on Day 4. We conclude that the amount of stimulus-specificity can vary: increasing stimulus variability during practice may induce the use of strategies that increase generalization of learning to new stimuli.

43.309

Perceptual Learning of Noisy Oriented Gratings as Revealed by Classification Images

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Classification image analysis is a psychophysical technique in which the noise components of signal+noise stimuli are analyzed to produce an image that reveals the critical features of a visual task. Here we examine classification images during the time course of a perceptual learning task to gain a greater understanding of what subjects learn through training on detection of oriented gratings in noise. To do this, we optimized standard classification image procedures by using designer (m-sequence) noise and a relatively low-dimensional stimulus space, so that we could achieve reasonable classification images within a single thousand-trial session. Subjects were trained across ten sessions to detect the orientation of a grating masked in noise, with an eleventh test session conducted using an oriented stimulus orthogonal to the trained stimuli. Subjects showed improvement in performance metrics such as reaction time and signal detection threshold. Clarity of the classification images and their correlation to an ideal target was also observed to improve across training sessions. These improvements showed only partial transfer to the orthogonal test session, indicating an orientation-specific learning effect. The main benefit of classification image techniques is that they allow for a variety of image-based analyses. We discuss how orientation tuning curves can be derived from the classification images and how these change through the time course of training, how individual correlation measures change for bright and dark components of the stimuli, and how per-trial feedback affects various metrics of learning. Our results shed insight on what is learned during orientation discrimination and demonstrate that classification image techniques are a promising method by which to study perceptual learning.

43.310

Training effect on the useful visual field with and without a central task

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[Purpose] We pay attention to more than one locations and/or objects sequentially or simultaneously to perform complex tasks such as driving. Previous works have shown that training reduces the influence of the central task, suggesting extending the size of the useful visual field. However, no direct measurement of the useful visual field size change due to training has been made and it is not clear how the visual system changed after the training. We conducted psychophysical experiments to measure the useful visual field and investigated the effect of training on the field size.

[Experiment] The central task was a Rapid Serial Visual Presentation (RSVP) task. The peripheral task was to detect a gradual luminance increment with a temporal Gaussian profile. The peripheral stimulus was presented at a location randomly chosen from different distance from the fixation point. There were three experimental conditions: the central, the peripheral and the dual task condition. Based on the detection rate as a function of the eccentricity, we defined the size of the useful visual field within which the detection rate was higher than 62.5% before and after several days of training sessions.

[Results] The performance of the peripheral task improved after training and the useful visual field size was enlarged substantively both in the dual and the peripheral task conditions. These results suggest that the useful visual field size increases after the training by repeating the tasks.

43.311

Comparing perceptual learning and perceptual expertise with matched stimuli

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Perceptual learning training (PL, e.g. Karni & Sagi, 1991; Sigman et al., 2000) typically leads to learning specific to trained stimuli and task. In contrast, perceptual expertise training (PE, e.g. Gauthier, et al., 1997; 1998) leads to greater generalization, both for new objects in the trained category and in new tasks. It is unknown whether the contrasting training effects result from differences in stimuli, training tasks or presentation conditions (e.g., foveal vs. peripheral presentation). We investigated the role of the training task by comparing eight-hour PL and PE learning protocols with identical objects in the same peripheral visual positions. For PL training, participants searched for objects in a specific target orientation among an array of 8 identical objects rotated in 90°, 180° or 270°. PE training involved naming each individual shape. Over trials, the same stimuli, all from the same homogeneous category, were used in both tasks. Both types of training replicated the typical behavioral effects of previous studies. PL training led to behavioral improvement for the visual search task specific to the trained orientation and trained objects, while PE training resulted in improved shape matching performance for trained objects compared to control objects. Both types of training generalized to the untrained task, in contrast to the task specificity in previous PL studies (Fahle, 1997). Thus, observers learned from the irrelevant variability in shape across trials during PL training, and PE training generalized to an orientation task in a more crowded display. In sum, by manipulating training experience with identical training objects, training visual positions and testing tasks, our PL and PE training replicated the typical training effects, and demonstrated divergent behavioral generalization after each type of training. This suggests that the contrasting training effects of PL and PE training can be obtained when stimuli and presentation conditions are matched.

43.312

An effect of mere exposure on visual category learning

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See page 3 for Abstract Numbering System

Few theories of categorization make predictions about the effect of mere exposure on categorization behavior. Statistical learning studies suggest that mere exposure to stimuli can result in significant learning about the correlational structure of stimulus features. While correlational structure may be learned, there is little or no evidence that this learning might facilitate subsequent visual category learning. We tested whether pre-exposure to a stimulus set enhanced or impaired learning to categorize the stimulus set according to a simple conjunctive rule. During a pre-exposure phase, participants performed 480 trials of a 1-back task on a series of numbers appearing at the center of the screen. In one condition (pre-exposure), each number in the 1-back task was accompanied by one of 24 novel six-featured "alien" stimuli that appeared in the background behind the numbers and were irrelevant to the 1-back task. In the control condition the numbers appeared without the stimuli in the background. In the subsequent category learning phase, both groups learned to categorize the aliens according to a 2-dimensional conjunctive rule. The participants that had seen the alien stimuli during the 1-back task (pre-exposure group) were able to learn the rule in fewer blocks than the control group. This finding suggests that rule-based category learning can benefit from unsupervised learning – possibly visual statistical learning. The finding also suggests that category learning of this kind may be resistant to latent inhibition, a phenomenon observed in classical conditioning studies where mere exposure impairs learning. A second experiment examined the effect of pre-exposure to stimuli with various patterns of correlation between the stimulus dimensions. Results suggest that an effect of pre-exposure on category learning is dependent on the pattern of correlation between pre-exposed stimulus features.

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43.313

Are label associations necessary for the acquisition of expertise?

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Whereas the differences between how experts and novices process objects are well established, the process of developing visual expertise is still not well understood. Some results suggest that individuation is an important aspect of expertise training: not only do participants trained at the subordinate level outperform those trained to attend to a more general classification in a same/different discrimination task, but they are also better able to generalize subordinate level classifications to novel objects (Tanaka, Curran, & Sheinberg, 2005; Wong, Palmeri & Gauthier, VSS08). Individuation training also typically includes label associations, which could play an important role in the development of expert object representations. We examined whether a discrimination task using an online computer game, which does not involve any label association, can give participants a head start towards the acquisition of perceptual expertise.

Prior to starting the traditional expertise-training paradigm with Greebles, participants completed an arcade-game-like task that provided participants practice discriminating either test (Greebles) or control (Yufos) stimuli. The task involved "shooting" items in waves of objects according to the current identity of the shooting device. The specific objects used during the game and those used in the subsequent training task did not overlap, in order to ensure that effects reflect generalization to the entire category. Preliminary results (n = 7) reveal that prior experience that involves exposure and discrimination of objects without label learning gives a "head start" in the Greeble training paradigm, with better performance in verification trials particularly for the individual level. These results will be compared to a mere exposure condition that does not involve individuation, to determine whether exposure to objects can facilitate the early stages of expertise acquisition.

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43.314

Cross-modal perceptual learning is non-trivial: synchronous and semantically plausible auditory cues were not recruited for a visual appearance task

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Background: Haijiang et al. [PNAS 2006] used a rotating Necker cube (a perceptually bistable stimulus) to show that inherently uninformative cues such as the cube's position and translation direction could bias perceived rotation direction during test trials, after being associated with a particular rotation direction during training trials. However, they did not observe any such cue recruitment for an auditory cue (a repeating two-tone sequence that started 600ms before the appearance of the cube).Goal: We hypothesized that a more "plausible" auditory cue might be recruited. We therefore used auditory cues associated with rotating objects, audio synchronized with intermittent rotation, and a virtual sound location at the cube. Methods: "Ratchet" and "camera-film winding" sounds were the auditory cues. On each trial, a stationary cube appeared, then the cube rotated to the sound, stopped, and rotated again. In one experimental condition, only the sound type (ratchet or camera-film winding) was contingent on rotation direction during training. The auditory cue's location was fixed; it was simulated to emanate from the cube. In the second condition, both the sound type and the location of the sound were contingent on rotation direction during training. Results and Conclusion: Twelve trainees showed no cue recruitment in either of the two conditions, which suggests that the construction of visual appearance may be inherently less likely to be influenced by new auditory cues than by new visual cues. Cross-modal interactions are known (e.g. the McGurk effect [McGurk & MacDonald, Nature 1976] and the bounce/pass effect [Sekuler, Sekuler & Lau, Nature 1997]) so it seems likely that such learning could occur under appropriate circumstances that remain to be determined.

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43.315

Cue recruitment for the construction of perceptual appearance: World location competes with retinal location in an associative learning paradigm

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Through the use of classical conditioning procedures, the perceived direction of rotation of a wire-frame cube, which is a bistable stimulus, can be trained to depend on stimulus position (Haijiang, Saunders, Stone, & Backus, 2006). Backus & Haijiang (2007) tested whether this effect was mediated by retinal position or position in the world. They trained two groups of subjects using consistent retinal or world positions, respectively, through trial-by-trial manipulation of fixation. Cue recruitment occurred quickly for retinal training but did not reach statistical significance for world training. We revisited the question of whether position in the world can be recruited as a cue in new experiments that were designed to facilitate the use of world position as a cue. A rotating wire-frame cube appeared at one of two world positions (screen locations) on each trial. On training trials, the cube's rotation direction was specified by disparity and occlusion cues in accordance with its position. On test trials there were no disambiguating cues. World and retinal position were deconfounded by manipulating subjects' fixation, using a marker that appeared at the start of each trial either to the left or right (Experiment 1) or at one of 16 locations (Experiment 2) relative to the cube. Our results show that the visual system can learn world position cues to a certain extent, but retinal position competed strongly as a determinant of apparent rotation direction, despite lack of consistent training in retinal coordinates. The relatively stronger learning of retinal position could be explained either by the behavior of specific mechanisms (early, retinotopically organized cortical areas such as MT may be trainable) or by appealing to computational principles (with location in the visual field being assumed by learning mechanisms to have greater ecological validity than location in the world).

43.316

Improved Perception Immediately Leads to Improved Movement Stability

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Background: Coordinated rhythmic movement is specifically structured in humans. Movement at 0° mean relative phase is maximally stable; movement at 180° is less stable; and no other relative phase is stable without training. Previous work has demonstrated this pattern in perceptual judgment tasks, and also that perceptual feedback manipulations affect movement stability. These results are seen as evidence that perception plays a key role in determining the coordinated movement stabilities.

Methods: Stable movement at other relative phases (e.g. 90°) can be acquired through practice of the movements. We investigated whether such stable movements can be acquired through perceptual learning. We first assessed Baseline movement stability at 0°, 90° and 180° by having participants use a joystick to coordinate the movement of two dots on a screen at the three phases. Perceptual stability at 90° and 180° was assessed with a 2-alternative forced choice (2AFC) task in which participants identified the target phase from a pair of displays. Participants then practiced to improve their perceptual resolution of 90° by making progressively harder discriminations, with feedback. We then assessed movement and perceptual stability in Post Training and Retention sessions.

Results: Improved perceptual discrimination of 90° immediately led to improved performance in the 90° movement task without any motor training. The improvement persisted between Post Training and Retention without further task exposure. Movement stability at 90° for a control group (movement assessment only) did not improve.

Conclusions: Movement stability is a function of perceptual stability - improving the latter improves the former. Perceptual information is an integral part of the organization of this dynamical system.

Motion: Representations

Monday, May 11, 8:30 am – 12:30 pm
Poster Session, Royal Palm Ballroom 6-8

43.317

Rapid estimation of the spatiotemporal contrast sensitivity surface

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Purpose. The spatiotemporal contrast sensitivity surface (CSS) describes visual sensitivity (1/threshold) to moving or flickering gratings as a function of spatial and temporal frequency1. The CSS provides a fundamental characterization of the visual system in both normal and clinical populations. Many neuro-ocular diseases exhibit characteristic frequency-specific deficits on the CSS2. To overcome the long testing times typical needed to measure the CSS, we develop a family of adaptive methods for its rapid estimation.

Method. The CSS is typically studied in orthogonal and diagonal slices through its surface: spatial contrast sensitivity functions (CSFs) at fixed temporal frequencies, temporal CSFs at fixed spatial frequencies, or constant-speed CSFs at co-varied spatial and temporal frequencies. We estimated these contrast sensitivity slices by combining Bayesian adaptive inference with a trial-to-trial information-gain strategy3. To estimate the entire CSS, our novel procedure combined the information gained from adaptive runs dedicated to individual slices. Before each trial, the procedure evaluated expected gain within individual slices (6 spatial, 6 temporal, and 7 speeds) and selected a stimulus maximizing the information gain expected among all the slices. The final CSS estimate combined the surface estimates from all slices. In psychophysical experiments, we measured human sensitivity for motion direction discrimination over a large range of spatial (0.5-8 cycles/deg) and temporal frequencies (0.25-24 Hz).

Results. Simulation and psychophysical results suggest accurate CSS estimates are possible within 300-500 trials (15-25 minutes) with an average precision of 2-3 dB. Monte Carlo sampling of posteriors provides confidence regions for the CSS based on single adaptive runs.

Conclusion. This procedure offers a useful tool for clinical and practical applications that require a rapid but comprehensive evaluation of visual sensitivity.

1. Kelly (1979)
2. Regan (1991)
3. Lesmes et al. (2008)

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43.318

Visual sensitivity to acceleration: Effects of motion orientation, velocity, and size

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Traditional studies of acceleration perception have measured acceleration sensitivity in terms of the ratio of final to initial velocity or the proportion of change in velocity relative to the average velocity. From these studies, it is unclear as to how sensitivity to visual acceleration is affected by stimulus properties such as motion orientation, base velocity, and size. Here, we measured visual sensitivity to acceleration by parameterizing acceleration as it is defined: the change in velocity per unit time. Observers (n = 18) were asked to discriminate an accelerated stimulus from a constant velocity stimulus equated for mean velocity and size. Acceleration was adjusted according to the QUEST staircase procedure and thresholds, defined as the acceleration discriminated at the 82% correct-level, were obtained for positive and negative acceleration, horizontal and vertical motion, two base velocities, and two trajectory sizes. Consistent with previous findings, thresholds, if expressed according to proportion of velocity change relative to the base velocity were relatively constant across base velocities and sizes. Critically, we show that absolute acceleration thresholds varied in a manner analogous to Weber's law. We show also that thresholds were better for motions along the horizontal axis than the vertical axis, but only at the high base velocity and smaller size. Furthermore, acceleration sensitivity was not affected by the sign of acceleration or stimulus direction within the principle axes. These findings are discussed in the context of predictions of acceleration sensitivity from previous data for the perception of animate and inanimate motions.

43.319

Rapid forms of visual motion priming and motion aftereffect have similar time course but different neural substrates in first- and second-order motion

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Fast adaptation biases the perceived motion direction of a subsequently presented ambiguous test pattern (Kanai & Verstraten, 2005). Depending on both the duration of the adapting stimulus (ranging from tens to hundreds of milliseconds) and the duration of the adaptation-test blank interval, the perceived direction of an ambiguous test pattern is biased towards the opposite direction of the adaptation pattern (rapid Motion After Effect), or in the same direction (Visual Motion Priming). These rapid biases grow and extinguish rapidly over time. However, using adaptation durations up to 300 ms, and an adaptation-test blank interval longer than 2 sec the perceived motion direction is biased again toward the same motion direction of the adaptation pattern (Perceptual Sensitization). This effect arise gradually over time and seems to reflect potentiation at high-level along the motion processing hierarchy. These findings were obtained employing drifting luminance gratings (Kanai & Verstraten, 2005). However, many studies have shown that first-order motion (luminance-defined) and second-order motion (e.g., contrast-defined) stimuli are processed by separate mechanisms. We assessed if rapid visual motion priming, rapid motion aftereffect and perceptual sensitization exist also within the second-order motion domain. Results showed that fast adaptation to second-order motion can bias the perceived direction of an ambiguous test stimulus as well; moreover, these effects had a similar time course to that obtained with first-order stimuli. In order to asses if a single and common mechanism could account for the results obtained, we also run a cross-order adaptation condition. Results showed little or no transfer between the two motion cues and probes, suggesting a certain degree of separation between the neural substrates subserving fast adaptation of first- and second-order motion.

43.320

Attentional modulation of the static and flicker MAEs

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[Purpose] After the exposure to overlapped sinusoidal gratings with different spatial frequencies moving in the opposite directions, the motion aftereffect (MAE) 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. We interpreted the MAEs by assuming the slow and fast motion detectors (VSS '06). The purpose of the present study is to investigate how attention influences the static and flicker MAEs of the overlapped grating adaptation. If either of the static and flicker MAE reflects attention-based mechanism, different effects of attention are expected between the static and flicker MAEs.

[Experiment] We measured MAE duration after the exposure to the overlapped gratings moving in opposite directions. The spatial frequency of one grating was 0.53 c/deg and the other was 2.13 c/deg. Temporal frequency was varied between 0.63 and 20 Hz in adaptation. After 20 s of adaptation, the observer judged MAE duration in the stationary or the flicker (4 Hz) stimulus of the overlapped gratings, by pressing one of two keys to indicate the disappearance of the MAE and the direction of perceived motion. There was an RSVP task at the central field to control attention, where the observer was instructed to detect numbers in a letter sequence.

[Results] The static and flicker MAEs showed different dependency of temporal frequency: the static MAE duration peaked at lower temporal frequency than the flicker MAE. However, the RSVP task did not influenced the temporal frequency dependency of both of the static and flicker MAEs, reducing the duration in similar amount across temporal frequencies. The results indicate that the static and flicker MAEs are based on motion detectors at the same stage of the motion analysis.

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43.321

Impaired luminance detection in apparent motion trajectory

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Yantis & Nakama (1998) found that letter discrimination was impaired when the letter fell within the path of an apparent motion (AM) trajectory of a spot. Thus, the internal representation of AM stimuli can interfere with perception at a relatively high processing stage (letter discrimination). Here, we investigated whether AM interference also occurs at an earlier processing stage (pattern detection). We presented two square inducers (1x1 deg) at 5 deg below a fixation cross, separated horizontally by 5 deg. The inducer durations and interstimulus intervals (ISIs) were 106 ms. Background luminance was 30 cd/m2; the inducers' Weber contrast was 100%. In the On-AM-path condition, a target of identical shape and dimension as the inducers was presented for 26 ms in-between inducers. In the Off-AM-path condition, the vertical positions of the target and inducers differed by 2 deg. In the FL condition, the inducers flickered so that AM was not perceived. Five observers conducted a target detection task. Two interleaved staircases varied target contrast across to estimate the 50 % detection threshold. We found that threshold in the On-AM-path condition was higher (contrast: 37.9 %) than threshold in the Off-AM-path (contrast: 17.1 %) and FL (contrast: 13.3 %) conditions. Similar results were obtained when the inducers and target had negative contrasts (On-AM-path: -53.3 %; Off-AM-path: -19.2 %; FL: -15.8 %), and when the contrast of the target was negative and that of the inducers was positive (On-AM-path: -27.6 %; Off-AM-path: -13.5 %; FL: -15.9 %). These findings suggest that AM stimuli affect early visual processes involved in detecting a luminance increment or decrement and that the internal representation of AM stimuli reflects the stimulus's attribute (contrast polarity).

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43.322

Spatiotemporal properties of apparent-motion perception in aging

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Recent studies have found age-related declines in motion perception from random dot kinematograms (e.g. Bennett et al., Vis. Res., 2007; Norman et al., Perception, 2003). However, some temporal integration abilities seem to remain intact (e.g. Andersen & Ni, Vis. Res., 2008). Here, we used random-dot two-frame apparent motion stimuli to investigate whether such age-related changes in motion direction discrimination can be attributed to a decline in the ability to integrate visual information across space and/or time. Previous work using such stimuli has shown that the perception of apparent motion is influenced separately by the duration of the inter stimulus interval (ISI) between the two frames and the magnitude of spatial displacement of the dots (e.g. Baker & Braddick, Perception, 1985). In the current experiment, older (mean age: 69 years) and younger (mean age: 24 years) subjects reported the direction of motion of two sequentially presented random-dot patterns in a two AFC task. The patterns were presented for 100 ms each and were separated by a blank ISI that varied between 10 to 240 ms. The second pattern was identical to the first pattern, but was shifted to the right or to the left by a displacement ranging from 1.9 to 76 arcmin. The effect of age on direction discrimination performance varied with the amount of displacement. At the shortest and longest displacements, older subjects performed significantly worse than young subjects across all ISIs. At medium displacements, both age groups performed near ceiling at short ISIs, but performance decreased with increasing ISIs. This decline was significantly greater, and began at a shorter ISI, in older subjects. These findings indicate that older subjects integrate information across a smaller range of inter-stimulus intervals and spatial displacements compared to younger subjects.

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43.323

Human detection and localization of speed differences during fixation and smooth pursuit eye movements

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Human observers are quite good at detecting changes in the speed of a single moving object. However, there are usually several objects moving at different speeds in natural situations.Thus we wanted to explore a more complex situation where several objects are moving while the observer is either fixating or smoothly pursuing a target spot.

Two vertically oriented sinewave gratings were moving horizontally at a constant speed, called the pedestal speed. The gratings were 27 deg wide and 9 deg high and were separated vertically by a 2 deg gap. In this gap between the gratings a small fixation spot was either stationary or moved in the same direction as the gratings. During the movement one of the gratings changed its speed for 500 ms. Two different experiments were performed.

In a localization task, the subject had to indicate whether the top or bottom grating changed speed. In a detection task, the subject had to indicate in which one of two intervals the speed change took place.

While thresholds for detecting speed changes were in the normal range of Weber fractions of 10%-15%, localization thresholds were dramatically increased to Weber fractions of about 30%-40% whenever there was retinal motion due to differences in eye and pedestal speed. This effect was particularly pronounced when the retinal motion was mainly due to the pedestal motion, and less when it was mainly due to the pursuit eye movements.

We conclude that localization of speed changes is exceedingly difficult. This is probably due to the dominance of relative motion signals when several objects are moving independently. Smooth pursuit is an effective means to improve performance under these conditions.

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43.324

Apparent motion from outside the visual field: retinotopic cortices may register extraretinal locations

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Subjects made left and right saccades between two fixation points separated by 20 deg on a front monitor. At the same time, a target moved left and right by 20 deg on a side monitor set to the right of the subject. While the subject fixated the right point on the front monitor, a target was presented on the side monitor at a location determined to be the rightmost edge of the subject's visual field. This target was extinguished and the subject made a 20 deg saccade to the left point on the front monitor. The target was then presented 20 deg to the left of its first location on the side monitor but, because both eyes and target shifted by 20 deg, there was little or no shift between the target's two positions on the retina. In this condition, subjects reported leftward motion corresponding to the spatiotopic displacement (20 deg) not the retinotopic displacement (0%). Wurtz (2008) has described how spatiotopic responses may be simulated by purely retinotopic representations in saccade related cortical areas (LIP, FEF). Specifically, the saccade step can be subtracted from the target's current location to predict the retinotopic location it will have once the saccade lands. Using this efference copy to remap, the target's activity maintains a pointer to the target's location in space despite the image shift on the retina. In our stimuli, any mismatch between the remapped and actual target location is seen as apparent motion (see also Cavanagh & Szinte, VSS 2009). If this remapping explanation of spatiotopic apparent motion is correct, our results here require that a target's representation may even be remapped outside the visual field (by about 20 deg in our stimulus). This suggests that some retinotopic cortices may register locations that fall outside the limits of the retina.

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43.325

Prior Probabilities and Representational Momentum: A Signal Detection Analysis

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Memory for the final location of a moving target is often displaced forward in the direction of target motion, and this has been referred to as representational momentum. In many experiments on representational momentum, participants are presented with a probe after the target vanishes and then judge whether that probe is at the same location where the target vanished or at a different location. The experiments reported here examined whether manipulation of the actual or believed a priori probability that a same response would be correct influenced the magnitude of displacement. In Experiment 1, a same response was correct on 10, 30, 50, 70, or 90 percent of the trials, but observers were not instructed regarding these probabilities. In Experiment 2, a same response was correct on 11 percent of the trials, but different groups of participants were instructed a same response would be correct on 10, 30, 50, 70, or 90 percent of the trials. Probabilities of a same response to different probe positions, weighted mean estimates of the magnitude of representational momentum, hit rate and false alarm rates, and d′ and Beta are reported. Representational momentum occurred in all conditions but was not influenced by changes in actual or instructed a priori probabilities that a same response would be correct. Changes in actual a priori probabilities that a same response would be correct decreased d′ and produced a trend for more positive Beta, and changes in instructed a priori probabilities that a same response would be correct did not influence d′ but increased Beta. Overall, there might be shifts in both sensitivity and criterion as a function of actual or instructed changes in the a priori probability that a same response would be correct, but these shifts are not sufficiently large to significantly influence representational momentum.

43.326

Trapezoidal illusions: Windsurfers versus runways

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We demonstrate here a windsurfer illusion, a naturally occurring trapezoidal illusion in which the small end of a sail viewed at a distance appears to be pointed away from the observer even when it is pointed toward them. This naturally occurring illusion is so compelling that observers are both unaware of their gross perceptual misinterpretation and are unable to perceive the scene veridically. The windsurfer illusion is largely context-free; we demonstrate that context can be critical: the same 2D shape on the different walls, ceiling, or floor of a room produces vastly different shape interpretations. Four experiments further investigate the joint effects of object shape, retinal orientation, head position, relative motion, and the direction of gravity on automatic depth perception of white outline trapezoids rotating back-and-forth on a black background. The trapezoids are perceived as rotating in 3D; observers report the side that appears to be nearest. Left- and right- pointed trapezoids are perceived mirror-equivalently; the longer edge of the trapezoid is reported in front on 74% of trials (traditional trapezoidal illusion, "windsurfer effect"). When the same display is rotated 90 deg to produce a runway retinal configuration, there is striking perceptual asymmetry: the long edge is perceived in front 97% of trials when it is on the bottom but only 43% when it is on top ("runway effect"). The runway effect also occurs when the head is tilted 90 deg or when displays on the ceiling are viewed from the floor. The strikingly different 3D perceptions produced by similar 2D screen trapezoids are quantitatively explained by a model that assumes just three bias factors contribute additively to perception: (1) Implicit linear perspective, (2) assumed viewing from above in head-centered coordinates, and (3) relative height in the retinal field. The model accounts for 93% of the variance of the data.

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43.327

Visual Pathways and the Flash-Lag (-Lead) Illusion

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There has long been speculation that the M-cell pathway may be preferentially involved in the processing of the moving stimulus in the flash-lag illusion (Khurana & Nijhawan, 1995; Nijhawan, 2008). Chappell, Hine, and Hardwick (2002) found that making the flash near-equiluminant with its background increased the illusion magnitude, however, when they made the moving stimulus near-equiluminant there was no significant effect on the illusion. We sought to reduce M-pathway response more effectively by adding luminance noise to an isoluminant display, as this has previously been shown to remove remaining luminance signals from the chromatic motion response (Baker, Boulten, & Mullen, 1998; Mullen, Yoshizawa, & Baker, 2003). By splitting the display we were able to manipulate the equiluminant colour, luminance contrast and the presence of luminance noise independently for the flash and the moving stimulus. We found that

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making the moving stimulus equiluminant significantly reduced the magnitude of the illusion. In addition, when the flash was defined by luminance contrast and the moving stimulus was equiluminant, a number of participants exhibited a significant flash-lead illusion. Our data strongly support the notion that M-pathway processing of the moving object contributes to the flash-lag illusion.

43.329

Magnification of the Froehlich Effect under Noise

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The Froehlich Effect (FE) is a phenomenon where the onset of a moving stimulus is perceived as displaced in the direction of motion. Current explanations of the FE state that the early portion of the moving trajectory is erased from conscious awareness, either due to lack of attention as it shifts toward the motion onset (Müsseler & Aschersleben, 1998), or due to metacontrast masking of the earlier portion of the motion trajectory by the later (Kirschfield & Kammer, 1999). Here we used a noise paradigm to study the mechanism involved in the FE. We measured the perceived motion onset in the presence and absence of visual noise, which consisted of randomly displayed dots the same size and shape as the moving stimulus. We found that the magnitude of the Frohlich effect was significantly greater in the presence of the noise. One possible explanation for such an increase is that it takes longer for visual attention to shift to the motion trajectory in the presence of visual noise. Since it is known that an odd-colored target popsout among distractors (Triesman, 1986), we tested this explanation by using a moving stimulus with a different color than the noise. We found that the FE was still greater when noise was present, though the increase in magnitude was not as large as when the target and the noise were of the same color. This indicates that the magnitude increase under visual noise has both attention-dependent and attention-independent components. Further experiments suggest that the latter component is due to the delay in the object formation process. In the presence of the visual noise, it is more difficult for the brain to know with certainty whether a given frame of the stimulus is part of the motion trajectory, or is visual noise.

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43.330

Illusory position shift induced by plaid motion

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The position of a moving stimulus appears as shifted in the motion direction. This motion-induced position shift (MIPS) occurs for many kinds of motion, including random-dot kinematograms, second-order motion and illusory motion after adaptation (motion aftereffect). In this study, we investigated the relationship between the mechanism of this illusion and the motion integration process. For this purpose, a moving plaid was used as the stimulus. First, we examined whether the type-1 plaid induced the MIPS. The two component gratings (50% contrast, 5-cpd spatial frequency) of the plaid moved in ±22.5°, ±45°, or ±67.5° directions, with 0° indicating purely horizontal. The perceived speed of the plaid was equated to that of a vertical Gabor patch moving horizontally at 4 Hz. Because it was type 1, the plaid's pattern motion was faster than its component gratings. Two such plaids were presented at 4-deg eccentricity above and below the fixation point at the center of the monitor. The subject's task was to judge whether the upper stimulus was to the right or left compared to the lower stimulus. Surprisingly, the horizontally moving plaid appeared as shifted purely horizontally, and the MIPS induced by the plaid was larger than that induced by either component grating. Next, we used a pseudo plaid, which was composed of 12 small Gabor patches of random orientations, each moving in the direction that was consistent with a common horizontal global motion (Amano et al., 2008). Two such pseudo plaids were presented above and below, and the subject did the same task. Again, the pseudo plaid also induced the MIPS in the pattern-motion direction. From these results, we conclude that the mechanism of the MIPS is located after integration of local motions into a global one. We will discuss the contribution of the processing of motion integration to position perception.

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43.331

Perception of Motion Smear during Visually Induced Illusory Self Motion

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Purpose. Motion of the retinal image during an eye or head movement produces less perceived smear than when the same retinal image motion occurs during stable fixation. However, the reduction of perceived motion smear is asymmetrical, occurring only for targets that move in the opposite direction of an eye or head movement. In this study, we asked if perceived motion smear is reduced also during illusory self motion that is induced by rotation of the visual surroundings. Methods. Four normal observers matched the extent of perceived motion smear produced by a horizontally moving laser spot (velocity = 10 - 60 deg/s) during steady fixation. The observers were surrounded by a 148-cm diameter cloth drum, which either remained stationary or rotated at 15 or 30 deg/s in the clockwise or anti-clockwise direction. During rotation, the observers triggered trials only when they perceived themselves to be moving in the opposite direction of the drum. Horizontal eye movements were monitored and trials were rejected if the eye velocity exceeded 2 deg/s during presentation of the laser target. Results. The extent of perceived motion smear increased systematically from approximately 90 to 190 ms as the target duration increased from 100 to 300 ms. However, perceived smear did not differ significantly between drum-stationary and drum-moving conditions or, in the drum-moving condition, when motion of the laser spot was in the same vs. the opposite direction of perceived self motion. Conclusions. The reduction of perceived motion smear during eye and head movements is attributed to the influence of extra-retinal signals. Although vestibular and visual signals that contribute to perceived self motion are thought to combine in the brainstem, our results indicate these signals must remain separated to some extent, as only the vestibular signals for self motion decrease perceived motion smear.

Acknowledgement: Support: P30 EY07551

Eye Movements: Pursuit and Fixation

Monday, May 11, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

43.401

Smooth pursuit and cognition share attentional resources

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Most natural objects we pursue are larger than the spot pursuit stimulus, and extend beyond the fovea. Given, the pursuit system might benefit from the peripheral motion information they provide. Previous work showed that additional peripheral motion improves identification of or reduces saccade latency to changes in features of a pursuit stimulus, a result attributed to a motion releasing attention from the pursuit target to perform the tasks. We asked whether this attention was specific to the visuomotor system, or whether it was shared with a cognitive pool. To test this, observers performed a secondary letter memorization task during pursuit. The pursuit stimulus comprised a small (0.26^{o}) square and four surrounding spots (0.2^{o}) (3.7^{o} eccentricity) arranged in an 'X' configuration, that moved at $12\,^{o}$/s and was presented with or without consistent peripheral motion of a random dot cinematogram (RDC). First, observers pursued the stimulus and made a saccade to one of the surrounding four spots that was brightened. Con-

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sistent with previous work, saccade latency was reduced by the RDC, an indicator of how much attention was released from pursuit. Task difficulty was then decreased by increasing the luminance of the target spot, which eliminated the latency reduction provided by the motion. Next, observers performed the memory task in which two letters were briefly presented before each eye movement trial. Observers had to remember the letters from both the current and previous trials throughout the eye movement task, and following the current trial, identify the letters from the previous one. Adding the memory task restored the benefit of peripheral motion to saccade latency. The results suggest that attentional resources usurped by the memory task left insufficient resources for the eye movement task, and therefore attentional resources for pursuit and cognition are shared.

43.402

Differences in active versus passive short-term memory acquisition for smooth pursuit eye movements revealed by event-related fMRI

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Actively following, as opposed to passively observing, a predictable target motion results in a shorter latency and higher initial eye velocity of anticipatory smooth pursuit (Burke and Barnes, 2008). To investigate if this behavioural advantage to following the target is also observed in brain activity, 11 subjects participated in both behavioural and fMRI imaging (3T, Philips) experiments with the objective of determining differences in functional activation between active pursuit and passive observation of predictable target motion. We used a novel paradigm in which two sequentially presented motion stimuli were segregated by a variable delay (2, 4 and 6s). Subjects were instructed, via a coloured cue, to either follow both presentations of the target (Go-Go: green cue) or passively view the first target presentation and follow the second (NoGo-Go: pink cue). In the Go-Go and NoGo-Go conditions the target presentations in the pair were matched in both timing and velocity (i.e. the 1st presentation was predictive of the 2nd presentation). In an additional randomized condition a green cue with a cross indicated that the subject must follow both presentations; however, in this random condition the presentations differed in both timing and velocity. The pre-processed normalized fMRI results were segregated into 3 sections before a haemodynamic model was applied: (i) first target presentation, (ii) delay and (iii) second target presentation. We reveal significant differential activation in active versus passive tasks in all 3 sections, with significant differences in the delay period in posterior parietal, frontal/supplementary eye fields, and medial temporal brain regions. The results indicate clear task-related differences in how the brain processes and holds predictive target information during active and passive pursuit.

Burke, M.R. Barnes, G.R. 2008. Anticipatory eye movements evoked after active following versus passive observation of a predictable motion stimulus. Brain Research, 1245: 74-81.

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43.403

Smooth pursuit eye movements and the segregation of coherent motion

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Coherent motion has been used extensively as a research tool to study human motion sensitivity and the properties of motion sensitive neurons, but it has been rarely used to study smooth pursuit eye movements.

Here we measured smooth pursuit eye movements in response to coherent motion. The stimulus consisted of random dots that moved at a speed of 10 deg/sec within a circular aperture of 10 deg radius. The dot density amounted to 2 dots/deg, the dot lifetime was 200 ms. We varied the percentage of coherent moving dots from 20 to 100%. The coherent motion was always horizontal, either leftward or rightward.

In the first experiment, subjects were instructed to initiate smooth pursuit eye movements immediately after motion onset. We found that the amount of coherence had only minor influence on the latency of smooth pursuit initiation, but a strong influence on the acceleration during the initiation period, with faster acceleration for higher coherence levels. Steady-state pursuit gain, however, was similar for all coherence levels. To test if the dependency on coherence is an intrinsic property of smooth pursuit initiation or a result of incomplete motion segregation, we performed a second experiment. Subjects were initially required to hold fixation on a fixation point for 500 ms after motion onset. After fixation offset, they had to pursue the coherent motion for another 1000 ms. Again we found a strong influence of motion coherence: number and magnitude of fixation errors were higher for higher coherence levels. However, we did not find a strong relationship between coherence level and pursuit acceleration after the offset of the fixation point.

The results indicate that smooth pursuit acceleration depends crucially on the segregation of motion signals. If this segregation is completed before pursuit onset, pursuit acceleration is rather immune to noisy motion signals.

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43.404

Motion correspondence based on the proximity in the environmental coordinates during smooth pursuit eye movements

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When multiple elements are included in successive images of apparent motion, the visual system should solve a motion correspondence problem. An important determinant of correspondence matching is proximity. The closer the elements are, the more likely they are matched with each other. It has been believed that proximity is defined with respect to retinal coordinates. Here, we report that proximity with respect to environmental coordinates also affects motion correspondence during smooth pursuits. We flashed a square-wave grating twice on a dark background with an interval of 125 ms, while the observer's eyes tracked a marker moving smoothly below the grating. The two grating flashes were in the same spatial phase on the display, but 180-deg out-of-phase in the observer's retina due to a retinal shift induced by the eye movement. If retinal proximity determines correspondence matches, the perceived direction should be ambiguous because retinal motion energies will be balanced between the two directions. On the other hand, if environmental proximity determines correspondence matches, the perceived direction should be opposite to the pursuit direction because the displacement will be zero in the environment coordinates, and this was what we actually found. Our effect might sound similar to Filehne illusion, in which stationary background appears to move backwards during pursuit, but this classical illusion is considered as an error in combining retinal and extra-retinal (eye-movement) velocity signals when estimating object speeds in environmental coordinates. In contrast, our effect suggests that pursuit eye movements affect motion correspondence, a processing stage much earlier than the integration of retinal velocity with extra retinal signals. Motion correspondence based on environmental coordinates may be a novel mechanism for visual world stabilization despite retinal image motions during eye movements.

43.405

Psychophysical observation of head tilt vestibulo-ocular reflex

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Purpose: The vestibulo-ocular reflex eye movements can be observed psychophysically. When we roll, pitch, or yaw our head, we perceive the movements of texture due to the reflex. The eye torsion reflex by head tilt is of most interest, since it cannot be voluntarily controlled and manifest the clear reflexes.

Methods: Under the "world" conditions, the stimulus was fixed to the environment. Under the "head" conditions, the stimulus was presented by a head mounted display. The images had simple textures such as some horizontal lines depicted with low contrast grays or equiluminant colors. The lines and the background alternated with their colors, flickering at 10-20 Hz. The normal subjects tilted his head as observing the image.

Results: Under the "world" conditions, with the clockwise tilt from left to right lateral in 0.5 second, the subjects first perceived the salient clockwise rotation of the texture then perceived the rather slow counterclockwise rotation that soon died away. When the head was tilted slowly such as in 2 seconds from one lateral to the other, the subjects perceived the consecutive rotations of the texture and observed no counter rotation. The images in the head mounted display gave the opposite directional motion perceptions. The clockwise tilt caused first the counterclockwise and then the clockwise rotations. Though, the motions were rather less salient under the "head" conditions, they were qualitatively similar to that of the "world" except the directions.

Discussions: The motion under the "world" would be derived from the retinal slip of the image caused by the head tilt and the slightly delayed compensating reflex eye torsion followed by the eye returning to the primary orientation. Under the "head" conditions the retinal slips were caused only by the reflex torsions. The slips were in the opposite directions to that of the "world". These slips were consistent to the observations.

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43.406

Auditory deprivation during infancy affects the control of pursuit eye movements

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The responses of neurons in the inferior colliculus, a key relay station in the primary and secondary auditory pathways, are considerably altered by auditory deprivation. Because cells of the inferior colliculus also project to the deep layers of the superior colliculus implicated in the control of eye movements, we hypothesis that the lack of auditory input during early infancy will also disrupt oculomotor control. We assessed single saccade-fixations and pursuit in 12 adults who are deaf since early infancy and in age- and gender-matched adults with normal hearing function. The results of the statistical analyses indicate no difference amongst the two groups on the single saccade-fixation task ($p > 0.05$). In contrast, the oculomotor pursuit of a single target moving vertically, horizontally or in a circular manner is abnormal in deaf adults ($p <0.05$). We found a greater number of fixations and saccades for the group of deaf adults. Moreover, their fixations were of shorter duration and their saccades of longer amplitude, indicating more interruptions in pursuit than for participants with normal hearing. These results support our hypothesis and suggest that early auditory deprivation disrupts the development of the neuronal circuitry underlying the control of dynamic pursuit eye movements.

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43.407

Persistent abnormalities in the control of eye movements following a sport-related concussion

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Concussions are a common injury amongst athletes, causing impairments of motor and cognitive functions. Current methods of diagnosing and tracking recovery of concussion are mainly based on cognitive tests that show important learning effects. Since frontal and occipital lobes are likely affected by a concussion, and given that those regions are involved in eye movements, we hypothesize that eye movements are disrupted by a concussion. We assessed different aspects of eye movements (single saccade-fixation, pursuit, and microsaccades induced by the Troxler effect) in athletes with a recent concussion (<2 weeks), athletes with history of older concussions (1-5 years), and individuals without a history of concussion. Our findings indicate no difference amongst the three groups on the single saccade-fixation task. In contrast, whilst horizontal tracking of a slow or fast moving target is normal, the oculomotor pursuit of a single target moving either vertically or in a circular manner is abnormal in concussed athletes, with the greatest deficits in the recently concussed athletes. Athletes with a concussion make fewer saccades and fixations, have longer fixation durations, and greater saccade amplitudes. For the Troxler effect, in comparison to the control group, concussed athletes experience a more rapid onset, and the effect lasts longer. Finally, concussed athletes show suppression in the number and amplitude of microsaccades. Therefore, although concussions are often considered as transient and without long-term consequence, our results indicate persistent dysfunction in the brain regions involved in certain aspects of eye movements.

43.408

Intercepting moving targets: Estimating motion integration and saccadic dead time

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Saccade latency – the time between target onset and the moment the saccade begins – varies greatly even in situations where other affecting factors are controlled for. This is an important issue when we consider 'when' and 'where' processes in saccade programming. In the case of moving targets, one can argue that 'when' processing (how long the latency will be on a given trial) will dictate the 'where' outcome – longer latencies result in greater target displacement, which requires a different saccade endpoint. Previously, we have shown that in situations where observers are unable to predict the onset of a moving target, they are still able to generate accurate saccades. Here, we investigate how positional information about moving targets is integrated in the run-up to a saccade being generated. Participants were presented with two Gaussian patches moving at 18o/s. The contrast of one of the patches increased unpredictably, indicating the saccade target. In 50% of the trials, the patches were subject to a step-change to either a faster (30o/s) or slower (6o/s) speed at a variable interval after the contrast change. We find evidence of a surprisingly long dead time prior to each saccade of some 100-150 ms during which no new motion information is acquired. Preceding this there appears to be a period of motion integration of some 200 ms upon which the speed estimate determining saccade landing position is based. These results are inconsistent with the saccadic system taking a last-minute snapshot of target position and speed prior to the dead time, the latter presumably reflecting the operation of saccadic motor programming.

43.409

A simple technique to improve fixation performance in naïve observers

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Maintenance of stable central eye fixation is crucial for a variety of behavioral, electrophysiological, and neuroimaging experiments. Naïve observers in these experiments are not typically accustomed to fixating and are often unable to reliably maintain fixation and this may produce confounds in experimental results. Verifying fixation requires the use of cumbersome and costly eye-tracking and results in loss of participants when they are unable to reliably fixate. We devised a simple flicker display consisting of a random-dot pattern (single pixels [.047 deg], 50% black, 50% white) rapidly alternating (37.5 Hz; 75 Hz refresh rate) with its video reversed complement (i.e. white dots became black and black dots became white). This display appeared as a uniform gray patch when the eyes were stable (due to temporal luminance summation), but produced an easily detectable momentarily static noise pattern (due to disrupted temporal summation of luminance) whenever the eyes moved or blinked. A few minutes of training using this display dramatically improved the accuracy of eye fixation when observers later performed a demanding peripheral attention-cueing task. Observers reliably detected their own eye-movements when their eyes deviated by as little as 0.5 degrees. In contrast, the same amount of training using control displays that were uninformative about fixation performance did not produce significant fixation improvements, and some observers consistently made eye movements towards the attention cue, contaminating the observed attention-cueing effect. Our results indicate that (1) eye fixation can be rapidly improved in naïve observers by providing contingent feedback about eye movements, and (2) our simple flicker technique provides an easy and effective method for providing this feedback.

43.410

Fixational eye movements during quiet standing

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Fixational eye movements serve two competing functions: the stabilization of the current gaze position and the generation of retinal image slip to counteract photoreceptors adaptation. In laboratory measurements of eye movement, participants are typically restrained in their head movements, which might bias the functional role of fixational eye movements towards the generation of retinal refresh. Here we compare fixational eye movement statistics measured during upright standing with eye movements recorded with restrained head. Simultaneously with the recordings during standing we collected data from the movement of the center of pressure. Both types of movements are governed by temporal scaling properties with persistent behavior on the short time scale and antipersistent behavior on the long time scale. However, the transition points between scales are observed at different ranges. We show that changing the posture strongly modulates the scaling properties of fixational eye movements. Finally, we discuss possible models of the control of fixational eye movements.

43.411

Fixational eye movements and the autokinetic illusion

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A stationary point light source in an otherwise completely dark room is often perceived as moving, a phenomenon known as the autokinetic effect. Previous studies have linked autokinesis to eye movements. However, it has remained an open question whether the autokinetic effect originates from erroneously interpreted signals related to eye movements, or it results from the motion of the stimulus on the retina (retinal theories). According to extraretinal theories, the illusory motion of the stimulus is the result of suppressed motor commands that occur during prolonged fixation. According to retinal theories, the retinal motion caused by unmonitored fixational eye movements is responsible for autokinesis. Fixational eye movements always occur during fixation, but the changes in the retinal image they produce are normally not perceived. In this study, we used retinal stabilization, a procedure by which retinal image motion is eliminated, to sort between extraretinal and retinal theories. Retinal stabilization is a powerful method to test competing theories, as it decouples the motor signals related to eye movements from the visual changes they are normally associated with. In a forced-choice discrimination task, subjects reported whether a small, bright dot, briefly displayed on a CRT, was presented at fixed location or drifted with uniform motion at 30′/s. Trials randomly alternated between the two conditions of normal viewing and retinal stabilization. In the latter condition, the position of the dot was changed in real-time in order to eliminate the retinal motion caused by eye movements. We show that the autokinetic effect correlates with retinal image motion but not with the amplitude of eye movements. These results speak against extraretinal theories and suggest that autokinesis originates from a failure of the visual system in discarding the fixational motion of the retinal image during viewing of an isolated stationary stimulus.

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43.412

Fixational eye movements in a high-acuity visual task

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During the periods in between saccades, fixational eye movements continually jitter the location of gaze. Recent experiments that eliminated retinal image motion have shown that fixational instability facilitates discrimination/detection of high spatial frequency patterns (Rucci et al, 2007). This finding suggests an involvement of fixational eye movements in the processing of fine spatial detail. Previous studies, however, reported a reduction in the rate of microsaccades in tasks requiring high visual acuity. Microsaccades are one of the components of fixational instability. To explore the relationship between these two sets of results, we examined fixational eye movements during execution of a high-acuity visuomotor task, which consisted of threading a needle in a simulated virtual environment. Subjects used a joypad to control the relative positions of a needle and a thread on a CRT. We show that the rate of microsaccades highly depends on the threshold used to define them. In agreement with previous reports, microsaccades with amplitude smaller than 10′ were relatively rare. However, fixational saccades with amplitudes up to 30′ occurred frequently. Their average amplitude decreased and their rate increased as the thread approached the needle, a consequence of the fact that these small saccades moved fixation back and forth between the eye of the needle and the tip of the thread. Furthermore, evaluation of changes in the overall rate of microsaccades, i.e. whether the task led to an increment or decrement in microsaccadic rate, depended on the baseline used as a reference. Microsaccades were on average more frequent during sustained fixation, a condition that in some observers elicited a high rate of microsaccades, and less frequent during free-viewing, a condition in which microsaccades were always rare. These results suggest that fixational saccades are part of the strategy by which the visual system acquires fine spatial detail.

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Attention: Inattention and Blindness

Monday, May 11, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

43.413

Scene encoding is enhanced during target identification in a RSVP task

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When two target letters are presented among distracters in a rapid serial visual presentation paradigm (RSVP), correct identification of the first target often results in a deficit for identifying the second target if it appears within 200-500ms after the first target. This ‘attentional blink’ shows that the time-course of encoding successive elements in the stream is interrupted by the presence of the first target. However, less is known about how the presence of a foveal target affects the spatial encoding of information around the target location.

To test this, observers participated in a dual-task RSVP paradigm in which subjects were instructed to identify a white target letter embedded in a stream of black distracter letters. A randomly chosen full-field outdoor scene was placed behind each letter in each frame of the stream. Following each stream, subjects were presented with a test scene and asked if they recognized this scene as one from the RSVP display. On half of the trials the test scene was one of the scenes presented during the presentation stream. Correct recognition of the test scene was at chance performance (50%) when it had occurred behind one of the distracter letters. Surprisingly, we found that observers performed significantly above chance on trials when the test scene coincided in time with the target letter. We also report a deficit in recognition performance of the test scene when it occurred immediately after the target letter – an effect resembling the 'attentional blink.' These results suggest that the entire visual scene is encoded when the target letter is identified, and that the visual system performs something analogous to a 'screen capture' at behaviorally relevant moments in time in order to store this information for further processing.

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43.414

Intentional reduction of the attentional blink: The roles of motivation and attentional control

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The identification of the second of two targets (T1 and T2) in a rapid stream of items is often impaired when T2 is presented in close temporal proximity to T1 – a phenomenon known as the attentional blink (AB). Does the AB stem from ballistic allocation of attention to T1 or can observers purposefully redirect attention to T2? In the present study the AB was attenuated when participants were more highly motivated to identify T2 than T1. In one condition, participants received points equally for correct identifications of T1 and T2; in the other, they received points only for correct identification of T2, although they were asked on each trial whether they had incidentally identified T1. Participants were informed that the highest scoring participant would receive a prize. T2 appeared either as the first (lag 1), third (lag 3), fifth (lag 5), or seventh (lag 7) item after T1. Results revealed that when the incentive encouraged participants to prioritize T2, there was an overall reduction in the duration of the AB, even when analyses were limited to trials in which T1 had been reported correctly. In addition, with this incentive, participants who scored high in a self-report measure of attentional control were able to reduce the AB as early as lag 3, whereas those who scored low in self-reported attentional control were only able to do so at the later lags. These results suggest that rather than reflecting an entirely reflexive overcommitment of resources to T1, the AB can be reduced through combined motivation and attentional control.

43.415

Modulation of distractor processing during the attentional blink

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The selectivity of attention in both space and time is critical for processing our dynamic environment. The load theory of selective attention suggests that the spatial selectivity of attention is increased when the perceptual difficulty of a task increases, resulting in decreased processing of task-irrelevant distractors. In contrast, increasing load on control processes reduces the spatial selectivity of attention, resulting in increased distractor processing (Lavie, 2005). Studies of the attentional blink (AB) have demonstrated that temporal attention also influences distractor processing, such that distractor processing increases during the AB relative to outside the AB (Jiang & Chun, 2001). When considered in the context of load theory, the finding that distractors influence target selection during the AB more than outside the AB is consistent with the notion that the AB reflects a deficit in post-perceptual cognitive processes. Here we investigated the extent to which task-irrelevant distractor processing during the AB is modulated by the difficulty of the first target task. To investigate this issue, the first and second target tasks (T1 and T2) required discriminating the direction of a central arrow that was flanked by distractor arrows pointing in the same direction (easy) or in a different direction (hard). Consistent with Jiang and Chun (2001), T2-distractors impaired performance more during the AB relative to outside the AB. Critically, however, when the effect of T2-distractors was analyzed as a function of T1-load, the interference caused by T2 distractors was reduced when T1 was difficult relative to when T1 was easy. These results suggest that increasing T1-load decreases distractor processing during the AB and are congruent with studies demonstrating that the extent to which semantic information is processed during the AB depends on T1 task demands (Giesbrecht, Sy, & Elliott, 2007, Giesbrecht, Sy, & Lewis, 2008).

43.416

A Blip in the Blink: Novel Distractors Produce Sparing at Lag 2, But Not Lag 1

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In the typical Attentional Blink (AB) paradigm, identification of the second of two targets in a rapidly presented visual stream is impaired at short intertarget lags, with the exception that performance is typically high when the second target appears directly after the first, a phenomenon known as lag 1 sparing. In the present studies we report a new phenomenon in which performance is selectively spared at lag 2 instead of lag 1. The paradigm is based on recent study showing that when participants are required to report the red letter in a stream of multicolored letters appearing inside a box at fixation, briefly changing the color of the box to red produces an AB (Folk, Leber, & Egeth, 2008). This effect has been attributed to the involuntary selection of the irrelevant distractor item. The present experiments varied the categorical similarity between the red target letter and the item occurring simultaneously with the red distractor box (i.e., the "distractor item"). Target letters were preceded at varying lags by a distractor item consisting of a letter, a digit, a random dot pattern, or a blank. Relative to letter distractor items, the other three distractor item types produced an enhancement in target identification that was specific to lag 2. Subsequent experiments showed that this effect is sensitive to the categorical heterogeneity of the stream items. Specifically, when the items in the stream were a mix of letters, digits, dots, or blanks, lag 1 sparing was obtained and lag 2 sparing was reduced. It is proposed that the detection of a "novel" item in an otherwise homogeneous stream results in the focusing of spatial attention that (1) requires approximately 200 ms to enact, and (2) can be dissociated from the selection of the distractor item induced by the distractor.

43.417

Can Endogenous Spatial Cues Be Processed During the Attentional Blink?

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Identification of the second of two targets (T1, T2) is impaired when presented within about 500 ms of the first (attentional blink, AB). Ghorashi et al. (2007) found that temporally leading exogenous spatial cues presented at the T2 location facilitated T2 identification but did not reduce the AB magnitude. They reasoned that exogenous spatial cues are processed along the dorsal visual pathway whereas target identity is processed along the ventral pathway. Thus, cue and target were processed separately. It follows that, were the cue and T1 to be processed along the ventral pathway, cue-processing should suffer during the AB. To test this hypothesis, two types of spatial cues were used, both with an endogenous component but differing in dorsal- versus ventral-stream processing. In Experiment 1, T1 was a white letter in an RSVP stream of black letters. T2 was a tilted "T" among rotated "L"s, all positioned on an imaginary clock-face (2.5° radius), centered on fixation. Observers indicated whether the "T" was tilted left or right. On half the trials, a small dot (dorsal stream) was presented 100 ms before T2, at the clock-face location opposite T2. Participants were instructed to use the cue to find the "T" at the clock location opposite the cue. The results showed that this spatial cue could be processed efficiently even during the AB. In Experiment 2, the cue was a red number between 1 and 12 (ventral stream) that indicated the location of T2 on the clock-face. The number appeared briefly just above fixation 100 ms before T2. Processing of this spatial cue was impaired during the AB. These results sup-

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port the initial hypothesis that whether or not processing of a spatial cue is impaired during the AB depends on whether it is processed along the same (ventral) pathway as T1.

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43.418

Electrophysiological evidence for independent consolidation of multiple targets in the attentional blink

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Visual events often do not reach awareness because of temporal limitations on visual attention. For example, observers frequently fail to identify the second of two targets (T1 and T2) embedded in a rapid serial visual presentation, when T2 appears 200-500 ms after T1 (attentional blink: AB). It has been generally accepted that the AB deficit reflects a failure to consolidate T2 into working memory. However, the temporal dynamics of consolidation of targets during the AB period remains unclear. To investigate this issue, we focused on a sparing effect in which T2 and also T3 (third target) identification is unimpaired when triple targets are presented successively (Lag-1 and Lag-2 sparing). We examined the pace at which successively presented targets are consolidated by combining the three target paradigm and measurement of P3 event-related potential which is known to reflect updating processes in working memory. We hypothesized that if the visual system consolidated multiple targets simultaneously, a single P3 component would be observed. On the other hand, if the system consolidated each target independently, separate P3 components would be observed for each target. Behavior scores indicated Lag-1 and Lag-2 sparing, as well as the AB deficit. The results revealed P3 components elicited separately by each target at the midline parietal site (Pz) when Lag-1 and Lag-2 sparing occurred. We found, for the first time, the discrete consolidation of sequentially presented targets. This finding suggests that the successively presented targets can be consolidated independently every 100 ms. The present results are inconsistent with conventional AB models assuming that the AB deficit occurs because the delay of T1 consolidation directly blocks T2 consolidation. Rather we suggest that an attentional event or suppression triggered by distractors between the targets impairs T2 consolidation.

43.419

Feature-based guidance improves singleton detection during the attentional blink

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When two targets appear in a stream of rapidly presented distractors, report of the second (T2) is often impaired when it occurs soon after the first (T1). This phenomenon, known as the attentional blink, has often been explained as a failure of visual input to be encoded into a durable representation that can withstand masking by trailing objects. Joseph, Chun, and Nakayama (1997) showed that even the efficient task of singleton detection was massively impaired when presented soon after T1 in an attentional blink paradigm. This finding and others have led to the view that resources necessary for consolidation of T2 are not available while T1 processing is still engaged (i.e., Chun & Potter, 1995). Here we show that processing of T2 stimuli during the attentional blink does not necessarily occur as predicted by such a feed-forward, two-stage model. We find that the availability of feature-based attentional guidance reduces the magnitude of the attentional blink when T2 is a singleton detection task that is presented at short lags after a T1 letter identification task. This result was obtained when participants searched for a known color singleton, as well as for some types of known orientation singletons. Benefits in T2 performance were not due to reductions in T1 performance nor a change in response bias. The presence of these benefits indicates that feature biasing can be maintained even during the detection of T1. Importantly, top-down modulation increases the probability that well-specified visual representations will survive the attentional blink, gaining access to awareness and influence over behavior.

43.420

Under which conditions does T1 difficulty affect T2 performance in the attentional blink?

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When two visual targets (T1 & T2) are presented in rapid succession, performance of T2 suffers up to 900 ms. One theory of this attentional blink (Raymond, Shapiro, & Arnell, 1992) propose that T1 and T2 compete for limited processing resources (Chun & Potter, 1995), and predict that prolonging processing time for T1 by increasing its perceptual difficulty will induce a larger blink. Several studies have tested this prediction without reaching a consistent answer. McLaughlin, Shore, & Klein (2001) found no effect of the exposure duration of T1 on the attentional blink. Christmann & Leuthold (2004) found that increasing the contrast of T1 decreased the attentional blink but Chua (2005) found the opposite effect. In the current study, we varied the perceptual difficulty of T1 in the two-target paradigm (Duncan, Ward, & Shapiro, 1994) both by changing the contrast and by changing the exposure duration. In the hard condition, T1 exposure duration was 10 ms while T1 contrast was adjusted individually to reach 50% correct T1 identification. In the long duration condition, T1 exposure duration was increased to reach approximately 90% correct T1 identification. In the high contrast condition, T1 exposure duration was the same as in the hard condition while T1 contrast was adjusted individually to reach the same performance on the T1 identification task as obtained in the long duration condition. Six observers completed 260 trials in each of the three conditions. We found a strong effect of T1-T2 latency on performance in the T2 identification task in all conditions, replicating the finding of an attentional blink. However, we found no difference in the attentional blink between conditions. We conclude that increasing the perceptual difficulty of T1 either by decreasing T1 contrast or T1 exposure duration is not sufficient for modulating the attentional blink.

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43.421

Implicit Learning and the Attentional Blink

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A series of experiments are described in which participants performed two simultaneous tasks; a dual-target detection task in which a sequence of letter targets and distractors were presented in rapid serial visual presentation (RSVP), and a reaction time task requiring participants to respond to a cue presented immediately after the RSVP sequence. Under these RSVP conditions, it is usually difficult to identify the second target when it is presented in close temporal proximity of the first target, a phenomenon known as the attentional blink. However, here, participants showed an advantage for detecting a target presented during the attentional blink if that target signaled the presentation of the response cue. Participants also showed faster reaction times on trials with a predictive target. Both of these effects were independent of conscious knowledge of the target-response contingencies assessed by post-experiment questionnaires. The results suggest that implicit learning of the association between a predictive target and its outcome can automatically facilitate target recognition during the attentional blink, and therefore shed new light on the relationship between learning and attentional mechanisms.

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43.422

Noise Overlay on the RSVP stream reduces the AB

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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.

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43.423

Word superiority in a dual-task RSVP: familiarity or task definition?

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When subjects are asked to report on two targets from an RSVP stream, impairment of the second target (T2) identification can be observed if it is presented 200-500 ms after the first target (T1). This phenomenon is referred to as the attentional blink (AB).

It has previously been shown that if a stream of letters forms a familiar word, the AB disappears (Falikman, 2002). To demonstrate that, mutable words were used that could be read in two different ways, with a letter which could be skipped due to the AB: e.g., monkey/money. However, subjects reported full words even when the task to read a word was the second one. This was considered a word superiority effect (WSE).

To reveal a mechanism of the WSE in a dual-task RSVP, we tested two hypotheses. The first one concerned the influence of experience. If a subject knows the word, the WSE will emerge; otherwise the AB would be observed.The second hypothesis supposed the influence of task definition. If instructed to read words, the subject would demonstrate WSE; if not, the AB would be observed.

Letters appeared in an RSVP for 107 ms each, forming either words or pseudowords. There were two groups of subjects. Both participated in a dual-task experimental and a control condition. The first task was the same for both groups: to detect whether the first letter of the stream was written or printed (T1). The second one varied: group A was instructed to read words, whereas group B was instructed to report all letters.

Data analysis revealed differences between experimental and control conditions in group B for both word and pseudowords, demonstrating the AB. There were no differences between conditions in group A, demonstrating the WSE. Thus, the source of the WSE seems to be the task performed by subjects.

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43.424

A distinction between perceptual blindness and attentional blindness (II): backward masking versus attentional blink

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Various psychophysical techniques have been proven successful tools to render visual inputs subjectively invisible. For example, backward masking obstructs the awareness of a prior stimulus, and the masked stimulus remains invisible even with full attention at the correct spatiotemporal location. In contrast, observers would miss the presence of a strong stimulus if their attention were not directed to the stimulus. These two examples both demonstrate observers' failure to detect a stimulus. However, it remains unknown whether the nature of unawareness between those techniques is the same.

Here we developed a method for classifying different types of psychophysical blinding techniques such as in current study, backward masking and attentional blink (AB). In experiment 1, we impaired the visibility of a target luminance blob by presenting a mask immediately after. The observers' detection accuracy deteriorated as a function of ISI between the target and the mask. In experiment 2, we used AB to impair the visibility of the letter 'X' embedded in a RSVP letter stream by manipulating the lag between letter 'X 'and another attention-catching marker. In both experiments, the target was presented on half of the trials, and subjects were asked to report the presence or absence of the target together with their subjective confidence rating (high/med/low).

Our analysis showed that subjects were equally highly confident in reporting absence in 'missed' and 'correct-rejection' trials in backward masking, suggesting the unaware experience due to backward masking (miss) is subjectively similar to physical absence (correct-rejection). In AB, observers' confidence decreased together with the objective performance, implying that observers were aware of the transient attentional impairment. This distinct pattern in confidence rating supports the hypothesis that impairments in unconscious perception can be classified into sensory and attentional mechanisms, and this is in line with the view that perceptual (un)awareness involves multi-stage processing.

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43.425

Video game players excel at change detection

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As our everyday lives become increasingly more complex with technological advancements, an important question arises in whether certain experiences can lead to improved cognitive and perceptual abilities. Recent research has demonstrated that action videogame players (VGPs) consistently demonstrate improved performance across a variety of visual and attentional tasks when compared to non-videogame players (NVGPs; e.g., Green & Bavelier, 2003). Videogame exposure is thought to heighten and hone attentional abilities, thus guiding and enhancing performance in visually demanding tasks. Yet, it remains unknown how and why such benefits arise. To explore the causal mechanisms that could underlie the VGPs' improved abilities, we tested VGPs and NVGPs on a modified version of a change-detection 'flicker task' (previously used in Mitroff & Simons, 2002). In this paradigm, participants briefly view a scene, which is followed by a blank display, a modified version of the scene, and finally another blank display. Participants are to identify the location of the change between the two scenes. In a typical flicker task, this change sequence continuously repeats until detection, but in this modified version, participants make a localization response after each change presentation. When participants do not detect the change, they are to guess, thus providing several guessed locations leading up to their eventual detection. VGPs successfully detected a higher percentage of changes and did so in fewer presentations than

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NVGPs, consistent with prior claims of enhanced perceptual abilities in VGPs. Further analyses revealed different strategies wherein VGPs were more diligent in their searching; when participants happened to accurately guess the change location, VGPs were more likely notice the change, whereas the NVGPs were more likely to continue searching for the change without noticing their happenstance detection. These results suggest that both enhanced search strategies and search abilities drive the VGPs' benefits.

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43.426

Inattention boosts subjective visibility: Implications for inattentional and change blindness

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Introduction: Inattentional and change blindness are characterized by an inability to detect unattended events. Interestingly, subjects consistently overestimate their ability to detect such events and are

surprised when informed that an undetected event has occurred. We hypothesized that this effect is due to the subjective visibility of unattended stimuli being disproportionately higher than what would be warranted by their objective information processing. We tested this hypothesis using the formal tools of Signal Detection Theory.

Methods and Results: Subjects detected strongly and weakly attended gratings whose contrasts were adjusted online to produce the same discriminability (d'). We found that subjects were conservative in detecting the strongly attended gratings and liberal in detecting the weakly attended gratings. Further, we used a number of fixed contrasts for both the strongly and weakly attended stimuli. We found that in the weakly attended condition, subjects were close to optimal (i.e. unbiased) for all contrasts used, while in the strongly attended condition, subjects became very conservative for lower contrasts. Thus, surprisingly, subjects were less optimal in detecting the more strongly attended stimuli. We confirmed that this was still the case even when subjects were encouraged to be unbiased by explicitly specifying pay-offs, were informed about the prior probabilities of occurrence of the gratings, and were given feedback after each trial. Finally, when d' was matched in a discrimination experiment, participants gave higher subjective ratings of visibility for the weakly attended gratings, confirming that our previous results were due to differences in the subjective visibility of the stimuli rather than simple detection biases.

Discussion: We demonstrated that the subjective visibility associated with weakly attended signals is much higher than what would be warranted by the quality of these signals. This effect can explain subjects' surprise at their bad performance in inattentional and change blindness experiments.

Attention: Linguistic, Motivational and Affective Factors

Monday, May 11, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

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Spatial relationships as a visual routine: Evidence from linguistic influences on perceptual judgment

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There are likely to be a variety of ways that the visual system represents spatial structure among a set of objects. One counter-intuitive possibility is that our visual system represents some spatial relationships like language does, as an ordered sequence over time. That is, to perceive that your computer's mouse is to the right of your keyboard, a covert attentional routine might shift between the two objects. If so, then presenting the two objects in a temporal sequence might help or hinder our ability to judge spatial relationships between objects. We asked participants to judge relationships between red and green circles while presenting either color 233, 183, 133, 83, 33, or 0ms before the other. The first circle gave no information about the response, as the second circle could appear randomly on either side. Before each block of 8 trials, we biased participants toward different routines with the framing of the question, e.g., "Is red to the left of green?" or "Is green to the right of red?" The design crossed the 2 color orderings, 2 directional words (left or right), and temporal priority (red or green), with all possible timings. Response times were faster when the 'target' object (e.g., "Is green...") preceded the 'reference' object (e.g., "...of red"), but only at delays of 33 and 83ms. Using a second set of questions, "Which object is to the left (or right)?" response times were faster when the response object (red or green) appeared on the side specified by the question (left or right). This effect was not present for the first set of questions that emphasized featural information over directional information. These interactions of the question's framing and the timing differences between object appearances are consistent with the possibility that static spatial relationships might be represented by dynamic routines.

43.428

Linguistic Control of Visual Attention: Differential Access and Focus or Just Confusion?

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Investigation of the linguistic control of visual selective attention has shown that spatial language cues produce a cued-location effect (increased RTs in response to "left" and "right" when compared to "Above" and "Below"; Logan, 1995; Gibson & Kingstone, 2006). The cued-location effect is generally interpreted as representing differential access to spatial locations. In addition, an opposite-compatibility effect (distractors at uncued locations opposite the target decrease RTs when compatible and increase RTs when incompatible; Gibson, Scheutz, & Davis, in press) has been demonstrated that is unique to the cues "Left" and "Right." The opposite-compatibility effect has been interpreted as representing a differential focus of attention. The present experiment explored an alternative explanation that confusion about locations along the horizontal axis is the underlying cause of these effects by separating cue processing from the visual selection task. In this experiment, subjects were presented with the spatial cues "Above," "Below," "Left," and "Right" and asked to move a joystick in the corresponding direction. Immediately following their response, subjects engaged in color discrimination task where the target was indicated by the preceding word cue. Results of the joystick task showed that subjects were both slower in responding to "Left" and "Right" and also made significantly more errors when compared to "Above" and "Below." Results of the selection task demonstrate a significant cued-location effect but not a significant opposite-compatibility effect. These results suggest that left/right confusion cannot explain the differential efficiency of accessing spatial locations across the axes but may influence attentional focus. An alternative "embodied cognition" interpretation of the non-significant opposite-compatibility effect is also discussed.

43.429

What's in a cue? How value learning affects exogenous selection in dual-stream RSVP

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The visual world is typically full of familiar, valued objects, i.e., objects previously associated with rewards or punishers. How does the presence of such motivationally significant objects affect visual orienting to other targets that have immediate task-relevance? To address this question, we combined an instrumental value learning procedure with a dual stream rapid serial visual presentation (RSVP) spatial cuing procedure that uses response accuracy to yield a precise reflection of the temporal dynamics of visual orienting (Klein & Dick, 2002). First, participants engaged in a simple choice task where they gained or lost money with high or low probability in response to choosing specific visual stimuli (faces or Chinese characters). Then, they engaged in a spatial cuing task in which the pre-learned images served as irrelevant spatial cues. Two RSVP streams of letters were presented above and below fixation. A number target, to be reported at the trial's end, was presented at a randomly chosen serial position unpredictably in one of the two streams. On each trial, a non-informative cue (face or character) was presented in each of the two streams simultaneously prior to target presentation. Cue-target lag was varied between 1 and 5 serial positions. One cue was always novel and its mate (in the opposite stream) was familiar with acquired expected value (i.e., from the prior instrumental learning session). Thus, within each experimental block we varied the cue-target lag, expected value of the familiar cue, and the location of the familiar cue (congruent, incongruent with the target's location). Although spatially uninformative, we reasoned that familiar cues (either associated with reward or punishment) might bias visual orienting. We found in two different experiments that cues associated with value, independent of familiarity, affected performance in a location-specific manner dependent on cue-target lags.

43.430

Can the value of irrelevant cues influence visual orienting?

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In this study we explored whether the presentation of an irrelevant object with previously acquired motivational value causes conflict for task-directed visual orienting. To assess visual orienting, we used a conventional spatial cuing paradigm in which a non-predictive cue (face stimulus) preceded target (simple circle) presentation by a short (100 ms) or long (1500 ms) interval; the task was to locate the target as quickly as possible (left or right). On half the trials (cued trials), cue location matched that of the target; on remaining trials (uncued trials), cue and target appeared at opposite locations. Prior to engaging in the spatial cuing task, participants learned to associate monetary reward or loss with different faces images by making repeated choices in an instrumental learning task. Both valence (win, loss) and probability (high, low) of outcome was manipulated in the learning task yielding different expected values for each stimulus (including zero, i.e., never yielding any outcome). These learned stimuli were then presented as cues in the spatial cuing task. For long cue-target intervals, the expected slowing of responding for cued versus uncued locations (inhibition of return) was found to be unmodulated by the expected value of the cue. However, for short cue-target intervals, we observed longer RTs when cues had non-zero expected value versus zero value (matched in familiarity), but only when targets appeared at the same location as the cue. Uncued RTs were unaffected. This location-dependent effect of cue expected value worked to abolish the typical speed advantage for targets appearing at cued locations with short cue-target lags. These results were interpreted within a framework of spatial interference, created by converging and overlapping neural representations of cue value and target location present in cued trials but not uncued trials.

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Consequences of visual selective attention for evaluations of affectively positive and negative stimuli

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In visual attention tasks, stimuli that must be ignored or otherwise inhibited for accurate performance subsequently receive more negative evaluations than novel stimuli or those seen as the targets of attention (e.g., Raymond, Fenske & Tavassoli, 2003). Such distractor devaluation effects have been taken as evidence that the application of attentional inhibition has negative affective consequences for visual stimuli (Fenske & Raymond, 2006). This view predicts that inhibited stimuli should be rated more negatively regardless of their a priori affective status. Here we test a competing hypothesis that attentional inhibition does not impact subsequent evaluations by eliciting a negative affective response, per se, but acts instead to affectively 'neutralize' a distracting stimulus. This alternate view posits an inhibition-related attenuation of emotional salience that should produce different effects depending on the valence of the 'neutralized' stimulus affect. By this view, attentional inhibition applied to affectively positive stimuli should depress subsequent ratings, whereas inhibition of affectively negative stimuli should enhance subsequent ratings. A pilot rating study was used to identify images of faces depicting people judged on average to be either trustworthy (affectively positive) or untrustworthy (affectively negative). Pairs of these affectively positive or negative faces were then presented to a new group of subjects in an attentional cuing task designed to associate attentional inhibition with one face from each pair. Trust judgments obtained in a subsequent evaluation phase revealed similar levels of devaluation for both sets of cued (inhibited) faces relative to the uncued (non-inhibited) faces. These results are inconsistent with an inhibitory 'neutralization' hypothesis, and are taken instead as evidence that attentional inhibition has negative affective consequences for visual stimuli, regardless of their prior affective status. Generating negative affect for previously distracting stimuli might serve to make it easier to avoid such items in future encounters.

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Visual Marking: The effect of emotional change on time-based visual selection

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The de-prioritization of old (previewed) items already in the field enables increased search efficiency for new items in the preview search paradigm (Watson & Humphreys, 1997). This effect has been replicated using valenced schematic faces (Blagrove & Watson, submitted). Previous work shows that changes to old previewed items that are likely to be of behavioural relevance (e.g., shape changes made when the new items are added), cause the old items to re-compete for selection with the new items. In contrast, less behaviourally relevant changes (e.g., color or luminance changes) have no effect and the old items remain suppressed. Here we examined the effect of changes in emotional valence to old previewed items. Specifically, we compared the detection of a schematic face target (either positively or negatively valenced) in a Preview condition (neutral preview, changing to a valenced distractor set) with a Half Element Baseline (neutral distractors only) and Full Element Baseline (mixed valenced and neutral distractor set). A neutral to negative change in the valence of previewed faces (Experiment 1) saw the preview benefit abolished, with search efficiency impaired, relative to both baseline conditions. In contrast, a neutral to positive preview change (Experiment 2) demonstrated a partial preview benefit, where participants were more efficient than in the Full Element Baseline. This contrast across experiments was also reflected in the numerical strength of the Preview Benefit, via an index of Preview search efficiency (PEI) (Experiment 1: PEI=0.08; Experiment 2: PEI= 0.41). Overall, the findings show that ignoring a negative change in expression is more difficult than ignoring a positive change in expression, consistent with ecological considerations.

43.433

Positive and anxious mood influences on selective visual attention

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Recent research has suggested that when people are in a positive mood they show reduced attentional selectivity and broadened attentional filters. Rowe, Hirsh, and Anderson (2007) investigated this effect by inducing happy and sad moods with happy or sad music while participants were completing attention tasks. Participants completing a flanker interference task were more influenced by response-incompatible flanker letters when they were in a positive mood. This effect occurred even as flanker eccentricity increased, suggesting positive mood broadened attentional scope resulting in impaired selective attention to the target. The current study extends these findings by manipulating mood with film clips played before, not during, the attention task, and by inducing an anxious rather than sad mood. Sixty-nine undergraduate participants completed a flanker task in positive and anxious moods, with the order of the film clips counterbal-

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anced between participants. Mood ratings suggested that the film clips effectively induced happy and anxious moods that lasted through the subsequent flanker task. Participants showed a greater flanker interference effect in the positive mood condition than in the anxious mood condition. Planned contrasts revealed that participants responded more quickly to the targets with response-congruent flankers in the positive mood than in the anxious mood. However, this effect only occurred when the flankers were one letter width away from the target and not when flankers were two letter widths from the target. Thus, the effect of positive mood on visual attention was restricted to facilitating responses to trials with response-congruent flankers only within a limited spatial extent. This study suggests that the broadening of participants' attentional filters during positive mood states causes greater flanker interference because participants are more able to use the response-congruent information when in a positive mood, and not because they are unduly influenced by the response-incongruent flanking information.

43.434

Top-down modulation of reflexive social orienting

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Perceived gaze direction is an important social cue that elicits automatic orienting of spatial attention. This effect is experimentally revealed by faster response times (RTs) to targets occurring at gazed-at relative to not gazed-at locations. Although social orienting typically occurs rapidly and automatically even when eye direction is uninformative of the target location, its properties are influenced by top-down factors such as appropriate context, social status, and the familiarity of an individual. However, at present it is difficult to estimate the relative contribution of cognitive factors in social attention because past investigations have typically confounded stimulus (e.g., face or gaze direction) and cognitive factors (e.g., context). Here we investigated the role of cognitive control in social orienting by holding the stimulus factors constant and manipulating the relevance of the gaze cues by informing participants whether the depicted individual was blind or sighted. Observers studied photographs, names, and demographic information of two individuals, and were tested on the their accuracy in retaining this information. Then, these images, displaying averted eye direction, were presented as spatially non-predictive central cues in a cuing task. The results revealed that irrespective of face identity, gaze direction of individuals known to be sighted elicited typical reflexive cuing effects in contrast to gaze direction of individuals known to be blind which overall produced less robust orienting effects and failed to trigger rapid orienting of attention. Together these data suggest that social orienting is critically influenced by the extent that eye deviation is considered socially relevant.

Face Perception: Brain Mechanisms

Monday, May 11, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

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Reverse correlation between the N170 and fractal noise yields human faces: A time-frequency spectrum analysis

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Reverse correlation based on behavioral responses to white noise stimuli can render in external space the internal representation of faces held by human observers. Interestingly, such external renditions of the internal face representation can be obtained in tasks where no face signal is ever presented (Gosselin & Schyns, Psych Sci, 2003). Here, we sought to bypass behavioral measures and derive whole face representations directly from neural activity in the human brain. We presented fractal noise stimuli (i.e., noise patterns with amplitude spectra slopes similar to human faces) in combination with a behavioral response continuum while simultaneously recording EEGs. Fractal noise stimuli were presented for 750ms (preceded by a 250ms base-line mean luminance blank) followed by a 1500ms response interval. EEGs over the P7, P8, P9, P10, P07, and P08 electrodes were subjected to a time-frequency analysis near 170ms (i.e., negative amplitudes at 170ms at these electrodes have been linked to early face processing) on a trial-by-trial basis regardless of the behavioral response. Fractal noise patterns eliciting significant negative EEG amplitudes as well as those that elicited weak or non-negative amplitudes were differenced to generate separate sets of face classification images for delta, theta, alpha, beta, and gamma frequency (Hz) ranges as well as across all frequencies. EEG derived face classification images based on the entire time-frequency spectrum at and near 170ms produced the strongest external renditions of faces, suggesting that it is the entire range of EEG frequencies which contribute to the N170 representation of human faces. Convincing EEG derived face classification images were also generated from the theta-alpha frequency range near 220ms (negative amplitude), theta frequency range near 380ms (negative amplitude), and theta-beta frequency range near 500ms (positive amplitude). In none of the observed cases did the EEG derived face classification images match those derived from the participants' behavioral responses.

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43.436

Virtual Brain Reading: A connectionist approach to understanding fMRI patterns

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Is the fusiform face area (FFA) a module specialized for processing faces, or does it simply support generic visual expertise? Researchers have investigated this question using Multi-Voxel Pattern Analysis (MVPA) applied to fMRI results. Haxby et al. (2001) showed that patterns of neural activation in object-selective visual cortex can be used to discriminate object categories, even when voxels selective for those categories are removed. This provided evidence for a distributed neural code, in which information about faces exists outside the FFA. In contrast, Spiridon and Kanwisher (2002) showed that activation patterns in face-selective cortex were more effective for making face vs. non-face discriminations than for non-face vs. non-face discriminations, whereas this was not true for other object categories. This implied FFA neurons contain special information about faces, but that there is no specialized module for other categories.

We applied MVPA to our neurocomputational model of visual processing. Images are subject to Gabor filtering, then PCA, then input to a Kohonen network – a self-organizing neural network that groups similar inputs together, forming a two-dimensional "semantic map" of stimulus space. We trained the model on images of cups, cans, books and faces. As in Haxby et al. (2001), activity of units in areas dedicated to one category can be used to distinguish other categories. However, in line with Spiridon and Kanwisher, the face area is better at distinguishing faces from non-faces than at distinguishing non-face categories from each other, while non-face areas are on average equipotent at both tasks. In the model, this can be explained by lower within-category variability of faces in the representations compared to, say, cups. Hence, in a model of visual cortex possessing no special mechanism for face processing, we simulate Spiridon and Kanwisher's results, casting doubt on their interpretation in favor of a specialized face module.

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fMRI-Adaptation and category selectivity in human ventral temporal cortex: Evidence for the scaling and sharpening models

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Repeating object images produces stimulus-specific repetition suppression (or fMRI-adaptation, fMRI-A) in the ventral stream. However, the effects of stimulus repetition on functional selectivity are unknown. We investigated the effects of short-lagged (SL, 0-2 stimuli between repeats) and long-lagged (LL) repetition (~ 20 stimuli between repeats) on category selectivity in the human ventral stream using high-resolution fMRI. Specifically, we examined whether repetition produces scaling, sharpening or additive offset of fMRI responses. We found that scaling best explained fMRI-A across the fusiform gyrus (FG) and occipito-temporal sulcus (OTS): fMRI-A was largest for the strongest stimulus, and there was linear relation between responses to repeated vs. nonrepeated stimuli, whereby the slope determined the scaling factor. Results were similar across SL and LL paradigms and regions selective to faces or limbs. However, a collateral sulcus (CoS) house-selective region showed differential effects across paradigms suggestive of differential repetition mechanisms at different time scales: it exhibited scaling for SL repetitions and sharpening for LL repetitions. Specifically, there was lesser fMRI-A to preferred than nonpreferred stimuli for LL repetitions. Finally, multi-voxel pattern analyses across lateral (FG and OTS) and medial (CoS) anatomical regions showed that distributed responses across ventral temporal cortex for object categories largely did not change when objects were repeated for both SL and LL repetitions, consistent with scaling. Nevertheless, in the medial region, repetition increased the decorrelation between distributed responses for inanimate stimuli during the LL experiment consistent with sharpening. Our results suggest differential repetition effects across medial (CoS) and lateral (FG and OTS) regions during LL repetitions, which highlight the possibility that interpretation of long-lagged fMRI-A experiments may vary across ventral subregions.

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Decoding distinct modes of face categorization in the cortical face network

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The fusiform face area (FFA) has been associated with stimulus (i.e., face)-specific coding rather than with a specific mode of processing (e.g., featural or configural) (Yovel & Kanwisher, 2004) using standard univariate fMRI analysis. Here, we used multivoxel pattern analysis (MVPA) to investigate whether a distributed pattern of activity in cortical face-selective areas reflects distinct modes of face categorization.

Subjects were trained to carry out one of two face-categorization tasks: gender (male vs. female) or race (Caucasian vs. Asian), in alternating blocks of trials. The difficulty of the face categorizations was manipulated by using stimuli consisting of a morphed mixture of Asian males with Caucasian females and Asian females with Caucasian males. MVPA was performed on a set of regions of interest defined by a functional localizer (faces selective regions: fusiform gyrus, inferior occipital cortex and superior temporal sulcus, and a house selective region: parahippocampal gyrus) and by retinotopic mapping (e.g., V1).

A linear classifier (support vector machine) was trained to discriminate the gender or race categorization task using leave-one-run-out cross validation. The average classification accuracy was significantly greater than chance (77%) in the cortical face network whereas that in the PPA is not different from chance (55%). The average classification accuracy in V1 was also greater than chance (65%).

These results suggest that the pattern of activity in face-selective visual processing areas contains information about the modes of processing associated with different categorization tasks. These patterns could reflect top-down attentional biases on sub-population of neurons in these areas that process task-diagnostic facial features or spatial regions of the face.

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Interaction between electrical stimulation of face-selective area and perception of face stimuli

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Face perception is important for recognizing others and their thoughts. For example, we can easily recognize identities and intentions of individuals although faces have similar visual features to each other. How can we do it? Previous studies suggest that the Fusiform Face Area (FFA) is important for face perception because it responds selectively to faces. Current study investigated FFAs of 10 epileptic patients. Specifically, we measured the effect of electrical stimulation of FFA on face categorization and how the effect of stimulation varied depending on the signal strength of face stimuli. We first defined face-selective area around FFA by using both anatomical and neurophysiological criteria. For the anatomical criterion, we first found Talairach coordinates of the implanted electrodes by MR-CT co-registration and then compared them to the FFA coordinates of previous researches. When the Talairach coordinates of our electrodes were within FFA coordinates of previous researches, we considered these electrodes as face-selective. We analyzed the magnitude of face-selective component (N200) for the neurophysiological criterion. When electrodes showed significantly larger N200 component to faces than to scenes, we defined these electrodes as face-selective. After categorization of electrodes depending on the two criteria, we measured face-categorization thresholds with electrical stimulation and compared them to those without stimulation. Face categorization thresholds with stimulation were increased only when both the anatomical and the neurophysiological criteria were satisfied, suggesting that electrical stimulation on face-selective area disrupted face perception. We also found that this disruption was compensated by increasing the visual signal of face stimuli. Our findings demonstrate a direct causal link between the face-selective area and face perception.

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What is between face detection and face recognition?

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Current models suggest that face processing is accomplished by distinct visual pathways. Each pathway specializes in a particular aspect of facial information, such as emotion or identity, and has neural substrates that are at least partially separable from those of other pathways. Our research examines the pathway subserving face identification, which is traversed to identify a face by name. The face identification pathway is believed to occur in sequential stages, consisting of at least five stages, including face detection, face recognition, and face name identification.

We integrated magnetoencephalographic (MEG) and behavioral research to examine the staged nature of the face identification pathway. Specifically, we used Gaussian blur on celebrity face, non-celebrity face, and building images to produce three main findings. First, we gauged where a known face-processing MEG signal, the M170, is positioned within the face identification pathway. Second, we examined the effect of familiarity on the M170, and used this result to propose a functional description of the M170 and other stages that may lie between face detection and recognition. Finally, we gained insight into the relationship between face identification and the visual processing of non-face objects. To explain these findings, we incorporate a pragmatic view of what MEG can tell us about the face identification pathway and other neural processes, and we present the findings within the cohesive framework of the staged model of face identification.

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Selective contrast enhancement at category boundaries in the superior temporal sulcus

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In this fMRI study we use multi-voxel pattern analysis (MVPA) to investigate the representation of emotional expressions in the superior temporal sulcus (STS). Subjects were shown a series of videos of morphed emotional expressions ranging on a 10-point continuum between pure fear and pure anger. The task required subjects to categorize the videos as one of these two emotions. For each morph level, we used sparse multinomial logistic regression (SMLR) to measure the similarity between the neural response during the perception of the morphed emotion and during the perception of a pure emotion. This can be accomplished by first training the SMLR classifier on the pure emotions. Then, when testing the classifier on each intermediate morph, the classifier produces a logit, which is a measure of how strongly the classifier believes the morph is anger as opposed to fear. We expected to see one of three outcomes: First, the relationship between morph level and logit could be linear. That is, as the morph level moves away from fear, the neural response moves linearly away from the representation of fear and towards the representation of anger. Second, the relation could be sigmoidal. Under this outcome, the difference in neural representation between two morphs within the same category is smaller than the difference between two equally spaced morphs that belong to different categories. Finally, as predicted by recent work on the STS (Said et al. 2008), the relationship could be nonmonotonic. Under this outcome, neural representations of pure emotions are closer to the neural representations of same-category morphs near the category boundary than same-category morphs further from the category boundary. Our results support this last hypothesis. We conclude that the STS can engage in sharp contrast enhancement at category boundaries, in a process that may help prevent confusion between competing categories.

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Electrophysiological evidence for biased competition in V1 favoring motivationally significant stimuli

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Conscious experience is selective: we are not aware of everything we see. So, how do some percepts reach conscious awareness while others do not? According to one influential model, stimuli will either be detected or go unnoticed based on the result of a competition for neural representation between multiple concurrent stimulus inputs. The winner of this competition will be selected for more detailed analyses.

The goal of this study was to use event-related potentials (ERPs) to investigate whether stimuli of motivational significance “win” this competition for neural representation in visual cortex. Specifically, we took advantage of the C1 component which, due to the architecture of the calcarine fissure in V1, evokes either a negative or positive potential when stimuli are displayed in either the upper or lower hemifields respectively. When stimuli in the upper hemifield receive greater neural representation as compared to those concurrently displayed the lower hemifield, activity will summate to produce a distinct negative C1 component. In a first experiment, we contrasted a pair of task irrelevant fearful faces and their Fourier transformed derivatives, displayed in opposite hemifields, while participants engaged in a central task. Results showed that when fearful faces were displayed in the upper hemifield (evoking a negative potential) and Fourier transformed faces were displayed in the lower hemifield (evoking a positive potential), activity summated to produce a negative C1 component. Importantly, when Fourier transformed faces were presented in the upper hemifield, the C1 component was eliminated. This pattern was replicated when contrasting fearful and neutral faces, and also with fearful faces and their inverted counterparts.

These findings demonstrate that (a) displays of threat competing for awareness are prioritized over other concurrent stimuli, and (b) this biased competition is resolved within 70 ms of visual processing; likely before any feed-back from higher level visual cortices occurs.

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43.443

On the neural mechanism of fear recognition

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Fifteen years ago, Adolphs and his collaborators described a rare patient (SM) with bilateral damage restricted to the amygdala who was unable to recognize fearful faces. Her impairment has recently been attributed to her inability to spontaneously make use of high spatial frequency information from the eye region known to be crucial for fear recognition (Adolphs et al., 2005). This findings support the view that the amygdala’s role in fear perception may be much broader than originally believed (i.e., saliency and unpredictability; Adolphs, 2008). We now report the case of a brain-damaged patient, IR, a 52-year-old woman who suffers from large bilateral lesions including the insula and the superior temporal gyrus (STG) but excluding the amygdala. Despite a normal IQ and relatively intact face recognition skills, she is more impaired at recognizing fearful expressions than SM. In order to understand the nature of her selective deficit with fearful faces, IR was instructed to rate the intensity of static and dynamic basic facial expressions on multiple continuous scales. She accurately recognized all expressions except fear (normal hit rates), which she systematically confused with all other expressions. Second, we tracked her gaze while she categorized static basic facial expressions—her gaze maps were relatively normal. Third, we used Bubbles to examine what information she uses to classify fearful and happy expressions. While IR required more information to identify the expressions than controls, she did not differ from them in her use of visual information. Together, these results suggest that IR has a decisional bias against fear. While the amygdala seems to be necessary to appropriately process fearful faces, it does not appear to be sufficient to do so; instead, the case of IR indicates that cortical regions such as the right anterior insula and STG contribute to the recognition of fearful faces.

43.444

The right FFA is sensitive to subtle physical changes between personally familiar faces

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Neuroimaging studies have provided conflicting evidence with respect to the fusiform face area and its sensitivity to facial identity. Rotshtein et al. (2005) reported discrimination of individual faces within this region solely given their perception as different identities. Contrariwise, others have demonstrated sensitivity of the FFA even to small physical changes along morph continua of faces (Galaie-Dotan & Malach, 2006; Loffler et al., 2005). Although fMRI-adaptation was used across all studies, their incompatible results may result from differences in the stimulus material presented. While Rotshtein et al. (2005) presented famous faces, unfamiliar faces—for which categorical perception (CP) is less pronounced—were presented in the latter investigations. Here, we readdressed this question while presenting faces personally familiar to participants (N=13). Additionally, we ensured a fully balanced design in that both identities of a morph continuum were perceived with equal likelihood, thus nullifying the potential of novelty-driven effects (Rotshtein et al., 2005).

Behaviorally, we found CP of identity: stimulus-pairs located on opposite sides of the perceptual boundary ("between") were more likely to be perceived as different, than those located on the same side ("within"). Regarding fMRI results, the magnitude of release from adaptation within the FFA was comparable for these conditions. This confirms the notion that the FFA is indeed sensitive to subtle physical changes between faces perceived as the same identity. A whole-brain analysis showed that various regions of the "core-system" (Haxby et al., 2000) adapted to face identity. Larger release from adaptation to "between" vs. "within" conditions was found within two face-selective regions not including the FFA (rSTG, left middle frontal gyrus).

Our results contradict the view that the FFA codes differences between familiar faces only if they are perceived as different identities. Furthermore, they highlight the importance of other face-selective regions for discriminating facial identity.

43.445

Attending to face-pair similarity decreases face adaptation in the fusiform area

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Attention has been shown to modulate the fMRI adaptation response to repeated faces in the fusiform regions (Yi et al., 2006). Specifically, when attention is diverted away from faces, the adaptation response is reduced. This study demonstrates that when the task requirement is to discriminate between face-pairs, the adaptation response is also reduced even though subjects were attending to faces. In this event-related fMRI adaptation study, 20 young subjects viewed serially presented face-pairs that were identical (repetition of the same face), moderately different (second face was morphed with 40% of prior face), or completely different (faces from two individuals). Subjects underwent two sessions involving different task instructions. The first task required subjects to identify a previously shown target face that was intermittently presented during the experimental session. This task maintained subjects' attention to the face identity, but made the face-repetition irrelevant to the task. The second task required subjects to make same-different judgments for each face-pair, thus face-repetition became task-relevant. During the target face detection task, the fusiform regions showed adaptation during the exact-repetition condition and the moderately-different condition relative to the completely-different condition as expected. During the face discrimination task, however, adaptation magnitude in this region was significantly reduced. This suggests that when the task requires, subjects are able to suppress the adaptation responses to faces in the fusiform regions, and to maintain face representation for efficient discrimination. We also found that the task-related decrease of the adaptation responses in the fusiform area was linked to face discrimination performance.

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43.446

Adaptation in FFA: Face or Person?

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Viewing an image sequence of faces of two different people results in a greater BOLD response in the fusiform face area (FFA) compared to when the sequence is composed of identical images of the same person. However, changes in identity necessarily involve changes in the image. Is the release from adaptation a result of a change in face identity per se, or could it be an effect that would be produced by any image change? In a fast event-related fMRI-adaptation (fMR-a) design, subjects viewed a sequence of two faces that could be of the same or different person, and in the same or different orientation (frontal or ~20º rotated in depth). Critically, the physical similarity of view changes of the same person was scaled, by Gabor-jet differences, to be equivalent to the image change produced by an identity change. Subjects judged, by button press, whether the pair of faces on each trial were the same or different in image size (both in square of 128 or 256 pixels, or one image at each size), a task that allowed them to ignore both person and orientation. Both person and orientation changes produced equivalent releases from adaptation in FFA (relative to images of the same person in the same orientation) suggesting that FFA is sensitive to physical similarity rather than to the individuals depicted in the images.

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43.447

It's all in your head: Why is the body inversion effect abolished for headless bodies?

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It has been recently argued that, like faces, human bodies are processed by a specialized processing mechanism. Similar to faces, recognition abilities are significantly reduced for inverted relative to upright bodies (body inversion effect), which led to the suggestion that upright, but not inverted bodies, are processed by holistic mechanisms. In a series of experiments we examined the effect of part removal on the inversion effect of bodies and faces. Subjects were presented with a sequential matching task of bodies that were either identical or differ in position of the head, leg and hand. Our results show reduced performance and no inversion effect for headless bodies relative to complete bodies. In contrast, performance level and the magnitude of the inversion effect for bodies without hands or a leg were similar to complete bodies. Similar discrimination tasks with faces showed no difference between the magnitude of the face inversion effect for complete faces and faces without eyes or without a mouth. These findings suggest that heads may have a special status in the processing of body posture. In a final experiment subjects discriminated complete bodies that differ in hand and leg but with a fixed head position (fixed-head). Similar to headless bodies, performance for upright bodies and the body inversion effect where much reduced for the fixed-head complete bodies . Our findings show that the processing of upright bodies and the body inversion effect are markedly reduced whenever the head is absent or not relevant for discrimination. We conclude that the body inversion effect may be due to the difficulty in head discriminating, which is less visable in inverted bodies, rather than holistic processing per se. Our findings also suggest that the body inversion effect may not reflect the same kind of mechanisms that generate the face inversion effect.

43.448

Dissociating between the role of exposure and individuation in perceptual expertise for faces

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It is well documented that recognition of faces of other races is impaired relative to own-race faces. Two factors may underlie this other-race effect: the lack of exposure to other-race faces and/or the lack of opportunity to individuate specific faces in the other-race group. Because exposure and individuation usually operate together, it is not clear which of these factors is more critical. The goal of this study was to provide a clear dissociation between these exposure and individuation in order to assess their relative roles in face recognition abilities. To that end, we assessed recognition abilities for newborn faces. Similar to other-race faces, we are hardly exposed to newborn faces and do not individuate them as we do with adult faces. Consistent with the other-race effect, adult participants showed worse performance for newborn than adult faces in a delayed match-to-sample task. To examine the role of massive exposure without individuation, we tested neonatology nurses who are highly exposed to newborn faces but discouraged from individuating them based on facial features. Interestingly, recognition of newborn faces was not better in neonatology nurses than age-

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matched controls. These findings suggest that massive exposure without individuation is not sufficient for face recognition. In a second experiment, young students were presented with a 3-day individuation training of 12 newborn faces. This relatively brief training improved recognition abilities not only for the trained newborn faces but also for a novel set of newborn faces. Our findings show that passive exposure plays no role in the development of perceptual expertise for faces, whereas the act of individuation does improve face recognition even with minimal exposure. We conclude that it is the quality rather than the quantity of exposure that determines recognition abilities.

43.449

Same- and Cross-modal Perceptual Effects on Gender and Identity Adaptation

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Accurate gender and identity judgments can be made from pictures (visual) and radio commentary (auditory). Visual gender adaptation effects (exposure to female faces causing a gender-neutral test face to appear male, and vice versa; Webster et al, 2004) have been widely reported and are considered to reflect neuron(s) that are selective for maleness/femaleness. Similar auditory effects have been observed when observers make judgments of the gender of morphed voices after exposure to male/female voices (Schweinberger et al, 2008). Crossmodal gender adaptation has not been reported for morphed test stimuli in the same perceptual domain. Is gender adaptation driven solely by domain-specific perceptual information? In this study, observers always judged visual information, but were adapted by visual, auditory or visual+auditory stimuli.

In the first series, observers discriminated the gender of a male/female morphed face, having been exposed to faces (visual), scrambled voices (auditory) or both simultaneously (visual+auditory). Consistent with Jordan & Fallah (VSS, 2008) observers were more likely to report gender-neutral stimuli as female after adaptation to male faces and vice versa. Adapting to male/female voices in the presence/absence of faces did not produce adaptation effects. This is consistent with same modality adapter-test adaptation effects and domain-specific processing of gender information.

Early stages of identification processing e.g. gender may rely on domain-specific input, while higher-level stages, e.g. identity, may utilise integrated perceptual information. To test this hypothesis, observers discriminated the morphed face of two well-known individuals. Observers were adapted to short video clips of one or other individual. When the observers were exposed to only the visual or auditory aspect of the videos clips, no adaptation was observed. Critically, when the adapting video contained both visual and auditory information, Identity Adaptation was observed.

The data will be discussed with reference to the integration of perceptual-modality information along the identity processing stream.

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URL: http://www.yorku.ca/hjordan/

43.450

Talk to the hand: the visual word form area responds to bodies and faces

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Previous fMRI studies have identified a region in the left mid-fusiform gyrus that selectively responds to visual words. This region is termed as the visual word form area (VWFA) based on a general consensus that the function of this region is domain specific (i.e. engaged by visual words, regardless of the type of processing). Here we used fMRI to test an alternative hypothesis that this region is engaged in a specific process that can be applied to stimulus class other than words. Specifically, we tested the sensitivity of the VWFA to body and face stimuli that were visually dissimilar to visual words and yet invoked the same cognitive process as visual words in terms of communication through body gestures or facial expression. Consistent with this process-specific hypothesis, we found that the VWFA responded significantly higher to both body parts and faces than to objects or scrambled objects. In addition, a conjunction analysis demonstrated that the joint representation of visual words, bodies, and faces was only observed consistently across subjects in the left fusiform gyrus, consistent with the lateralization of language processing. Second, we used fMRI adaptation to test whether VWFA response was sensitive to differences between bodies (or faces) or it was instead due to low-level properties of the stimuli. We found that VWFA response monotonically decreased as repetition frequency of body stimuli increased. This adaptation effect was not found in a set of novel objects that were visually similar to bodies but did not contain information for communication. Taken together, these findings indicate that the function of the VWFA is not domain specific for visual words forms but process specific possibly for translating the form of a symbol to the meaning of that symbol.

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Vision and Action: Locomotion

Monday, May 11, 8:30 am – 12:30 pm
Poster Session, Vista Ballroom

43.501

The relationship between eye and head movements during locomotion with visual pursuit tasks

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Purpose: In daily life, visual tasks from fixating and pursuit to search and discriminations, often have to be performed while the observer is in motion rather than immobile. Locomotion, however, induces various head movements (HM), which displace the eye and need to be compensated for in order for the eye to be directed appropriately. Here we studied the effects of locomotion on the accuracy of eye position during fixation and linear pursuit of moving spots. Methods: Observers were standing, walking or running on a treadmill. Translational and rotational HM (pitch, bob, yaw, heave) were measured with an OptiTrack motion capture system, and eye position was recorded with an EyeLink eye tracker, while observers attempted to keep their eyes on a stationary or horizontally or vertically oscillating spot with different amplitude and velocity. Results: Pitch and yaw angles remained constant for all pursuit movements when observers were standing, while these angles varied systematically with locomotion, especially for walking. Bob-pitch, and heave-yaw movements were correlated in most visual conditions, such as to compensate for each other's deviations. When comparing the influence of visual stimulus amplitude or velocity on pitch and yaw movements, standing and running gave fairly similar results, while walking resulted in increased downward pitch. Conclusion: While both kinds of locomotion introduced more pursuit errors and more variability, running was in many ways less disruptive than walking, providing some evidence for the contention that in the case of running, compensation for HM is especially well adapted (Bramble & Lieberman, 2004).

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43.502

Eyes or head: Which has the greatest effect on steering control?

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Do walkers follow their eyes or their heads? Our previous studies of goal-directed walking found that an active head turn toward a target light produced a small path deviation (4%, ~6cm) in the direction of the head turn. In contrast, an active head turn in response to a verbal cue produced a com-

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parable deviation in the opposite direction. The former result appears to be due to attentional capture, whereas the latter may reflect a compensatory mechanism.

Here we ask whether path deviations depend on the head turn, a gaze shift, or both together, and we record eye movements. To dissociate the head and eyes, we tested the following conditions during goal-directed walking: (a) active head turn towards a target light, with free eyes; (b) active head turn in response to a verbal command, with free eyes; (c) active head turn in response to a verbal command, while maintaining fixation on the locomotor goal; (d) saccade in response to a verbal command, while keeping the head facing the locomotor goal; and (e) active head turn and gaze shift in response to a verbal command. Eye movements were recorded with an ASL MobileEye tracker, and head and body movements with an Optotrak.

There were three main results. First, the largest path deviation was again produced by an active head turn in the direction of a target light, with gaze free (~8cm). Second, an active head turn in response to a verbal command produced similar deviations opposite the head with or without an accompanying gaze shift. Third, an active gaze shift without an accompanying head turn did not yield any path deviations. These findings suggest that small path deviations may be due to head turns, not gaze shifts, and are largest when driven by attentional capture.

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43.503

Perceiving the intention to pursue or evade in a moving avatar

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How do we perceive the behavioral intentions of another pedestrian? In this study we investigate whether participants can perceive the intention to pursue or evade based on the trajectory and humanoid appearance of a virtual avatar. The steering dynamics model of target interception and avoidance does a good job of describing pursuit and evasion of pedestrians (Cohen, Cinelli, & Warren, VSS 2007). Here we use the model to drive an avatar so it pursues or evades the participant. Thirteen participants wore a head-mounted display (63° H x 53° V) and walked in a virtual environment towards a goal while an avatar approached. The task was to evade avatars that appeared to be pursuing them, or pursue avatars that appeared to be evading them. We manipulated the avatar's trajectory (evaders moved toward a goal 2, 4, or 8° from the participant's initial heading and appearance (textured post or walking human). Head position was recorded using an inertial/ultrasonic tracking system (IS-900, 70 ms latency). The percentage of trials in which evasion was detected increased with the avatar's approach angle ($F(3, 10) = 19.04$, $p < 0.01$) and with a humanoid appearance ($F(1, 12) = 7.33$, $p < 0.05$), with a significant interaction ($F(3, 10) = 2.92$, $p < 0.05$). Perceived evasion was greater in the 2° evasion condition than the pursuit condition ($p < 0.01$), indicating that even a small approach angle was perceptible. Interestingly, participants perceived the intentions of the humanoid more accurately than the post in the 2° condition ($p = 0.005$), perhaps because its head and limbs were aligned with the direction of travel (heading). Future work will investigate the contribution of such heading cues, head turns, and the contingency of the avatar's trajectory on the participant's movements.

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43.504

Testing models of path integration in a multi-segment homing task

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Path integration is the updating of one's position and orientation during walking. Previously, we tested models of path integration in a triangle completion task (VSS 2008); here we attempt to predict performance on multi-segment paths. To perform such a homing task, estimates of the distances traveled and the angles turned must be combined to determine a return path to the home position. Large systematic errors are observed in triangle completion, which could be due to (i) encoding error in estimating the distances and angles traveled, (ii) integration error in combining these estimates to determine the homebound path, or (iii) execution error in turning and walking the homebound trajectory. Previously, we predicted triangle completion from performance on distance and angle reproduction tasks. Monte Carlo simulations of individual data revealed that a model based solely on encoding error (Fujita et al., 1993) does not account for errors in triangle completion. In contrast, models that include execution error predict triangle completion much more closely. In the present study, we test model predictions on more complicated paths. Participants wear a head-mounted display (60˚ H x 47˚ V) while walking in virtual hallways; head position is recorded using an inertial/ultrasonic tracker (70 ms latency). They walk a prescribed outbound path, then they turn and walk directly back to the remembered starting position in a new hallway determined by their heading. We varied the number of segments in the outbound path (2, 3, 4) while holding outbound path length constant (10 m), and varied outbound path length (10, 14, 18 m) while holding the number of outbound segments constant (3). As segment number or path length increases, so does the cumulative homing error. Model simulations demonstrate that execution error is a major factor determining path integration performance.

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43.505

Are attentional resources required to anticipate moving obstacles?

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Avoiding moving obstacles is critical to our ability to locomote safely. Further, it may be advantageous to anticipate which environmental objects are likely to get in our way, particularly when traveling at high speeds (as in driving). Fajen & Warren (2003, 2007) proposed an on-line dynamical model of locomotor behavior that requires no higher-level planning or anticipation. However, recent experiments have shown that people can learn to anticipate the trajectory of a moving obstacle, though only when necessary to avoid an immanent collision (Owens & Warren, VSS 2007, 2008). Here we present two studies that investigate whether visuo-spatial attentional resources are required to learn to anticipate moving obstacles.

Participants walked in a virtual environment while wearing a head-mounted display (60˚ H x 47˚ V), and head position was recorded with a sonic/inertial tracker (70 ms latency). In Study 1, participants performed a modified Brooks Letter Task while walking to a visible goal, and were instructed to avoid moving obstacles. En route to the goal, some obstacles would veer to impede their path. In the Predictable block of trials, all obstacles' trajectories were cued by their appearance, whereas in the Random block the trajectory was independent of appearance. We found that the secondary task impaired participants' ability to anticipate obstacles in the Predictable block, but only when that block was presented first. When the Random block was presented first, practice on the secondary task allowed anticipatory avoidance in the Predictable block.

For Study 2, we increased the difficulty of the secondary visuo-spatial task. The results showed increased impairment of obstacle anticipation and greatly reduced practice effects, such that locomotor paths were consistent with the dynamical control model. We conclude that visuo-spatial attentional resources are required for anticipatory control of locomotion, and that interference with these resources returns locomotion to on-line control.

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43.506

Cortical arousal influences early but not late visual perception

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Recent theories of embodied perception posit that emotion and physiological effort influence early (contrast threshold) and late (egocentric distance perception) visual perception, respectively. Manipulations of effort and emotion may have their effect by indirectly altering cortical arousal. However, quantifiable measures of arousal have been lacking, and the linkage between cortical arousal and changes in visual perception is poorly understood. METHOD: In two groups, we administered a stimulus commonly used in clinical settings to increase physiological arousal (cold pressor stimulation [CPS]--immersing the foot in iced water for 50 seconds): One group completed a two-alternative forced choice contrast threshold task (n=17), while the other group verbally estimated egocentric distances (n=18). Participants were tested at 3 time points: pre-CPS, immediate-post-CPS, and 20-minutes post-CPS. To prevent the "distance perception" group from associating specific verbal estimates with particular local features across time points, we alternated the viewing location for each time point. RESULTS: Contrast thresholds improved upon application of CPS ($t=2.38$, $p<0.05$), while verbal indications of distance remained unchanged ($t=-0.02$, $p=0.9$). Although there were some changes between immediate- and 20-minutes post-CPS performance for both tasks, only the contrast threshold changes were consistent with an arousal effect. To verify that arousal was indeed enhanced by CPS, participants in the contrast threshold group underwent EEG recording to measure P50 amplitude—an established physiological marker of cortical arousal. The EEG data confirmed that CPS enhanced arousal, with a significant treatment effect in P50 amplitude from pre- to post-CPS ($t=2.24$, $p<0.05$). CONCLUSION: The increase in arousal post-CPS was associated with significant decreases (improvements) in contrast threshold, but no change in verbal distance estimates. To our knowledge, this is the first evidence that early visual processes can be influenced by changes in cortical arousal. However, more complex forms of visual perception may be resistant to alterations in cortical arousal.

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43.507

Finding Your Way: The influence of global spatial intelligibility and field-of-view on a wayfinding task

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Previous work, derived mainly from the fields of architecture and urban planning, has shown that the global spatial configuration of an environment, known as its spatial intelligibility, can account for some aspects of wayfinding behavior and movement of traffic in constructed environments (Penn, Environment and Behavior, 2003). These studies have subsequently been used to argue that wayfinding is based largely on the use of simple heuristics which control route decisions at choice points. However, some recent studies suggest that manipulations which interfere with perceptual processing (Meilinger, Franz, & Bülthoff, Environment and Behaviour, 2008) are also capable of influencing wayfinding behavior, but the connection between such perceptual processes and heuristics based on global spatial configuration remain unclear. In the present study, participants were asked to navigate to a central landmark in a novel virtual environment, and then return to the starting position. We manipulated both spatial configuration (high intelligibility vs. low intelligibility) and available perceptual information (150o field-of-view vs. 60o field-of-view) between participants. An analysis of variance on the path, duration of navigation, and pausing and gaze behaviors revealed a significant main effect of intelligibility on both distance and duration of navigation. More interestingly, a significant main effect of field-of-view was found such that a wider field-of-view resulted in more varied gaze within intersections. Further, a significant interaction between intelligibility and field-of-view was found such that participants with constrained field-of-view would pause more frequently overall, more frequently in intersections, and for longer periods of time in the highly intelligible environments as compared to unintelligible environment. The reverse pattern was observed for the unconstrained field-of-view condition. These results clearly support the idea that both perceptual processing at choice points and the global organization of a spatial configuration influences the wayfinding process.

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43.508

Locomotion for Navigation in Virtual Environments: Walking, Turning, and Joystick Modalities Compared

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Considerable evidence shows that people have difficulty maintaining orientation in virtual environments. This difficulty is usually attributed to poor idiothetic cues, such as the absence of proprioception. The absence of proprioceptive cues makes a strong argument against the use of a joystick interface for locomotion. The importance of full physical movement for navigation has also recently been confirmed (Ruddle and Lessels, 2006), where subjects performed a navigational task better when they walked freely rather than when they could only physically rotate or only move virtually.

Our experiment replicates the experiment of Ruddle and Lessels but under different conditions. Here all conditions are conducted using a head-mounted display, whereas Ruddle and Lessels mixed display types. Our environment contains no environmental cues to geometry, as all landmarks are either randomly placed and oriented, or absent, whereas the Ruddle and Lessels environment included a simulated rectangular room that was always visible. People are sensitive to environmental geometry, but the effect on navigation is an active area of research (Kelly et al., 2008), thus our environment omitted them.

In this experiment, subjects (N=12) locomoted through an environment in one of three ways: they walked, they used the joystick to translate while physically rotating their bodies to change orientation, or they used a joystick to both translate and rotate with no physical movement occurring.

A within-subjects design found that subjects were marginally better in the walking condition than in other conditions ($F(1,11) = 2.88$, $p=.07$). Subjects were significantly slower in the joystick condition than in other conditions ($F(1,1)=5.44$, $p=.01$). Subjects traveled significantly less distance in completing the task in the walking condition than in other conditions ($F(1,11)=4.28$, $p=.03$). In general, we conclude that walking seems a better method for locomotion in virtual environments than locomoting with a joystick.

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43.509

A gateway into the visual control of locomotion: walking through doors in Parkinson's Disease

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Freezing of gait (FoG) is a locomotor phenomenon exhibited in a subgroup of patients with Parkinson's Disease. In FoG a patient comes to an involuntary halt while walking, or cannot start walking despite a desire to do so. FoG commonly occurs in certain environmental conditions, including walking through doorways. This suggests a possible perceptual aspect to the phenomenon which we investigated in two ways.

First we investigated whether freezing was associated with atypical perceptual processing of door width information. To do this we used a judgment task where participants were asked to judge the width of door they could just walk through (Warren & Whang, 1987). Some groups of PD patients show 'space compression' in this task (Lee, 2001), but it has not been investigated in PD patients who 'freeze'. As a group, PD freezers show some

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space compression compared with a healthy control group. Additionally, we found greater space compression in patients who showed doorway freezing than patients who did not. Although PD patients have a damaged motor system, this implies that the freezing phenomenon may result from an additional perceptuomotor deficit.

Second, using a motion capture system we showed that the presence of a doorway affected gait parameters in freezers. There were changes in step length, heel lift, and step time in the approach to the doorway. These results imply that visual information about upcoming obstacles is used to make motor plans several steps in advance, but that the results of this process are abnormal in PD freezers.

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43.510

The Argus II Retinal Prosthesis: From laboratory psychophysics to real world tasks

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The feasibility of the Argus II chronic epi-retinal implant to partially restore vision to subjects blinded by photoreceptor degeneration is currently under investigation in several clinical centers worldwide (ClinicalTrials.gov #NCT00407602). We measured visual performance of retinal prosthesis subjects in laboratory tests (visual stimuli presented on a monitor) and in real world tasks (walking in a controlled environment). The array of 60 stimulating electrodes was attached to the inner retina over the macula using a retinal tack. Video captured by a miniature camera mounted on the subject's glasses was continuously sampled and the stimulation current in each electrode was matched to the brightness at the corresponding area of the scene. In the first laboratory psychophysics experiment, square stimuli were displayed at random locations on a touch screen monitor and the subject was instructed to touch the monitor in the center of the perceived square. In the second laboratory psychophysics experiment, a white line of fixed width moved across the monitor at an arbitrary angle and the subject was instructed to draw the perceived direction of motion on the touch screen. In the first real world task, the subject was instructed to walk along a 20 foot long, 6 inch wide white line on a black surface. In the second real world task, the subject attempted to walk to a 3x7 foot "door" (black felt on a light-colored wall) 20 feet from their starting location. For all tasks, system ON and system OFF performance was compared. Results show that the Argus II retinal prosthesis enabled blind subjects to perform laboratory and real world visual tasks.

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43.511

Mirror, mirror, on the wall: Can I walk through this aperture?

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Previous research has shown that manipulating the action capabilities of observers alters their perceived affordances for passage (Higuchi, Takada, Matsuura, & Imanaka, 2004; Wagman & Malek, 2007). Little research has manipulated the environment, instead of the observer, to assess whether changes to the environment can alter the perception of affordances and of the environment itself. In a series of studies, we manipulated the environment by placing a reflective surface (a mirror) behind an aperture, for which participants were asked to judge the width and whether or not they could pass through. Experiment 1 revealed that the presence of a mirror, which distorted the size of the aperture, elicited larger perceptual estimates and a greater willingness to pass through than the absence of a mirror. Experiment 2 demonstrated that the effects found in Experiment 1 were the result of the specific location of the mirror (behind the aperture) and not simply due to a mirror being present in the environment. Experiment 3 investigated the distorting effects of the mirror by varying the distance to the mirror at which the aperture was placed. Experiment 3 revealed that when the aperture was closer to the mirror, participants made larger estimates of aperture width and were more likely to indicate passage than at further distances from the mirror. Results suggest that participants weighted the distorted visual information reflected by the mirror more heavily than visual information about the actual aperture width. This distortion influenced both their judgment about whether they could pass through the aperture and their perception of the size of the aperture.

43.512

Comparing the Reliability of Vision and Walking for Target Localization in a Hallway

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When navigating in an environment, humans can learn the locations of objects (e.g., rooms or landmarks) with two types of sensory cues: visual information obtained by viewing the objects, and information obtained by walking to the objects (proprioceptive and vestibular). We are interested in whether humans weight these two types of information according to their reliability when learning locations in a real hallway. Reliability is defined as the inverse variance ($1/\sigma 2$) of the localization estimates. As a first step towards a cue conflict study, we compared the reliabilities of different levels of visual information (normal and blurry) and walking information in a spatial localization task. In the visual condition, participants viewed targets in a hallway with overhead lighting. Viewing was monocular with either normal or blurry (Snellen acuity of approximately 20/675) vision. Targets were high-intensity Light-Emitting Diodes located 5 to 11 meters away from the observer. After viewing a target, participants (N = 3) wore a blindfold and indicated the target's location on a tactile map of the hallway. In the walking condition, blindfolded participants (N = 3) walked until stopped by the experimenter (distances of 5 to 11 meters), and then indicated their location on the tactile map. In both conditions, map estimates were scaled to obtain equivalent distances in the real space. Results indicate that estimates made with blurry vision ($\sigma 2$ = 1.08 m) were less reliable than with normal vision ($\sigma 2$ = 0.16 m), but were more reliable than estimates made after walking to locations ($\sigma 2$ = 1.79 m). These results predict that when both visual and walking information are available, observers will weight information from walking more heavily in the blurry viewing condition compared with the normal viewing condition. Preliminary results support this prediction.

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43.513

When imagined walking is inaccurate, what is misperceived?

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People tend to underestimate the time required to walk to a previewed target in imagined walking tasks (Kunz et al., 2007, 2008; Yamamoto & Philbeck, 2008). One explanation is that the initial target distance was visually underperceived. Other explanations are possible, however. Here, we tested two alternative hypotheses. First, people may overestimate walking speed in imagined walking. Second, imagined walking may be subject to errors of anticipation (the general tendency to terminate a response prematurely). To test these ideas, an experimenter marked out various time intervals (1-8 s), during which time blindfolded participants were to physically walk or to imagine walking. At the end of the specified interval, participants verbally estimated the distance they walked or imagined walking. In the real walking condition, participants were guided along a linear path at a fixed rate of 1 m/s. The experimenter determined the stopping point. In the imagined walking condition (conducted after the real walking condition), the experimenter specified the time interval by saying "start" and "stop"; during the specified interval, participants were required to imagine walking in the same manner as in the real walking condition. According to the first hypothesis, if there is a tendency to overestimate walking speed during imagined walking relative to real walking, estimated walked

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distances would be longer in the imagined walking condition. The second hypothesis predicts that similar distance estimates would be made in both conditions because participants had no prior knowledge about where they would be walking (and therefore errors of anticipation were removed). Results showed that there was no significant difference in distance estimates between real and imagined walking, indicating that the participants did not overestimate their walking speed in imagined walking. This finding suggests that the underestimation of imagined walking time is explained in part by errors of anticipation.

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43.514

Computing Head Direction from Interacting Visual and Vestibular Cues During Visually-Based Navigation in the Rat

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Visually-based navigation depends upon reliable estimates of head direction (HD). Visual and path integration cues combine for this purpose in a brain system that includes dorsal tegmental nucleus, lateral mammillary nuclei, anterior dorsal thalamic nucleus, and the post subiculum. Learning is needed to combine such different cues to provide the most reliable estimates of HD. A neural model is developed to explain how these cues combine adaptively to generate a consistent and reliable HD estimate, in both light or darkness, that explains the following types of data: Each HD cell is tuned to a preferred head orientation (Taube et al. 1990: Sharp et al 1995: Taube 1995). The cell's firing rate is maximal at the preferred direction and decreases as the head turns from the preferred direction. The preferred direction is controlled by the vestibular system when visual cues are not available. However, a well-established visual cue will control the preferred direction when the cue is in the animal's field of view (Taube 1995; Zugaro et al. 2001; Zugaro et al. 2004). Distal visual cues are a more effective than proximal cues for controlling the preferred direction (Zugaro et al. 2001). The introduction of novel cues in either a novel or familiar environment can gain control over a cell's preferred direction within minutes (Goodridge et al. 1998). Turning out the lights or removing all familiar cues does not change the cell's firing activity, but it may cause drift in the cell's preferred direction (Taube et al. 1990; Goodridge et al. 1998).

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43.515

Leaky integration (and proactive memory distortion) in non-visual path integration

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When passively exposed to optic flow, implied travel distance is underestimated. Conversely, participants stop early when deciding how much optic flow specifies a given distance, as if travel distance were overestimated. Lappe et al. (2006) argued this was due to a leaky integrator that loses magnitude while trying to accumulate traveled distance from a starting point, but loses magnitude from its representation of the distance remaining to the target. An alternative theory suggests that the decision to stop is stochastically biased. We tested for leakiness in non-visual path integration, by describing a task either as reproducing a distance or returning to a starting point. Blindfolded subjects walked 5-40 m along a guide wire until told to stop. Step counting was prevented with an alphanumeric memory task. In the Return condition, subjects tried to walk back to their starting point. In the Reproduce condition, subjects switched to a second guide wire and tried to reproduce the distance walked. Consistent with leaky integration, the slopes of distances produced in the Return condition were lower than in the Reproduce condition. For the longest distance subjects stopped short in both conditions, but reliably shorter in the Return condition (27.4 m) than in the Reproduce condition (31.3 m), $t(12) = 2.733$, $p = .0182$. Consistent with the results of Sun et al. (2004), performance at 10-20 m was relatively unbiased. The success of the instructional manipulation is consistent with the idea of a leaky integrator for non-visual path integration. However, the data also indicate memory contamination from previous trials: Compared to an initial 7m practice trial (6.9 m), subjects traveled reliably farther for the 7m target later on (9.0 m), $t(5) = 2.72$, $p = .0434$, whereas the average travel distance for the 28m target, initially 26.6 m, decreased to 22.5 m.

43.516

The contribution of visual inputs for homing accuracy in the path completion task

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Our basic research interest is contributions of sensory inputs for path-integration-type navigation in our day-to-day life, for example, the navigation in a town of narrow streets or hallways inside buildings. While optic flow has been assumed to be the one and only visual input used for path integration as originally defined, sequences of views including information about upcoming path (i.e. the edges of streets and layouts of buildings or walls) would be also used for the navigation (Loomis, Klatzky, Golledge, & Philbeck, 1999). The present study explored contributions of two visual inputs in homing accuracy by a path completion task using visual stimulus with the optic flow and the sequences of views (Video), or only the latter one (Image). Participants remained seated and watched two videos that showed equivalent views from a person traveling inside a maze along paths with 3 and 7 turns & legs (Path3 and Path7), or successive still images that were processed from the videos. Right after the videos or the images ended, they were asked to indicate starting points. The judgments were recorded as directional data and analyzed by some tests for randomness to infer homing accuracy. In Path3, the data of both conditions were clustered around a correct angle rather accurately, and there was not a marked difference in homing accuracy between Video and Image. Compared to Path3, the judgments of Path7 tended to be inaccurate especially in Image. Whereas the data of Video were still considered to cluster around a correct angle, the data of Image were completely random. These results suggest that in a simple path, the sequences of views are independently sufficient for homing. On the other hand, in a complex path containing more turns and legs, the optic flow added to the sequences of views significantly improves the homing accuracy.

43.517

Active control of lane keeping uses optic flow, bearing, and splay angle information

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Previous studies have shown that people rely mainly on splay angle (the optical angle of the lane markers with respect to the vertical in the image plane) for lane keeping during driving (e.g., Beall & Loomis, Perception, 1996). Here we investigate whether optic flow and bearing also contribute to the control of lane keeping. The display (110° H x 94° V) simulated an observer steering a vehicle down a straight path at 3 m/s under three conditions: (a) an empty ground with lane markers providing bearing and splay angle information; (b) a random-dot ground with lane markers providing bearing, splay angle, and sparse optic flow information, and (c) a textured ground with lane markers providing bearing, splay angle, and dense optic flow information. Participants used a joystick to control the vehicle's lateral velocity to stay at the center of the lane while the vehicle's lateral position was perturbed by the sum of seven non-harmonic sinusoids (0.1 to 2.19 Hz). For 11 participants (9 naïve), the vehicle's lateral deviation from the center of the lane, indicated by the RMS error, was larger for the empty ground (mean±SE: 0.39±0.02 m) than for the random-dot and the textured ground display (0.37±0.02 m in both cases), indicating the influence of optic flow on lane keeping. We then varied the optical gain of bearing in the display by providing lane markers (3.1° V) at three distances (3.2 m, 7.8 m, & 22.2 m). For eight participants (7 naïve), the RMS error increased with the distance for the empty ground but not for the random-dot or the textured

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ground display, indicating that bearing information helps lane keeping in the absence of optic flow information. We conclude that optic flow, bearing, and splay angle all contribute to accurate lane keeping.

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43.518

Right-side Walking Bias is Additive for Approaching Pedestrians

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Previous research has confirmed that American and right-handed pedestrians exhibit a bias to turn right, whereas British and left-handers are relatively more likely to turn left. The present study tests if these same populations exhibit similar walking-side biases when racing around either a stationary obstacle or another passing pedestrian. We also examined if the solo walking-side bias increases in an additive manner in the case of two approaching pedestrians, and if these changes are consistent with individual biases associated with driving-side training and handedness. Right and left handed British and American pedestrians were tested in both Great Britain and America, racing either alone around an obstacle, or in pairs against each other. Our results revealed a robust overall right-side navigational bias, with Americans and right-handers exhibiting this bias most strongly, and the British and lefties less so. When approaching pairs raced each other, the right-side bias generally increased consistent with an additive function of bias. This appears to be a classic example in which weaker individual biases accumulate to create a stronger group bias. In the case of the Americans, the combination of their right-side driving training and the preponderance of right-handedness led to a 90% tendency to stay to the right when alone, and nearly 100% when approaching other Americans. This rate was progressively less to the right-side when Americans raced British, and further reduced when British raced other British, but even then, a right-sided preference prevailed. We found no main effects for locomotion-side due to eye-dominance, though there is some suggestion for higher-order interactions related to this variable. Consistent with prior research, these results support the notion that walking side is a function of both innate handedness and learned behavioral habits (nature and nurture), but with an overall right-side locomotive dominance that increases when pedestrians interact with others.

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Vision and Action: Reaching

Monday, May 11, 8:30 am – 12:30 pm
Poster Session, Vista Ballroom

43.519

Do the characteristics of reaching from visual memory reflect 'cautious reaching'?

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Reaching actions show characteristic kinematics (long duration, extended period of deceleration) when the target is made invisible before the onset of the reach. These have been interpreted as reflecting dependence on a ventral-stream visual representation compared to the specialized, but fast-decaying, dorsal-stream representation which controls reaching when on-line visual information is available (Westwood & Goodale 2003; Goodale & Westwood, 2004) . However, an alternative interpretation is that the kinematic changes reflect increasingly cautious behaviour when visual information from the target is reduced.

We have examined this possibility by comparing reaching kinematics for a cylindrical 'shot glass' when empty, in the light or the dark, and when filled with water and so demanding a cautious approach. Both the full and empty glass could be presented with internal illumination alone ('glowing'), giving visual information for the target but not for its spatial context or for hand position.

Reaches directed in the light toward a full glass showed increased duration, and period of deceleration compared to the empty glass. Kinematics of reaches to the glowing full glass showed no differences from those to an empty glass in the dark, suggesting that the 'cautious' reach to the visible full glass is a possible model for reaching behaviour in the absence of on-line visual information. Possible relationships between cautious reaching and the use of ventral vs dorsal representations will be discussed.

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43.520

What visual information can infants use for reaching in the dark?

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The information available for visual control of a reaching action differs between (a) a fully lit environment; (b) a visible target object in an otherwise dark environment; (c) occlusion by darkness of a previously visible object. In (c), Westwood and Goodale (2003) argue that the dorsal stream information, normally used to guide action, decays rapidly and that a ventral stream representation has to be substituted. We have examined the developmental role of visual subsystems in reaching control, by using an infrared motion tracking system to measure the kinematics of reaches by 9, 13, and 16 month infants (N=28) compared to adults in these three conditions. Unlike most earlier studies of reaching in the dark, we concentrate on the characteristics of the transport phase (duration, straightness, period of deceleration) rather than the final grasping action.

We find that, unlike adults', 9 month olds' reaching becomes less controlled and more ballistic in the dark and does not usually terminate in a controlled grasp. Older infants appear to be making more use of a continuing visual representation of the invisible target object although the penalty in accuracy and speed is greater than for adults, and they do not show an increasing penalty with increasing delay.

For a glowing target object in a dark environment, 13 month olds' reach duration shows a greater difference from full illumination than either younger infants or adults. We will discuss whether this anomalous behaviour results from absence of information from the hand or from the environmental context, and more broadly whether there is any evidence for a ventral stream representation that infants can access for reaching control.

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43.521

Do elderly people use online visual control when carrying out a reaching task?

Rachel Coats[1] (r.o.a.coats@reading.ac.uk), John Wann[2]; [1]Department of Psychology, University of Reading, [2]Department of Psychology, Royal Holloway University London

Young children rely quite heavily on closed-loop visual feedback to complete precise manual tasks. By the time they reach adolescence they can reach accurately using open-loop visual control and do not need to use continual visual feedback on hand position to regulate actions. Less is known about what happens as we reach old age. Two experiments were carried out to examine how elderly people interact with their environment through simple reach-to-grasp tasks. Nine elderly (mean age = 75) and nine young (mean age = 27) participants performed two reaching tasks in which vision of the hand was available on only half the trials. In the first task participants had to pick up one of three target objects by its grasp points (which varied in size). A mirror was used to produce a 'virtual' object in the trials when vision of the hand was unavailable. In the second task the set-up remained largely the same, but this time participants had to place a peg in one of three holes in a pegboard.

Mixed ANOVAs revealed that the elderly performed similarly to the young on all aspects of the reach when vision of the hand was available, but when vision was unavailable, compared to the young they seemed to under-reach, take longer to complete the movement, and were less accurate as evidenced by their higher root mean square error scores. Vision of the reaching hand seems to play a vital role as the elderly can perform at similar levels to the young adults when vision of the hand is available, but struggle when they cannot see their hand. Elderly people seem to be processing visual information online when carrying out a reach, and therefore returning to an attention-demanding closed-loop mode of visual control, similar to that used by young children.

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43.522

Visual Feedback is used to guide the Hand towards Endpoints not along Trajectories

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Many studies have shown that visual feedback of the hand is used to monitor or adjust ongoing movements. It is still unknown, however, whether vision is used to steer the hand along a desired trajectory or to guide the hand towards a desired endpoint. Even though these two functions of visual feedback appear similar on the surface, they are different from both a conceptual and a computational point of view.

Here we tested if visual feedback is used to steer the hand along a desired trajectory or towards a desired endpoint. We manipulated how visual information relevant for moving was presented to subjects (Endpoint vs. Trajectory task) and the availability of visual feedback of the moving hand (no feedback vs. feedback). We tested both direct and tool mediated movements (i.e. computer-mouse mediated cursor movements). In addition, we compared performance between free viewing and fixation of a peripheral target. Finally, we investigated whether or not performance changes when the visual information that specifies the desired Endpoint or Trajectory is extinguished at the moment of movement onset.

We found that subjects use visual feedback to correct movement errors online in both direct and tool mediated movements. Most importantly, we found that the availability of visual feedback reduces errors significantly more in the Endpoint than in the Trajectory task. The general pattern of results holds even when subjects fixate a peripheral target and when the visual information that specifies the desired Endpoint or Trajectory is extinguished at movement onset.

We conclude that visual information about the moving hand is used primarily to guide the hand towards a specific endpoint rather than to steer it along a trajectory. Moreover, this is true whether or not participants move their eyes, see the target during the movement, or use a mouse cursor rather than their hand.

43.524

Cortical oscillations in human posterior parietal cortex during visually-guided reach planning

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Planning reaching or pointing movements requires a number of processing steps involving different brain areas. One important step consists of transforming visual information into motor plans that are appropriate for movement control. A key brain region involved in this process is the posterior parietal cortex (PPC). Here we use magnetoencephalography (MEG) to investigate the spatio-temporal coding of PPC during reach planning on a millisecond time scale.

Human subjects sat upright, fixating a central white cross. After 500ms, a green or red dot was briefly presented right or left of fixation. The color of the dot indicated the task, i.e. to point towards (pro) or to the mirror opposite location (anti) of the target. Pro- and anti-trials required opposite motor output following identical visual stimulation, which allowed distinction between visual and motor coding. Subjects waited for the fixation cross to dim (1500ms later) before making a wrist-only movement. We used three different forearm/wrist postures and the left or right hand (in separate blocks of trials) for pointing. A beamformer-based spatial filtering algorithm was employed to reconstruct brain activity from the MEG recordings.

Comparing pro- and anti-trials revealed that PPC coded visual target location in retinal coordinates until ~150ms after target onset. Between 150-300ms after target onset, a transformation of the early representation of the target from visual coordinates into extrinsic (spatial) motor coordinates occurred in PPC. We also observed posture- and hand-dependency of the activity in PPC. Finally, we observed PPC activation before and during movement execution, indicating that PPC also plays a role in visuomotor memory and/or online motor execution.

In summary, our results indicate that PPC is involved in a dynamical network transforming visual signals into representations that are appropriate for the required motor output.

43.525

Temporal variation of spatial tuning of single units in macaque inferior parietal cortex under normal and distorted visual conditions

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Inferior parietal neurons in areas 7a and dorsal prelunate (DP) are spatially tuned for angle of gaze, visual stimuli, and reaching (MacKay 1992; Heider et al., 2006; Heider et al., submitted). The current study explores the evolution of the spatial tuning of single units under normal and distorted vision. Neural activity was recorded in areas 7a and DP contralateral to the reaching arm. The monkey was required to fixate one of nine positions on a touch screen while a visual stimulus (expansion optic flow, radius 6°) appeared behind the fixaiton point. The animal reached ballistically when the flow went from structured to unstructured. A binocular Fresnel prism introduced a 10° visual shift. The trained monkey correctly reached to the physical location of the stimulus within a few trials demonstrating swift adaptation. Each unit was tested under the pre-prism and the prism condition. Activity was assessed during: (1) fixation onset ("eye position signal"), (2) the "visual signal", (3) during motor preparation and (4) during the ballistic reach. Linear regressions with categorial variables for the four epochs quatified the evolution in spatial tuning. The spatial tuning changed for 78% of the 128 units. An index of variability was computed. The variability in spatial tuning was greater for the prism condition than the pre-prism condition. When the monkey is correcting for the prism, neural circuits may be brought into play within parietal cortex to actively correct for distortion. Such circuits may have more impact on the visuo-spatial tranformation as the actual reaching event becomes temporally proximate. When the prism is absent, no corrections are needed as the perceptual and reach coordinates are in register in eye-centered coordinates. Hence minimal change in spatial tuning occurs as the task progresses.

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43.526

Coding of Goal, Perspective, and Kinematics in Action Observation

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The neural representation of action observation involves brain regions that encode goal-related information, such as the anterior intraparietal sulcus (aIPS) as well as other regions that encode action kinematics, including inferior frontal cortex and superior temporal sulcus (STS). Little is known, however, of the role that visual perspective plays in the coding of actions. In this fMRI repetition suppression (RS) study, subjects (N = 11) watched video clips of a hand reaching to grasp objects from different perspectives and detected rare targets in which the hand wore a ring. Novel or repeated grasp goal (utilize vs transport), perspective (first- vs third-person) and object type were presented in a 2x2x2 design. Surface-based analysis revealed that, in addition to typical action observation regions such as

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inferior frontal cortex, aIPS, and STS, a widely distributed network showed goal-, perspective-, and object-dependent RS effects. Repeated visual perspective on successive trials produced RS in left insula and cuneus, and right lateral occipitotemporal cortex, while goal repetition reduced the response in the right sylvian fissure. Regions previously implicated in action observation, however, appeared to code for interactions between goal, perspective and object repetition. RS to goal repetition varied depending on perspective in the right ventral premotor cortex and bilateral aIPS. In particular, it appeared that aIPS coded goal-perspective interactions, with either a novel goal or a novel perspective eliciting an increased response relative to repetitions of these stimuli. RS in left STS depended on repetition of goal and object, suggesting a coding of grasp kinematics in this region. In sum, we found that RS effects for goal-directed transitive actions depend on multiple factors including perspective, suggesting extraordinarily high-level encoding of actions. These results provide new details of the visual coding of actions within the human brain.

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43.527

Shifted visual feedback of the hand affects perceived reachability of moving objects

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In many situations in which one reaches out to interact with an object one must estimate when the object will be reachable. Thus motion of the object relative to the body has to be taken into account. When one does not interact directly with the object in question, and the object does not move relative to ones body, judgments of reachability are influenced by displaced visual feedback about the position of ones hand. Here we examine whether displaced feedback of the hand also influences reachability judgments when the task is to interact with a moving object. Subjects saw virtual cubes that moved along straight paths in various directions. Their task was to intercept the virtual cube with their unseen index finger as soon as the cube was judged to be reachable. If the cube could not be reached along the entire path, subjects were instructed to keep their index finger at the starting position. Subjects received visual feedback about the position of their index finger, but this feedback was shifted in depth by 5 cm, either away from or closer to their body. The feedback disappeared when the arm was extended or when the hand came close to the virtual cube. Perceived reachability increased when feedback of the hand was shifted away from the body and decreased when the feedback was shifted closer to the body. We conclude that visual feedback about the position of the hand affects the perceived reachability of moving objects.

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43.528

Learning times do not alter adaptation rates in rapid reaching tasks

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Humans recalibrate the mapping between their visual and motor systems when they perceive systematic changes in the environment. Two main factors influence the rate of this recalibration, the extent to which the current mapping is reliable (mapping uncertainty) and the extent to which the visual feedback is reliable (feedback uncertainty). As an optimal adaptor, the Kalman filter takes these factors into account and hence, may be best suited to model such a system. This model makes different predictions depending on the nature of the feedback noise. For correlated noise (Random walk), the mapping randomly shifts with every trial, which should increase the mapping uncertainty and therefore increase the adaptation rate. On the other hand, uncorrelated noise in the feedback (Gaussian noise around a constant mapping) should increase feedback uncertainty and therefore decrease the adaptation rate. To test these predictions for the visuo-motor system, we used a rapid pointing task similar to the one used by Burge, Ernst & Banks (2008). We also systematically varied the trial times over which subjects could learn the statistics of the environment. We replicated the result for random walks and found that adaptation was indeed faster. The expected decrease in the adaptation rate for the uncorrelated Gaussian noise, however, could not be found. Surprisingly, we did not find any significant effect of prolonged learning time on the adaptation rate in either noise environment. Hence, it appears that the temporal window for the estimation of the statistics underlying the visuomotor mapping is relatively small. The results further indicate, that the assumption the Kalman filter makes about the stationary statistics of its measurement and system noise may not be accurate. Hence, in future work it might be useful to alter the model in order to account for dynamic statistics of the measurement and internal noises.

43.529

Early correction model of human goal-directed movement

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In VSS2008 we presented the intermittent feedback model of goal-directed forearm movement. In the model a goal-directed movement consists of two submovements, with the trajectory of each submovement being individually optimized. Simulations using the model showed that the optimal transition between two submovements occurs at an early stage of the movement, and produces a sharp increase in the acceleration profile in agreement with the preliminary psychophysical data.

In the present study, we directly measured the acceleration profiles of goal-directed movement using accelerometer to avoid the large noise caused by successive differentiations. The new data allows us to examine the patterns of individual trials in addition to verifying the previous findings. Analysis of individual trials show that the time of peak acceleration is relatively constant across the trials, and the amplitude of this peak systematically affects the shape of the acceleration profile during the later stages of the movement. These profiles are very similar to those produced by the model. All these results confirm the model's prediction that humans apply early correction just after the initiation of the goal-directed movement. Finally, we tested our model in various distance and accuracy conditions. We found that the simulated movement durations across conditions are consistent with Fitts' law.

43.530

Arm Movement Errors are Coded in Target-Centered Coordinates

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Typically, one describes the planning of human arm movements in terms of a vector from an initial position (e.g., of the fingertip) to a target. In addition, movement plans might make use of egocentric coordinates (e.g., the joint angles required to land on the target). If movement errors used to correct subsequent movements are coded in vector terms, then performance in a series of reaches will be best when movements are blocked by initial-position-to-target vector. If, in addition, humans make use of egocentric coordinates for coding errors, performance should be better when movements are blocked by egocentric target location, independent of the initial position. We compare these two hypotheses in a reaching task.

Methods: Subjects made reaches on a tabletop. Initial position, current fingertip location and target position were shown on a fronto-parallel display. Reaches included all combinations of 6 reach vectors and 6 egocentric targets (36 distinct reaches) within two contexts. In the 'egocentric' context, reaches were blocked according to target location independent of initial position; all reaches to a given target were completed before reaches to any other target were made. In the 'vector' context, reaches were grouped according to reach direction without respect to target identity. In each context, 20 repeti-

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tions of each reach were made (randomized within blocks). The order of the two contexts and of blocks within context were randomized across subjects. Target size was tuned by subject to equate task difficulty.

Results: Performance, measured in terms of target hit rate, was superior in the egocentric context. This supports the hypothesis that when the reach context affords its use, error information obtained from egocentric target coding is combined with vector coding to improve human movement planning.

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43.531

Fitts's Law for saliency

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In 1954, Paul Fitts showed that the time needed for manual movements increases as a logarithmic function of Index of Difficulty (ID; relationship between target size and movement amplitude). Fitts's formula for predicting the movement time from ID has since then also been known as Fitts's Law and has been investigated for a large range of target sizes, movement amplitudes, types of response and has also been applied to ergonomics. In the current study we investigated whether Fitts's Law is also valid for saliency by using a simple visual search task with manual pointing movements. Thus in this experiment, the stimuli only varied in context features (manipulation of saliency), whereas in the original idea of Fitts, local features (size manipulation) of stimuli differed. The factor target size as manipulated in the original experiment was replaced by the factor level of saliency. The task of the participants was to perform a pointing movement as fast as possible to a pop-out target which differed from surrounding distracter items to a varying degree in luminance or orientation. An additive effect was found for both factors, i.e. for highly salient targets and low movement amplitudes, movement time was shorter compared to less salient targets and larger distances to the target. Thus, as predicted by Fitts's Law, the movement time increased with ID, which was in our experiment the different movement amplitudes and the different levels of saliency. This indicates that Fitts's law can also be applied to saliency. The bottom line is that the system can access the saliency information which is persistent throughout the whole movement preparation and the actual movement. Applied to ergonomics it is not sufficient to simply consider target features but as well take context features into account.

43.532

Stuck in the middle: Kinematic evidence for optimal reaching in the presence of multiple potential reach targets

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Neurons in motor cortex simultaneously encode multiple potential reach targets prior to the unambiguous selection of a final motor plan (Cisek and Kalaska, 2005). Here we used hand-path trajectories during rapid reach responses (Song and Nakayama, 2006) to investigate behaviourally the simultaneous planning of multiple target reaches. Human participants made reaches to touch a single target in the presence of multiple potential targets on a touch screen. On each trial in Experiment 1, one or two possible targets (hollow circles) appeared on the screen in different spatial configurations. At movement onset, one circle was filled in and the participant's task was to touch the filled-in target within 750 ms of stimulus onset. When one target was presented and thus only one motor plan encoded, initial trajectories headed directly toward its location. Interestingly, when two possible targets appeared, requiring two motor plans to be encoded, initial trajectories headed almost exactly between the two target locations before correcting to the filled-in location. Experiment 2 was similar except that two or three possible targets appeared on the screen and these targets were either filled in before (early) or after (late) movement onset. On early trials, initial trajectories headed directly toward the filled-in target. On late trials, we replicated Experiment 1. Additionally, we showed that initial trajectories in three-target trials were biased toward the side of space with more possible targets. Experiment 3 further tested whether this bias was driven by the number of potential reach targets or their eccentricity. Analyses show that both properties affect initial trajectory heading. Taken together, these results are consistent with the hypothesis that potential targets are simultaneously encoded prior to movement onset. Moreover, our findings suggest the visuomotor system plans optimal trajectories with respect to the number and location of potential reach targets in cases of target uncertainty.

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43.533

Blurring the boundaries between perception and action

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In order to perceive and interact with the visual world local image characteristics (e.g., orientation, spatial scale) arising from V1 must be appropriately distributed to both dorsal and ventral pathways. While significant evidence exists suggesting the importance of V4 for establishing the link between simple form analysis and the perception of complex object based scenes (Pasupathy & Connor 2002) little attention has been given to how similar processes are accomplished in the motor (dorsal) pathway. In this investigation we examined the relative precision and congruence of perceptual and motor estimates of luminance defined object boundaries. Twelve participants were asked to (a) point at, or (b) estimate the size of circles presented along their AP axis. Circles ranged in size from 1-4 cm and provided either a clear edge boundary (white/black transition) or were defined by a 2-d Gaussian such that the circle center was white and degraded to black at 2sd. Overall, participants demonstrated decreased RT associated with both increasing target size and edge salience. Further, and in accord with the seminal work of Fitts' (1954), participant movement times decreased with increasing target size. However, movements made to the Gaussian-blurred images were performed more rapidly. In order to more directly examine size estimates across perceptual and motor systems, an effective target width was calculated for pointing movements to all targets and the 95% confidence interval was compared to the mean perceived target size. While both motor and perceptual system scaled to target size the perceived target estimates were larger for blurred objects; the endpoint variability of the motor system showed not sensitivity to boundary blur. Thus it appears that the ventral and dorsal systems use edge features arising from early visual areas differentially when 'constructing' visual objects.

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Spatial Vision: Mechanisms and Special Populations

Monday, May 11, 8:30 am – 12:30 pm
Poster Session, Vista Ballroom

43.534

Conservatism in a 2AFC Discrimination Task

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In single-stimulus categorization and yes-no signal-detection tasks with asymmetric payoffs or priors, human observers often display conservatism: The likelihood ratio at criterion (β) is closer to one than the optimal criterion maximizing expected gain (assuming an underlying Gaussian model). Are observers similarly conservative in a typical 2-alternative, forced-choice (2AFC) discrimination task? Methods: Six subjects viewed brief (200 ms) displays containing two noise patches (diameter: 3 deg) to the left and right of fixation (eccentricity: 8 deg). A vertical Gabor patch (3 cycle/deg) was

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added to one of the noise patches. Subjects indicated which noise patch contained the Gabor. Eye movements were monitored; trials were excluded if subjects moved their gaze more than 1 deg away from the fixation mark. A pilot experiment with symmetric payoffs was used to estimate Gabor contrasts corresponding to d′ values of 0.5, 1 and 2. In the main experiment, incorrect responses resulted in a 100-point penalty. Correctly detecting a target on the left resulted in a 100-point gain. Rewards for correctly identifying targets on the right varied between blocks (40, 65, 100, 160 or 250 points). Subjects completed 15 blocks (5 payoff schedules × 3 contrast levels) of 200 trials. Results: Values of d′ and β were estimated by maximum likelihood for each subject. A linear regression of optimal vs. estimated β yielded a slope less than one (i.e., conservatism) for nearly every subject and d′ condition. Pooling data across subjects and conditions, a similar linear regression yields a slope significantly less than one (p<.01). Conclusion: Observers are conservative in setting their criterion in a 2AFC discrimination task.

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43.535

Decision criterion is determined by interaction's strength from inside or outside the perceptive field

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Signal Detection Theory (SDT) assumes that sensitivity (d′) is determined by the strength of the sensory input and the background noise (the signal-to-noise ratio). However, the decision criterion (Cr) is affected by internal properties that are not directly related to the sensory input. It was shown, using two temporal alternative forced choice, that two collinear Gabor patches (GPs) placed outside the perceptive field (PF) increase the d′ (facilitation) of the target GP but decrease d′ (suppression) when they were placed inside the PF. We recently showed, using a Yes/No paradigm, that d′ does not follow the expected collinear facilitation. On the other hand, subjects tend to report targets present in a consistent way with the spatial tuning of collinear facilitation. Here we investigated, using the Yes/No paradigm, whether Cr is modulated by suppression from inside and facilitation from outside the PF. We measured the results for inside the PF for a target-flanker separation of 1.5 (fovea) and 3 wavelengths (periphery, 4 deg), whereas effects outside the PF were tested for 3 (fovea) and 7 wavelengths (periphery, 4 deg). Target-flanker orientation's differences (0, 11, 22.5, 45, 90 degrees) were intermixed. We found that pHit for the collinear is lower than the orthogonal configuration inside the PF and the collinear outside the PF. Cr for collinear configuration is shifted from positive inside the PF to negative outside the PF. Thus, subjects tend to report targets absent for the collinear configuration inside the PF and targets present outside the PF. All together, our results show that Cr is directly modulated by center-surround neural activity, following suppression from the center and facilitation from the surround of the PF. The decision criterion may provide a good estimate for the visual crowding effect that increases with increasing eccentricities.

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43.536

A Contrast Polarity Search Effect in Letter Identification

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Contrast polarity effects have been ascribed to the negative polarity system being more sensitive and having higher spatial resolution. Higher cell density for negative polarity ganglion cells has been found in Macaque peripheral parasol cells. We repeated the letter identification task we presented here last year, adding a condition in which the letters were presented in one of four peripheral locations instead of in the central fovea. Single letters of positive or negative polarity were either presented normally or as background gray letters surrounded by a small positive or negative pedestal. The pedestal polarity determined the channel polarity, opposite the apparent polarity of the pedestal-defined letter. Response latencies were collected from 16 observers for 3 repetitions of 12 letters presented randomly at 6 letter or pedestal contrasts (±0.4, ±0.2, ±0.1) and at two eccentricities (0 and 3 degrees). For the foveal presentations, only the absolute amount of contrast significantly affected the latencies. Peripheral presentations led to slower latencies overall, and for the highest contrast peripheral conditions neither contrast polarity nor pedestal vs. letter mattered. At the lowest contrast, there again was no polarity effect, but the pedestal condition was much faster than the letter condition, the increased stimulus area of the pedestal apparently guiding fixations better. At the middle contrast level, the positive contrast letters were slowest to be identified. This could be the result of poorer fixation guidance or smaller letter span by the positive polarity system.

43.537

Contributions of Motion Information and Displacement Priors to Spatial Perception of Stationary Objects

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People use motion information to locate moving objects in space, and they mislocalize objects when the background moves. But motion processing might also help locate stationary objects, given that people saw them moving before and regard movements as likely. This is predicted by an optimal inference model of transsaccadic integration that we have previously proposed. Here we show that the model applies to space perception outside the saccade as well. We asked participants to view objects from the corner of their eyes and to remember their location. Then we displaced the objects while modulating perception of displacements in two ways: (a) we displaced the objects either before or during saccades to examine the influence of saccadic suppression of motion; (b) we blanked displacements to degrade visual motion information. Also, blanking might make it more conceivable that a new object has appeared rather than the old one moved, thus altering expectations about displacements. As predicted by the model, blanked displacements outside the saccade biased localization towards the new location. In contrast, blanked displacements inside saccades were veridically perceived but displacements with no blank were misperceived, consistent with Deubel and colleagues' (1994) blanking effect. Our data support the idea that spatial perception integrates past motion information to process object locations.

43.538

Evidence for intact spatial updating in observers with severely degraded vision

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In low-vision navigation, an essential ability is the accurate judgment of object locations in the environment. We investigated distance perception in normal vision and simulated low-vision conditions to examine the perceptual capabilities of individuals with profound low-vision. In order to replicate our previously reported findings that distance judgments remained accurate even under simulated low-vision (VSS 2008) and to explore the effects of simulated low-vision on a more complex distance-dependent spatial updating task, we employed the triangulation task of eyes-closed indirect walking. This requires that the observer continually update the location of stimuli while walking, without any further visual feedback of their movement or the stimuli location. Participants were normally sighted and tested monocularly in two conditions. In the first condition, participants wore goggles with theatrical lighting gels, resulting in a tested acuity between 20/381 and 20/1261, and a tested contrast sensitivity between near 0 and 0.75. In the second condition, 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 had 7.7m x 10.5m of walkable space and was lit approximately evenly. Targets were two sizes of black matte boxes, located on the ground-plane at egocentric distances of 1.5, 3.1, and 6 meters. The observer viewed the target and the environment for 5

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seconds. While blindfolded, they were instructed to either perform a direct or indirect walking task. They then walked without vision to the apparent target location directly or indirectly. For both walking tasks, walked distances did not differ between normal and degraded vision conditions. Walked distances in the normal vision condition showed somewhat less between-subject variability than for the degraded vision condition. Future work will examine if the order of the conditions, or if advance knowledge of the task affect performance.

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URL: http://www.cs.utah.edu/research/areas/percept/DEVA/

43.539

The quality of filled-in surface at the blind spot

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Visual system is known to restore missing information at the blind spot using the information surrounding the blind spot (monocular information) as well as the information represented in the opposite eye (binocular information). To understand the mechanism of filling-in process, we compared the quality of the surface perception resulting from monocular (Experiment 1) and binocular (Experiment 2) filling-in process. Experiment 1 tested whether the same effect of collinearity and orientation differences on contour integration was observed at the blind spot. We presented two separate bars, a reference at the one edge of the blind spot and a test bar at the opposite edge, constituting various angles. The bars contained gratings collinear or orthogonal to their orientations. Participants' task was to report the minimum length of the test bar yielding perceptual connection between the two bars. The test bar filled in the blind spot with shorter length when the gratings were collinear and the two bars were straighter, implying that the filling-in process engages the same contour-integration mechanism. Experiments 2 investigated whether this filled-in surface differed from physical surface by comparing the amount of interference effect from filled-in and physical surface. Dot patterns were presented either around the blind spot, corresponding location in the opposite eye, or both, so to interfere with detection of a small dot appearing in the opposite eye in location corresponding to the blind spot. Detection performance was the best when only filled-in surface was presented as an interference pattern comparing to the same interfering stimuli presented to non-blind-spot area, suggesting that perceptual quality in filled-in surface is not identical to that in physical surface. In sum, though filling-in process in the blind spot share common filling-in mechanism, the resulting percept does not correspond to that from physical reality.

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43.540

Digital Map Reading: Experiments investigating different wayfinding tasks in familiar and non-familiar locations

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Advances in digital technology and computing have led to the development of numerous online map services and 'wayfinding' devices, indicating that the use of electronic maps has become widespread. However, little research has been undertaken investigating how people use maps, in particular online maps and digital displays. Two eye-tracking experiments were carried out, one using the dynamic google maps (available at http://maps.google.co.uk), and the other using a static digital map display. People completed 3 different tasks designed to invoke different types of map reading, in a familiar and non-familiar location. In the first experiment, 3 different map display types were compared (ie. regular, satellite and satellite overlay maps), and the second experiment compared task performance in static maps and investigated individual differences in spatial ability, using Hegarty et. al (2002)'s Santa Barbara Sense of Direction Scale (SBSOD). Results of the first experiment indicated a significant effect of familiarity of location on speed and accuracy. The second experiment showed a similar effect of familiarity, and an effect of a person's spatial ability. This study represents a naturalistic task that is relevant in the current age of digital map use, and is therefore relevant in assessing how humans interact with these displays, and also whether there are particular map display types that are associated with successful accomplishment of different tasks.

Hegarty, M., Richardson, A. E., Montello, D. R., Lovelace, K., & Subbiah, L. (2002). Development of a self-report measure of environmental spatial ability. Intelligence, 30, 425-477.

43.541

Fusing Sine Waves with Optotypes: A New Test of Human Spatial Contrast Sensitivity

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Purpose: Current tests of spatial contrast sensitivity (CS) fall into two categories, those that employ luminance-modulated sine-wave gratings (e.g., the FACT chart), or those that use recognizable Snellen-like optotypes (e.g., the Pelli Robson chart). Both forms possess distinct advantages but an ideal test would combine the desired characteristics of each format. Here, we report on a novel prototype for one such test.

Methods: Five wall charts were constructed using custom software and a high quality PostScript printer. The optotypes on each row of a chart were Landolt Cs which, from the outside edge to the inside edge of each C, modulated sinusoidally in luminance. The average luminance within each C matched the chart's background. Each chart contained sine-wave Cs representing 1 of 5 spatial frequencies (0.75, 1.5, 3.0, 6.0 and 12.0 c/deg), with contrast on each successive row decreasing from 40% to 1% in equal log steps. 25 adults were tested monocularly at 3m, and for comparison and validation, were also tested with standard commercial CS tests: the FACT, Rabin, Pelli-Robson, and low contrast Sloan tests. To examine applicability with children, 25 4-and 5-year-olds were also tested.

Results: Adults easily completed the test in an average of only 2.3 min. Results showed that each subject generated an interpretable contrast sensitivity function (CSF), with individual performance on the sine-wave Cs predicting very well, the results on the standard CS tests. Children required more time (5.7 min) but most (94%) were capable of successful completion.

Conclusions: The new sine-wave C test of contrast sensitivity appears very successful. Both adults and children show definitive responses and clear estimates of threshold. Thus, the test holds promise as a hybrid tool for assessing simultaneously, both optotype CS and full spectrum contrast sensitivity, a feature that should have both experimental and clinical value.

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43.542

Off-kilter: Orientation Discrimination during Childhood

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In the only study measuring sensitivity to orientation during childhood, we showed that 5-year-olds are four times worse than adults when tested with high contrast gratings (Lewis, et al., 2007). Here, we tested older children to chart the development of sensitivity to orientation between 5 years and adulthood. Methods. We measured orientation discrimination in 20 7-year-olds (± 3 months) and 20 9-year-olds (± 3 months) using methods identical to those used previously with 5-year-olds and adults (Lewis, et al., 2007). The stimuli consisted of 1 cpd black-and-white high contrast sine-wave gratings within a 10° circular aperture. The task on each trial was to indicate whether the top of the stripes was tilted to the left or right of vertical. Tilt was varied over trials according to a ML-PEST staircase procedure (Harvey, 1986) to measure the minimum tilt discriminable from vertical. Results. Minimum discriminable tilt improved with age ($p < 0.0001$) from 3.5° at 5 years, to 1.6° at 7 years, to 1.2° at 9 years, to 0.9° in adulthood. Post-hoc analyses showed that 5-year-olds were significantly worse than all older ages ($ps < 0.001$) and that thresholds were adult-like by age 7 ($ps > 0.30$). The data were best fit by an exponential function ($r2= 0.35$, $p < 0.0001$)

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reflecting the rapid improvement in thresholds between 5 and 7 years of age and the more gradual improvement thereafter. Conclusions. The pattern of development for sensitivity to orientation (this study) resembles those for the development of sensitivity to spatial frequency (Patel, et al., 2009) and contrast (Ellemberg et al, 1999). These similar patterns are consistent with theories of common underlying mechanisms (Vincent & Regan, 1995; Shapely et al., 2003). The immaturities at 5 years of age may be caused by higher internal noise.

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43.543

Which Stripes are Fatter? The Development of Spatial Frequency Discrimination

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Adults can discriminate a 2 – 11% change in spatial frequency (Hirsch & Hylton, 1982; Mayer & Kim, 1986). Purpose. To provide the first measurement of the development of spatial frequency discrimination. Methods. Participants were adults (range: 17-20 yrs, M = 18.9 yrs) and children aged 5, 7, and 9 years (all ± 3 months; n = 20 per age). Participants saw sequential presentations of a baseline sine-wave grating of 1 or 3 cpd and a comparison sine-wave of higher spatial frequency. The task was to indicate whether the wider stripes occurred in interval 1 or 2. The spatial frequency of the comparison was varied over trials according to a ML-PEST staircase (Harvey, 1986) to measure the minimum spatial frequency discriminable from baseline at 82% correct. Results. An ANOVA showed no significant differences between thresholds at the two baseline spatial frequencies ($p > .20$), significant improvement with age ($p < .0001$), and no interaction ($p > .60$). The minimum change from baseline necessary to discriminate spatial frequency decreased from 30.1% in 5-year-olds to 11.6% in 7-year-olds ($p < .0001$), at which point it was not significantly different from adults' threshold of 6.1% ($p > .20$). The data were best fit by an exponential function reflecting the rapid improvement in thresholds between 5 and 7 year of age and more gradual improvement thereafter until adulthood ($r2 = .046$, $p < .0001$). Conclusions. The pattern of development for sensitivity to spatial frequency (this study) resembles those for the development of sensitivity to orientation (Lewis et al., 2009) and contrast (Ellemberg et al, 1999). These similar patterns are consistent with theories of common underlying mechanisms (Vincent & Regan, 1995; Zhu et al., 2008). The immaturities at 5 years of age may be caused by higher internal noise.

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43.544

Children's visual acuity charts: effects of blur and eccentricity

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Crowding has a more detrimental effect on the visual acuity of strabismic amblyopes than anisometropic amblyopes, when measured with Tumbling-E patterns (Bonneh et al, 2004). Spatial vision in amblyopia can be estimated in normals by imposing increasing levels of blur and retinal eccentricity (e.g. Levi & Klein, 1982). As the detection of amblyopia in children relies on accurate assessment of visual acuity, we measured the effects of increasing blur and retinal eccentricity on visual acuity in normal adults with commercially available crowded and uncrowded children's vision charts.

High contrast optotypes, derived from common children's acuity charts, were presented on a high resolution monitor in isolation (Sheridan Gardiner letters and Kay pictures) and in configurations of commercially available crowded charts (logMAR Crowded Test, Cambridge Crowding Cards, Sonksen logMAR Test, and Kay Picture Test). These charts differ in the optotypes and crowding features used, and in the separations between them. For each chart, psychometric functions were obtained at the fovea for four levels of dioptric blur (0, 0.5D, 1D and 2D) and at four levels of retinal eccentricity (0, 1.25 deg, 2.5 deg and 5 deg in the lower field). E2 values were calculated for each chart. Four adult observers with corrected to normal vision participated.

Blur had a similar degradative effect on visual acuity across all charts (ANOVA; $p>0.10$). Increasing retinal eccentricity had a greater effect on visual acuity measured with the crowded charts (Mean E2 ~1 deg) than with isolated uncrowded optotypes (Mean E2~2 deg).

Based on models of amblyopia and the above results, a greater level of visual acuity loss with crowded charts than with isolated optotypes would be expected in strabismic amblyopes, but not in anisometropic amblyopes.

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43.545

fMRI-based perimetry: single-point visual field testing and evaluation using retinotopic mapping

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Background: Retinotopic mapping using fMRI objectively determines the functional topography of visual cortex. Behavioral visual field mapping (perimetry) is a subjective method because it depends on the patient's judgment. Comparison between retinotopic and perimetric maps is difficult. Our goal was to develop an fMRI-based visual field test that is objective, provides high spatial resolution, and allows comparison of behavioral and brain activation data as well as longitudinal observation of visual performance. Methods: In 10 normally-sighted subjects, retinotopic mapping (checkerboard stimuli, 8Hz flicker) and fMRI-based perimetry were performed using a 3T Philips Intera MR Scanner (FEEPI, TR=2000ms, 28 slices, 2mm, no gap, resolution 128 x 128). For fMRI-based perimetry, small flickering stimuli (~2.5 to 12.5 degrees eccentricity, M-scaled) were presented at 48 positions, with two randomly positioned stimuli appearing simultaneously in each trial (2000ms), one in the left and one in the right hemifield. BOLD response, stimulus detection, and reaction times were acquired in five runs (30 repetitions/ position). Data were analyzed with Brain Voyager QX software (GLM, linear correlation maps, ROI analysis) separately for the left and right hemisphere. Retinotopic maps were used to determine the consistency and validity of fMRI-based perimetry results. Results: Retinotopic maps in healthy subjects were comparable to results reported in the literature. FMRI-based perimetry yielded locally specific activation maps at the locations expected based on retinotopic maps. We found interindividual differences in BOLD amplitudes of activation maps. Conclusions: fMRI-based perimetry is an objective tool for testing visual field function with a higher spatial resolution than conventional retinotopic mapping and permits point-by-point relation of behavioral parameters (stimulus detection, reaction times) to locally specific activation of early visual cortical areas. Thus, it is also suitable for the assessment of visual cortex function in visually impaired patients.

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43.546

Clinical Applications of Multiple Scaling Theory: Focus on the Big Picture

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Patients suffering of foveal vision loss (e.g. macular degeneration) must rely on peripheral vision to perform most visual tasks. Often, this is insufficient, and corrective measures are necessary: (1) magnification, i.e. enlarging the stimulus (e.g. moving closer to the stimulus, using magnifying lens), and/or (2) stimulus optimization (e.g. controlling the spacing between letters, using a font optimized for peripheral vision).

The current focus in peripheral vision research in normal populations is to measure, at each eccentricity, the smallest stimuli that can maintain threshold performance (i.e. lower limit). However, using multiple scaling theory

Monday Sessions

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(MST; Poirier & Gurnsey, 2002, 2005), we argue that this information is incomplete. Researchers also need to measure, at each eccentricity, the largest stimuli that can maintain threshold performance (i.e. upper limit).

Upper limits are not uncommon in perception: (1) texture discrimination has an upper limit, where texture discrimination is impaired if textels on either side of a texture edge are spaced too far apart, and (2) reading has an upper bound, where normal scanning and reading span functions are disrupted when letters are too spaced apart.

The relationship between these two limits determines if the task can be solved peripherally, and if so, what corrective measures are required. We will also review various sampling strategies used in peripheral vision research, and for each provide concrete ways to detect lower and upper limits.

We discuss several applications of this research, including (1) guidelines for generalizing results from normal to clinical populations and vice-versa, (2) guidelines for generalizing results from incomplete data sets or sub-optimal sampling strategies, and (3) guidelines for identifying the proper corrective measures. These guidelines could play an essential role in bridging peripheral vision research across clinical and normal populations.

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43.547

Variations in Stimulus Onset Asynchrony Affect Attentive Processing in Amblyopia

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Crowding is a phenomenon generally characterized by decreased ability to identify a target among nonoverlapping 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). Recent experimental results have suggested that amblyopes experience disrupted attentive processing (Popple and Levi, 2008) as well as a different timecourse for temporal integration (Song and Levi, 2008) when compared with normally sighted observers. Our aim in this experiment was to assess the extent to which varying the stimulus onset asynchrony (SOA) between an attentional cue and a crowded stimulus affected the ability of attention to reduce crowding. We measured this in terms of performance improvement for a task in which observers were asked to identify the central target among an array of distractors under one of two conditions: (1) no cue, and (2) the target was cued with a colored, size-appropriate spatial cue of the same mean luminance as the background presented at one of five durations of stimulus onset asynchrony. Our stimuli consisted of vertically and horizontally oriented black and white bars as well as probable conjunctions of two bars (one horizontal and one vertical) presented on an otherwise homogenous gray field of mean luminance. All experiments were conducted monocularly; both amblyopic and fellow eyes of participants with amblyopia were tested along with non-dominant eyes of normally-sighted control participants. We found that for normally sighted observers, an accurate attentional precue improved performance relative to the uncued condition with the greatest improvements being at a 120 ms SOA, while for amblyopic observers, improvements were smaller on the whole with the largest improvements being at a 40 ms SOA.

43.548

Spatiotemporal template for visual perception in normal and amblyopic vision

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Reverse-correlation methods can provide both quantitative and intuitive information about the information used and mechanisms underlying a visual task. In this study, we use reverse-correlation to measure the spatio-temporal templates for both normal and amblyopic observers.

We measured contrast discrimination for a target bar embedded in spatio-temporal noise (11 noise bars, each 0.1 x 0.8 deg; 21 noise frames, each 10ms). Five normal and six amblyopic observers participated. The preferred eye of each normal observer and both eyes of each amblyopic observer were tested at fixation. The same measurements were repeated on normal observers with spatiotemporally filtered stimuli (2-d Gaussian filter) at fixation, and with unfiltered stimuli at 2.5 deg eccentricity in the lower visual field. We used reverse-correlation to calculate the classification images (templates).

The classification image for normal observers and non-amblyopic eyes has a positive peak at the spatio-temporal location of the target, with negative flankers 0.1~0.3 deg on each side of the central peak. Along the time coordinate, it has a negative peak 30~40ms following the onset of the target. In the amblyopic eye, however, the negative peak in the temporal profile is completely missing in almost every case, and the inhibitory flankers in space are either missing or scattered. When the stimuli are blurred by a 2-d Gaussian spatio-temporal filter, the classification image of normal observers is not qualitatively different from that with the unfiltered stimuli. But when the stimuli are viewed eccentrically, the classification image shows a lack of inhibition, similar to the amblyopic eyes.

Our results suggest that low level visual processing in amblyopia is abnormal mainly in that the inhibition, but not the excitation, is significantly reduced, both in space and in time. This deficit cannot be explained by "blur", but is similar in nature to normal peripheral vision.

43.549

Visual illusions involving contextual modulation are weak in schizophrenia

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Several studies have reported that visual perception in schizophrenic patients, compared to healthy individuals, is relatively immune to illusions induced by surrounding visual context (Daki, Carlin, & Hemsley, 2005; Tadin et al., 2006; Uhlhaas et al., 2006). Given the important role of context in normal vision, these abnormalities might have considerable impact on visual processing in schizophrenia. Prior studies, however, focused on single visual sub-modalities (e.g., motion), precluding more general conclusions about contextual deficits in schizophrenia. In this project, we investigated contextual effects across a variety of visual tasks in normal adults and in adults diagnosed with schizophrenia or with bipolar disorder. We used adaptive psychophysical techniques to measure six different aspects of visual appearance of a central stimulus viewed in the presence of a surrounding visual context. In separate test runs, contextual modulations were measured using center-surround differences in luminance, orientation, contrast, size, or two different versions of motion direction. All participants, healthy adults and patients, performed accurately on control conditions in which each task was administered in the absence of surround context, verifying that participants understood and could perform the tasks. Healthy adults showed robust surround context effects on all tasks, as evidenced by pronounced misperception of the brightness, orientation, contrast, size, or motion direction of the center stimulus. Based on evidence to date, schizophrenic patients (N=8) were less influenced by contextual effects (meaning they performed more accurately than controls) induced by surrounding tilt, contrast, and motion. On some tasks individuals with bipolar disorder (N=11) produced results similar to those of schizophrenics, implying that neural processes underlying contextual interactions may be defective in clinical populations besides schizophrenics. Quantifying the strength and selectivity of visual contextual effects in schizophrenia could determine whether a common underlying deficit exists in contextual processing.

Tuesday Sessions

Eye Movements: Mechanisms

Tuesday, May 12, 8:30 – 10:00 am
Talk Session, Royal Palm Ballroom 1-3
Moderator: Leland Stone

51.11, *8:30 am*

Coordinate system of visual motion signals driving pursuit initiation

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Smooth pursuit combines retinal motion with extra-retinal signals to track a moving object in the world (Young et al., 4th Annual NASA Manual 1968). While the retinal motion signals driving pursuit initiation have been well characterized (e.g., Lisberger and Westbrook, 1985), the existence of extra-retinal signals related to ongoing eye motion in the visual motion pathways involved in driving pursuit (e.g., Newsome et al., 1985) makes the nature of the visual command signal less clear. Here, we use the pursuit "oblique effect", a directional anisotropy, as a fingerprint to examine the coordinate system of the visual motion signals driving the onset of pursuit.

Methods. With their head upright or tilted to the right, observers were asked to pursue a small spot that made an initial step from fixation at a random angle, then moved back through fixation at one of four speeds (5, 10, 20, 30 deg/s) in a Rashbass design. De-saccaded eye-velocity responses were used to measure pursuit direction (near open-loop interval 200-300 ms after motion onset) and to compute direction gain (Krukowski & Stone, Neuron 2005). To compute the head and eye tilt, we used pairs of high-resolution digital photographs in the upright and tilted configurations, and measured head rotation using selected features and eye rotation using a circular cross-correlation of the iris.

Results. When the head tilts by 19-21 degrees, the oblique effect for pursuit changed orientation (mean shift: 15.7 ± 1.9 deg, $p<0.0001$, paired t-test). The oblique-effect shift was significantly smaller than the head tilt (paired t-test, $p<0.05$), but indistinguishable from the eye tilt (paired t-test, $p>0.05$).

Conclusion. The neural signals for pursuit initiation are linked to an eye-centered reference frame (not world- or head-centered coordinates).

Acknowledgement: NASA Space Human Factors Engineering.

51.12, *8:45 am*

Smooth-pursuit eye-movements suppress motion processing

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If retinal motion signals arising from smooth-pursuit were not discounted, smooth-pursuit eye-movements could generate spurious motion signals that generate a motion after-effect (MAE). Last year (Tse & Hsieh, VSS 2008) we showed that while the duration of the MAE experienced over stationary oriented lines increased with increasing duration and speed of smooth-pursuit, the strength of the MAE was effectively zero for vertical and horizontal bars, even though the vertical stimulus had the greatest image motion magnitude in the horizontal direction (of smooth-pursuit), presumably because motion suppression operates to discount spurious signals. The MAE was strongest for bars oriented slightly (about ten degrees) away from horizontal. We hypothesized that the motion processing system discounts component motion with less success for bars oriented at angles very close to the direction of smooth-pursuit, suggesting 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. Here we extend this work and show that radial motion appears to subjectively slow down dramatically during smooth-pursuit eye-movements. Stimuli were concentric 'expanding' and 'contracting' sinusoids. Using the method of constant stimuli, subjects equated the speed of a given stimulus expansion/contraction with and without smooth pursuit. Stimuli had to have much greater speed during smooth-pursuit to be subjectively equivalent in perceived motion magnitude to the same stimulus presented during static fixation, implying motion suppression as during saccades.

51.13, *9:00 am*

Short-latency torsional ocular following in humans

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Using scleral search coils, we recorded the initial torsional ocular following responses (tOFRs) that were elicited in 3 human Ss when textured patterns occupying a circular area (diameter, 32º) in the frontal plane were centered on, and briefly rotated (200 ms) about, the optic axis. With random-dot patterns, the angular speed giving best responses averaged 166º/s and the associated latencies averaged 80-90 ms, which was ~15-20 ms longer than the latency of the horizontal and vertical OFRs to optimal motion along the cardinal axes. The initial tOFRs were quantified by measuring the changes in torsional eye position over the 80-ms period commencing 70 ms after stimulus onset (open-loop measures). Excluding one half of the field (upper, lower, right or left) indicated that motion was more effective in the lower hemifield than in any other hemifield. When polar 1-D angular sinusoidal luminance gratings were rotated in successive ¼-wavelength steps at 10-ms intervals, tOFR measures showed a Gaussian dependence on log angular wavelength ($r2>0.97$; mean peak and SD: 22.9º and 0.55 log10 units, respectively) and a dependence on contrast that was well described by the Naka-Rushton equation ($r2>0.97$; mean c50 and n: 5.5% and 2.2, respectively). When these polar gratings were reduced to 2-15 equally-spaced concentric annuli each with the same radial width (0.5º), same angular wavelength (22.9º) and same contrast (range, 2%-32%), all tOFR measures were well fit by a single monotonic function ($r2>0.97$) that showed only minor saturation when plotted as a function of the product, log(A*Cn), where A is screen coverage, C is Michelson contrast and n is a free parameter (mean $n=2.1\pm0.4$SD). This is very different from the divisive normalization we reported recently for the horizontal and vertical OFRs, and consistent with the hypothesis that the tOFR here is determined by the total motion energy in the stimulus.

Acknowledgement: NEI Intramural Program

51.14, *9:15 am*

Perception of a stable visual scene during fixational instability

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During natural viewing, the stimulus on the retina is never stationary, as small eye movements occur even during visual fixation. It is remarkable that we perceive a stable scene and do not see the fixational motion of the retinal image. When an object moves by the same amount, the resulting displacement of the retinal stimulus is instead clearly visible. How does the visual system identify and discard the fixational motion of the retinal image? It has long been debated whether such cancellation relies on information about the movement and/or position of the eye or whether eye motion is inferred directly from the visual signal. Retinal stabilization, a procedure in which fixational motion is eliminated, is a powerful technique for testing between retinal and extraretinal theories, as it decouples the motor signals related to eye movements from their associated visual changes. Here, we report the results of experiments in which we examined the influence of fixational eye movements on motion detection. In a forced-choice discrimination task, subjects reported whether a small, bright dot, briefly displayed on a CRT, was stationary or drifted with uniform motion at 30′/s. We compared performance measured during the normal instability of visual fixation to performance obtained under retinal stabilization. Whereas, in the normal condition, the stimulus was stationary or moved with uniform motion on the screen, in the stabilized condition, it was translated under real-time computer control to compensate for the subject's eye movements, so that it remained immobile or followed a linear trajectory on the retina. We show that the motion of the retinal image resulting from fixational eye movements is inferred from the visual signal and that no extraretinal information is used for this purpose. These findings provide support to Koffka's (1935) original proposal that spatial localization occurs within a framework.

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51.15, *9:30 am*

Saccadic Plasticity in Visual Search

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Can human observers adapt their saccadic strategies to a new retinal sensitivity map? Performance in a visual search task depends critically on both the observer's pattern of retinal sensitivity and the observer's saccadic strategy. Certain retinal diseases, such as macular degeneration, can dramatically alter an observer's pattern of retinal sensitivity, leading to impaired performance. It is unclear, however, whether these changes in performance result from inefficient saccadic strategies or simply reflect the loss of visual information from the damaged retinas. Here, we report the results of a study using gaze-contingent displays and an ideal observer model of visual search (Najemnik & Geisler, 2005) to determine whether human observers can appropriately modify their saccadic strategies following simulated changes to their retinal sensitivity maps. We used two experimental conditions: a 'central scotoma' condition that simulated a loss of vision in the central 4 degrees of the visual field, and a 'shifted fovea' condition that shifted the observer's sensitivity pattern upward by 2.5 degrees. In both experimental conditions, we compared the performance of our human observers with that of three types of simulated observers: 1) an ideal searcher that plans optimal fixations according to the transformed sensitivity map, 2) a naïve searcher that plans optimal fixations under the original (unaltered) sensitivity map, and 3) a random searcher that chose fixations randomly. All three simulated observers correctly updated the posterior probabilities over target locations following each saccade. In the 'central scotoma' condition, humans outperformed the naïve and random searchers and demonstrated near optimal performance. In the 'shifted fovea' condition, however, humans performed suboptimally, with performance near that of the naïve searcher. Our results suggest that human observers can rapidly adapt their saccadic strategies for visual search following simulated macular damage, but that this learning is limited and depends on the spatial pattern of vision loss.

51.16, *9:45 am*

Color Signals in the Primate Superior Colliculus

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Color is important for segmenting objects from backgrounds, which can in turn facilitate visual search in complex scenes. However, brain areas that control overt visual orienting (i.e., saccadic eye movements) are not believed to have access to color (Schiller et al., 1979), despite massive visual corticotectal projections (Lock et al. 2003), which include areas traditionally associated with color processing (e.g., V4). Here, we show the first evidence that neurons from the intermediate layers of the monkey superior colliculus (SC), a critical structure for both overt and covert visual orienting (Fecteau & Munoz, 2006; Ignashchenkova et al., 2004), can respond to pure chromatic stimuli with the same magnitude as a maximum contrast luminance stimulus. In contrast, neurons from the superficial SC layers showed little color response. Crucially, visual onset latencies were approximately 30ms longer for color, implying that luminance and chrominance information reach the SC through distinct pathways, and that the color response cannot be due to residual luminance signals. Furthermore, these differences in visual latency translated directly into differences in saccadic reaction time (SRT) between color and luminance, which closely match SRT differences reported in humans (White et al., 2006). These results demonstrate that the saccadic eye movement system can signal the presence of pure chromatic stimuli only one stage from the brainstem premotor circuitry that drives the eyes.

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Face Perception: Representations and Mechanisms

Tuesday, May 12, 8:30 – 10:00 am
Talk Session, Royal Palm Ballroom 4-5
Moderator: Pawan Sinha

51.21, *8:30 am*

Integrating holistic processing and face-space approaches to the coding of facial identity

Elinor McKone[1] (elinor.mckone@anu.edu.au); [1]Department of Psychology, Australian National University

The theoretical notions of holistic/configural processing, and of face-space, have each been very successful. Authors typically refer to holistic/configural processing when explaining why upright faces are discriminated better than inverted faces, or faces better than objects, and when explaining findings from associated paradigms (e.g., composite effect, part-whole effect). Authors typically refer to face-space when explaining why distinctive faces are discriminated better than typical faces, own-race faces better than other-race faces, or why adaptation aftereffects occur. In this theoretical presentation, I argue that (a) although each theory has been independently successful, both in fact purport to explain exactly the same thing – the coding of facial identity – and so, as a field, we must consider the relationship between them, (b) our current approach of simply picking the most convenient theory in a given paper is not sustainable in the long term, and (c) the problem of the relationship between holistic processing and face-space is not, as many of us might have assumed, intractable. To illustrate how progress might be achieved I propose three theories, and sketch potential or actual empirical studies relevant to testing them. Theory 1 is that either holistic processing or face-space is not, in fact, related to face identification (e.g., holistic processing subserves face 'detection'). Theory 2 is that both are related to identification, and make independent contributions (e.g., timecourses following stimulus onset are different; they derive from different cortical regions in fMRI; multiple regression for individual differences in face recognition shows independent contributions of holistic processing strength and face-space coding ability). Theory 3 is that holistic processing and face-space coding are the same thing, predicting tighly interlinked empirical findings (e.g., strength of holistic processing differs for typical and distinctive faces; adaptation aftereffects are in some way "special" for upright faces compared to inverted faces and objects).

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URL: http://psychology2.anu.edu.au/_people/people_details.asp?recId=135

51.22, *8:45 am*

View Transformations in Face Space: A Computational Approach

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Although a preponderance of research in face perception has focused on front views, the visual system analyzes many individual faces over a significant range of left/right views. The concept of Face Space (Valentine, 1991) suggested that faces might be represented by a learned prototype plus a distance and direction of individual variation from the prototype. This proposal tacitly dealt with front views only and avoided the problem of generalization across views. One way of rectifying this would be to construct a complete face space for each of N distinctive views and then somehow link views of the same individual across view spaces. However, storage of N views of every face produces a heavy memory storage load. Here I propose a hybrid model that retains the appeal of face space and generalizes it to multiple views with a minimum of additional memory storage. Furthermore, it specifies a transformation for comparison of face images across views. Finally, it accounts for errors in human matching across face views.

The computation is based on the face space concept that individual faces in front view are encoded as deviations from a learned front view prototype. To this are added learned prototypes for other views. To compare a side view to a front view, the view is first estimated from the image, and the relevant view prototype is then subtracted from the image information. Matching occurs by computing the distance between the residual image information and stored information in the front view space. Simulations using a data base of 80 Caucasian faces faces produce accuracy rates of 92%, in good agreement with human data. This approach also suggests explanations for face deficits in the elderly and in prosopagnosia.

Acknowledgement: CIHR grant #172103

51.23, *9:00 am*

Eye movement strategies adapted to individual differences in the loci of performance-maximizing fixations during face recognition

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Introduction: Many studies have shown a normal human preference for fixating the eyes during a variety of face-related tasks (Barton et al., 2006). Previously, we showed using ideal observer analysis that the eye region also contains an impressively large and dense concentration of identification-relevant visual information (Peterson et al., 2007). Furthermore, human face processing preferentially uses the eye region information when making an identification (Peterson et al., 2008). There remains the question of how optimal these eye movement strategies are given the face's distribution of information and the eccentricity-dependent processing properties of the retina and visual cortex. Here, we present evidence for observer-specific face identification eye movement strategies driven by individual differences in the fixation location that leads to maximal recognition performance. Methods: 10 cropped grayscale male Caucasian faces were embedded in white Gaussian noise. In each of 3 sections conducted in an eye-tracker the observer identified a randomly selected noisy face. In the first two sections, observers began each trial fixating around the edge of the screen. The stimulus was shown for either 1500ms (Section 1) or 500ms (Section 2), during which eye movements were allowed. Section 3 required the observer to maintain fixation on one of four randomly sampled locations along the midline of the face (between eyes, nose tip, center of mouth, chin tip) during a 500ms display. Results: In Sections 1 and 2, fixation patterns were highly observer-specific, with average landing points ranging from the eyes to just below the nose tip. Results from Section 3 showed that observer performance as a function of maintained fixation was also variable. Regression analysis reveals a very strong correlation between individuals' maximally performing fixation point and their preferred landing point. Conclusion: Human eye movement strategy for quick face identification beneficially incorporates a representation of the observer's fixation-dependent task ability.

Acknowledgement: Support: NIH-EY-015925

51.24, *9:15 am*

The benefits of poor acuity for face learning

Nicolas Pinto[1] (pinto@mit.edu), Margaret Moulson[1], Pawan Sinha[1]; [1]Brain and Cognitive Sciences Department, MIT

Within a few days after birth, a human infant begins to exhibit sophisticated visual skills. Primary amongst these is the ability to preferentially orient towards faces. Precisely identifying the endogenous and exogenous factors which facilitate this unsupervised face learning remains an unsolved challenge. Here we investigate one specific factor: the acuity of the infant's visual system. It is known that a newborn's visual acuity is quite poor. We examine how acuity interacts with face learning, and whether reduced acuity might in fact be beneficial for acquiring a robust face concept. We collected several short sequences of simulated parental interactions from a baby's perspective. This was accomplished via a small video-camera mounted on a life-sized baby doll's forehead. We then created acuity variants of these sequences by convolving them with diffusing filters of a range of different sizes. These sequences were then provided as input to a simple computational learning system that discovers clusters of salient image fragments without supervision. To demonstrate recognition, the clusters are then used as templates for detecting regions in new sequences/images that correspond to the learned concepts. We find that this procedure is effective for basic concept learning. Interestingly, our computational simulations reveal that learning performance is impaired with high-resolution inputs relative to low-resolution. The 'concepts' learned at high-resolution are fragmentary and do not capture the gestalt of faces. It appears, therefore, that the poor acuity of infants might indeed be advantageous for early face concept learning. An interesting implication of these findings lies in the domain of autism. Children with autism have been reported to have difficulties in orienting to faces as infants. Interestingly, recent work has found a strong correlation between autism and markedly elevated acuity. Together with our computational results, these findings might provide a partial explanation for impairments in face-learning in autism.

51.25, *9:30 am*

Gaze-contingent techniques reveal impairment of holistic face processing in acquired prosopagnosia

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Normal observers process individual faces holistically, meaning that facial features are processed simultaneously over a face-wide perceptual span and that the face is represented as a single perceptual unit. Acquired prosopagnosia, an impairment of face recognition following brain damage is thought to be caused by a problem with holistic processing of faces (Sergent & Villlemure, 1989). However, previous studies have only demonstrated an impairment of interactive processing of features in patients who, in addition, present general visual integrative agnosia (e.g., Boutsen & Humphreys, 2002; Levine & Calvanio, 1989), so that direct evidence for a deficit in holistic face processing in prosopagnosia is lacking. In an experiment with a brain damaged case of prosopagnosia (PS, Rossion et al., 2003), we used two gaze-contingent techniques allowing manipulation of the amount of information that was simultaneously available. First, a gaze-contingent foveal mask, prevented the use of foveal, high resolution information, necessary for detailed investigation of the facial features, but allowed holistic processing based on lower resolution peripheral information. Second, a gaze-contingent foveal window covering all peripheral information, prevented the simultaneous use of several facial features, but allowed detailed investigation of each feature individually. In a face matching task, normal control participants showed increased errors and RTs with a foveal window in comparison to conditions with a foveal mask or with a full face. PS, on the contrary, was almost unimpaired by a foveal window relative to a full face, while she had major difficulties recognizing faces with a foveal mask. Moreover, the eye movement data confirmed the findings from previous studies, that for face recognition, PS mainly relies on the mouth region, while normal observers attend to the region just below the eyes. These data provide direct evidence for impairment of holistic face processing in acquired prosopagnosia.

51.26, *9:45 am*

Isolating the perceptual nature of the face composite effect from decisional response processes: electrophysiological evidence

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The composite face effect has traditionally been taken as strong evidence for holistic perceptual encoding of faces. Recently, however, based on signal detection theory, some authors have suggested that the effect is driven almost entirely by decisional, rather than perceptual, factors (Richler et al., 2008). To dissociate the roles of perceptual and decisional factors in this effect, we recorded ERPs to composite faces while participants performed a go-no-go behavioral task in an oddball paradigm. Twenty participants were asked to lift their finger when the top half of a frequent face changed, but not when the bottom of the face changed. Compared to the presentation of the frequently repeated face stimulus, we found a larger ERP signal starting at the N170 face-sensitive component for the infrequent trials in which the face top changed (release from identity adaptation, Jacques et al., 2007) at right occipito-temporal electrode sites (150 ms to 170 ms). Importantly, at the same latency we also found an effect when the unattended face bottom changed (composite face illusion), indicating the perceptual nature of the effect. Participants performed half of the trials with the right or left hand, allowing to measure the lateralized readiness potential (LRP), reflecting motor preparation activation. We hypothesized that if decisional factors play a role in influencing subjects' responses, we would observe an LRP on the bottom-change trials, provoked by the initial reaction to the composite illusion, that would resolve when the stimulus was thoroughly processed allowing the subject to determine the no-go trial status. However, we found no indication of indecision in the response, as evidenced by the absence of any LRP deflection for the critical bottom-change trial. These observations provide direct evidence for a perceptual composite face effect measured on electrophysiological signals, well before and independently of any decisional or motor response processes.

Eye Movements: Natural Environments

Tuesday, May 12, 11:00 am – 12:45 pm
Talk Session, Royal Palm Ballroom 1-3
Moderator: Jeff Pelz

52.11, *11:00 am*

Inhibition of saccadic return is sensitive to the probabilistic structure of the environment

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Human observers take longer to re-direct gaze to a location they previously fixated (inhibition of saccadic return: ISR). Arguments have been made for the adaptive value of this phenomenon in the context of search and foraging. However, ISR is only adaptive if previously fixated locations are unlikely to become behaviourally relevant soon after the original fixation.

In this study we examined whether ISR reflects a "hard-wired" assumption about the probabilistic structure of the world or whether it is sensitive to variations in probabilistic structure across different contexts. Observers made sequences of 2 saccades triggered by central, symbolic cues in a gaze-contingent manner. The probability that the initial starting position would become the target of the 2nd saccade was systematically manipulated between three groups of observers (low, equal and high return probability).

All three groups initially showed a strong inhibitory effect, with return saccades having much longer latencies than non-return saccades. ISR was strongest in the group for which return probability was low. Over time, ISR was completely abolished in the group for which return probability was high.

Individual observers' latency distributions were fit with an evidence accumulation model. Replicating our previous work we show that, under equal return probability conditions, ISR is best modelled as a reduction in the rate at which evidence is accumulated to a response threshold. This rate reduction was independent of the probabilistic context. However, the magnitude of behaviourally observed ISR depended strongly on the probabilistic context. This effect was mediated by adaptive changes in the response boundary. We conclude that a flexible response boundary allows observers to overcome strong in-built assumptions about the statistical structure of the world, and ensures that behaviour is more optimally adapted to the local context.

Acknowledgement: Supported by The Wellcome Trust (079473/Z/06/Z) and EPSRC (EP/E054323/1).

URL: http://casimir.psy.bris.ac.uk

52.12, *11:15 am*

Shrinking the Oculomotor World Using Global Saccadic Adaptation

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Visual perception depends on saccadic eye movements to bring objects of interest onto the fovea. To achieve this with continuing efficiency, the oculomotor system needs to calibrate saccades so that they reliably land on their targets. Saccades can be made to systematically miss their target by shifting its position during the saccade, when the observer is oblivious to such a change. As a result, saccadic magnitude will progressively adapt until the saccades finally land close to the artificially displaced target. This saccadic adaptation is thought to be spatially selective, dropping off with distance from the adapted target saccade vector. Although this is a robust finding, it is hard to envision an error in the oculomotor system that would make such spatially specific calibration in saccade landing sites necessary. Global adaptation mechanisms for overall gain in all directions, or in directions of specific ocular muscle groups would seem more ecologically valid. To test for global adaptation, we implemented an adaptation paradigm in which saccades had random directions and amplitudes, following a quasi random walk within the display. During each saccade the target was displaced 25% closer to the current fixation position. We found that adaptation was indeed spatially generalized and, moreover, developed very fast. In fact, saccades adapted faster than during traditional adaptation, where typically only one saccade vector is adapted. Our findings suggest that the generality and speed of saccadic adaptation depend on the distribution of feedback the oculomotor system receives. We conclude that a global saccadic correction occurs rapidly whereas directional selectivity is probably implemented by slower and later stages of adaptation.

Acknowledgement: This research was supported by a Chair d'Excellence grant to PC

52.13, *11:30 am*

Effects Of Semantic And Syntactic Object-Scene Inconsistencies On The Allocation Of Attention During Naturalistic Scene Viewing

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There is evidence that attention and eye movements during scene viewing are preferentially allocated to semantically inconsistent objects compared to their consistent controls. However, there has been a dispute over how early during scene viewing such inconsistencies affect eye movement control. While the classical "octopus in a farmyard" study by Loftus and Mackworth (1978) and more recent studies by Underwood and colleagues (e.g., Underwood, Humphreys, & Cross, 2007) argue for extrafoveal detection of object-scene inconsistencies, other work has failed to find such early effects of semantic inconsistency on eye movement control (e.g., Henderson, Williams, & Hollingworth, 1999; Gareze & Findlay, 2007). The study presented here extends previous work by using highly controlled 3D-rendered images of real-world scenes instead of line drawings or photographs, which are either less realistic or more difficult to control for bottom-up saliency. In addition, we directly compared the effects of both semantic and syntactic object-scene inconsistencies on eye movement control during scene viewing. We therefore introduced syntactic object-scene inconsistencies (i.e., floating objects) in addition to semantic inconsistencies to investigate the degree to which they attract attention during scene viewing. In Experi-

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ment 1 participants viewed scenes in preparation for a subsequent memory task, while in Experiment 2 participants were instructed to search for target objects. In neither experiment were we able to find evidence for extrafoveal detection of either type of inconsistency. However, upon fixation both semantically and syntactically inconsistent objects led to increased object processing as seen in elevated gaze durations and number of fixations. Interestingly, the semantic inconsistency effect was diminished for floating objects, which suggests an interaction of semantic and syntactic scene processing. This study is the first to provide evidence for the influence of syntactic in addition to semantic object-scene inconsistencies on eye movement behavior during real-world scene viewing.

URL: http://www.psy.ed.ac.uk/people/mvo/index_html

52.14, *11:45 am*

Where to look? Dissociating the effect of reward, salience and attention

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How do distinct sensory and economic attributes like salience and reward combine to guide where we look? Are saccadic decisions dominated by visual salience or reward? Can saccadic decisions, like purely economic decisions, fail to maximize expected reward? To study this, we designed a treasure hunt experiment in which subjects were presented with a brief display containing two targets (horizontal and vertical bar) differing in reward and salience, embedded among 6 tilted distractors. Subjects were instructed to maximize the treasure earned in 0.5 sec, by sequentially fixating on as many stimuli and earning their corresponding reward values. Across 28 blocks, we systematically varied target reward and salience values. We analyzed the first saccade by testing four different hypotheses: 1) the observer searches for the most rewarding item, 2) most salient item, 3) item with highest expected reward, 4) the observer saccades to the location of maximum expected reward. Data from 6 subjects shows that instead of searching for a predefined target, humans optimize reward trial-by-trial, by saccading to the location of maximum expected reward. These findings generalize to other feature dimensions like intensity The optimal model predicts, and we empirically validate in humans, that for low internal noise in stimulus representation, intermediate reward values increase the effective stimulus salience multiplicatively, suggesting an underlying neural mechanism of gain control.Attention has been postulated to operate through a gain control mechanism, which raises an interesting question: are the effects of reward mediated through attention? According to this hypothesis, the rewarding target's features receive greater attention, hence drawing more saccades. In a second experiment, we find that top-down attention to a stimulus feature makes the stimulus appear more salient, however, rewarding a stimulus does not alter its appearance or perceived salience. Thus, reward and attention interact with salience through distinct mechanisms.

52.15, *12:00 pm*

Two Views of the World: Active Vision, Attention, and Perception and Action Loops in Real-World Interaction

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We report new findings using a novel method that seeks to describe the visual learning environment from a young child's point of view. The method consists of a multi-camera sensing environment consisting of two head-mounted mini cameras that are placed on both the child's and the parent's foreheads respectively. Two video streams from two first-person views were recorded simultaneously and as well as their head and hand movements in the interaction. Computational and data mining techniques were applied to detect various objects in the two views, and then discover reliable visual and perceptual patterns from these simultaneous views. In addition, Itti's saliency map algorithm was also employed to find saliency areas/pixels in terms of motion, orientation and intensity. The main result is that the adult's and child's views are fundamentally different in (1) the spatial distributions of hands and everyday objects in the child's visual field and where they are in the parent's field; (2) the salience of individual objects and hands in those two visual fields; and (3) the temporal dynamic structures of objects and hands in two views. Moreover, by correlating visual information with body movement data, we also found that the dramatic difference in two views is largely due to head and hand movements of both the young child and their social partner. In a recent study, we also recorded momentary eye movements from the parent which allowed us to pair the parent's visual attention with the child's visual attention, and further analyze how they jointly attended to the same objects and how one person's visual attention is dynamically coupled with the other person's visual attention. These findings have broad implications for how one studies and thinks about the critical role of embodied active vision and selective attention in various cognitive learning tasks and developmental processes.

52.16, *12:15 pm*

Travel gaze? Re-examining gaze behavior during locomotion

Jeff Pelz[1] (pelz@cis.rit.edu), Jonathan Purington[1], Andrew Herbert[2]; [1]Carlson Center for Imaging Science, Rochester Institute of Technology, [2]Department of Psychology, Rochester Institute of Technology

In studies by Patla, Vickers, and colleagues [1997, 2003, 2007] a gaze behavior termed 'travel gaze' was reported during walking tasks: the observer's point-of-regard was directed to the floor a fixed distance in front of the observer and traveled at the same rate as the observer as s/he walked forward. This travel gaze (vs. a sequence of saccades and fixations) is surprising because stationary observers are typically unable to make smooth pursuit eye movements without a moving target, and the reported behavior is similar to smooth pursuit in the absence of a target. It was also surprising that the observers reportedly maintained their gaze on the floor; the majority of fixations were reported to fall only 1-2 steps in front of the observer.

We hypothesized that the "travel gaze" and fixations on the floor may have been artifacts of the instrumentation and/or the experimental setup. In the 2003 experiments, observers walked 10-m paths marked with 1) evenly spaced footprints, 2) unevenly spaced footprints, or 3) no markings. While the original experiments reported randomizing the order of presentation, there was no analysis of an order effect.

We replicated the 2003 study using a Positive Science wearable eyetracker. Three observers performed the even-, uneven-, and no-footprint conditions. In addition, they performed a no-footprint condition under low light to eliminate visible texture that might inhibit travel gaze, and a condition in which a richly-textured, high-contrast pattern was present providing fixation targets not associated with any goals.

We did not observe travel gaze episodes; when footprint targets were visible observers made clear fixations with intervening saccades. Without visible footprints, path fixations fell dramatically as gaze shifted away from the path.

Our belief is that the original reports were due to temporal averaging of small saccades and order effects of the visible markers.

52.17, *12:30 pm*

Monitoring CCTV and watching football: expert-novice differences in the magnitude of a visuo-motor buffer

Christina Howard[1] (Christina.Howard@bris.ac.uk), Iain Gilchrist[1], Tom Troscianko[1], Ardhendu Behera[2], David Hogg[2]; [1]Department of Experimental Psychology, University of Bristol, UK, [2]School of Computing, University of Leeds, UK

The presence of a visuo-motor buffer of around half a second to a second has been proposed to account for performance in real-world tasks such as motor racing (Land & Tatler, 2001), hitting the ball in cricket (Land & MacLeod, 2000), making tea (Land, Mennie & Rusted, 1999) and sandwiches (Hayhoe, 2000). In addition, the magnitude of this buffer appears to be constant across experts and novices (e.g. Land and Furneaux, 1997). To examine this issue, we investigated performance on two very different tasks, but using similar methods: monitoring closed-circuit television (E1) and monitoring a football (soccer) match (E2). We tracked eye movements in both tasks. Observers viewed either real CCTV footage from an urban environment, or a videotaped 5-a-side football match. A joystick was used to continuously indicate either the degree of perceived suspiciousness (E1) or the probability of an imminent goal (E2). We performed correlations between manual responses and the between-subjects variability in eye position (i.e. the degree of spread of fixations at each time). To calculate buffer magnitude, we repeated this at all possible temporal lags between these two measures and searched for the maximal negative correlation coefficient. In both experiments, and particularly for CCTV monitoring, we observed a greater lag for trained than untrained observers. Undergraduate observers' performance was consistent with previous findings of a buffer of around half a second, but trained CCTV operators' responses occurred, on average, over two seconds after eye positions started to converge. This cannot be explained purely from previous lag estimates and is suggestive of differences in processing between experts and novices in these tasks.

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URL: http://gow.epsrc.ac.uk/ViewGrant.aspx?GrantRef=EP/E010164/1

Motion: Encoding

Tuesday, May 12, 11:00 am – 12:45 pm
Talk Session, Royal Palm Ballroom 4-5
Moderator: Aaron Seitz

52.21, *11:00 am*

Paradoxical Improvement of Motion Perception Following Disruption of Cortical Area MT/V5

Duje Tadin[1] (duje@cvs.rochester.edu), Juha Silvanto[2,3], Alvaro Pascual-Leone[3], Lorella Battelli[3,4]; [1]Center for Visual Science, University of Rochester, [2]Department of Psychology, University of Essex, [3]Bereson-Allen Center for Noninvasive Brain Stimulation, Department of Neurology, Beth Israel Deaconess Medical Center, Harvard Medical School, [4]Center for Neuroscience and Cognitive Systems, Italian Institute of Technology

As stimulus size increases, motion direction of high-contrast patterns becomes increasingly harder to perceive. This counterintuitive result, termed "spatial suppression," is thought to reflect center-surround antagonism; a neural mechanism ubiquitous in sensory systems. Our aim is to directly test this hypothesis by investigating the causal involvement of MT/V5 in spatial suppression. Given that MT/V5 center-surround antagonism is not inherited from feedforward inputs, we hypothesize that suppressing MT/V5 using offline low-frequency TMS should interfere with center-surround inhibition, and thus weaken spatial suppression. Moreover, as the main behavioral marker of spatial suppression is poor direction discrimination of large stimuli, we expect that disruption of MT/V5 will paradoxically improve motion perception of such stimuli.

To measure spatial suppression, we presented small (1.2°) or large (8°) high-contrast gratings (1cycle/°, 4°/s) in either the right or the left visual field, and measured duration thresholds for direction discrimination. We applied 15min train of 1Hz TMS to either left MT/V5 or the left occipital site that elicited phosphenes overlapping with stimulus location. Results revealed a significant interaction ($p<0.05$) between stimulus location and TMS condition. Pairwise comparisons showed that spatial suppression was reduced in the visual field contralateral to the stimulation site following TMS over MT/V5 ($p=0.01$) but not after occipital TMS ($p=0.53$). No changes in performance were observed for ipsilaterally presented stimuli.

These results confirmed our hypothesis. Disruption of MT/V5 processing significantly reduced the strength of behaviorally measured spatial suppression, a finding mimicking abnormally weakened spatial suppression found in elderly, schizophrenics and depression patients. Furthermore, as hypothesized, this result was principally driven by improvements in motion discriminations of large stimuli after TMS over MT/V5 ($p=0.02$). This improved motion perception indicates that the critical neural constraints limiting motion perception of large stimuli likely involve MT/V5 and it suggests a causal link between MT/V5 and perceptually observed spatial suppression.

52.22, *11:15 am*

Reduction of the flash-lag effect with TMS over MT/V5

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In the flash-lag effect a moving object is seen ahead of a physically aligned flash. Little is known about the contribution of cortical areas to this illusion. We investigated whether disrupting neural activity in area MT/V5 with transcranial magnetic stimulation (TMS) impairs the perceptual forward shift of the moving object. First, we measured the flash-lag effect for each participant without TMS. Participants judged whether a bar moving leftward in the right visual field was to the 'left' or the 'right' of a flash appearing at variable time points in a fixed position next to the bar's trajectory. All participants mislocalized the bar in the direction of motion. In the TMS runs, the flash was presented before the bar reached the flash position, when about 70% of trials were judged as 'left'. In each trial, TMS pulses were applied to MT/V5 at asynchronies from 40 ms before to 140 ms after the bar reached the flash position. To control for unspecific TMS effects, V1 or Vertex were stimulated in separate runs. With stimulation of MT/V5 there were fewer 'left' responses than with Vertex stimulation, indicating a reduction of the moving bar's forward shift. This reduction was most pronounced when pulses occurred just as the bar reached the flash position, and approximately 60 ms afterwards. Our results demonstrate that area MT/V5 contributes to the perceptual localization of moving objects, and to the illusory forward shift in the flash-lag effect in particular.

52.23, *11:30 am*

The harmonic vector average route to global motion calculation

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An object translating at a constant velocity gives rise to a variable local velocity field. The speed of the normal component to image contours varies with the cosine of the angle between the normal and the global motion vector. Dense arrays of randomly oriented Gabor patches with speeds chosen to conform to a single global translation can appear to move coherently with the correct global velocity. The global motion could be calculated from the distribution of pairwise intersections of the set of possible velocities consistent with the local estimates - the intersection of constraints (IOC) strategy. However, for noisy local measures there are multiple solutions leading to combinatorial complexity and problems in distribution representation and peak finding that make this approach unattractive as a biological model. The alternative of fitting a circle through the origin of velocity space is also non-trivial. The vector sum clearly does not give the global velocity and the vector average provides a vector close to the correct direction but with half the speed of the global motion. From inversive geometry we learn that a circle through the origin inverted in the unit circle maps to a line. Thus inverse speed measurements fall on a line. The correct global speed, represented by the normal to this line and its inverse magnitude, can be recovered in closed form using a simple least squares formula. Also unlike the vector average the harmonic vector average (the reciprocal of the mean of the reciprocal speeds) provides an accurate estimate of the global speed given an unbiased sample of orientations and even for a biased sample (as in a type II array) will give a velocity estimate that lies on the circle in velocity space - a valid global motion given a limited sample of orientations.

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52.24, *11:45 am*

Forward and reversed signals in two-stroke apparent motion: psychophysical data and computational modeling

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See page 3 for Abstract Numbering System

Two-stroke motion (Mather, 2006) contains a repetitive two-frame oscillation of a spatial pattern with a brief inter-stimulus interval (ISI) inserted after every second frame transition (so the sequence is Frame1-Frame2-ISI-Frame1-Frame2-ISI-Frame1…). This creates an impression of continuous, unidirectional apparent motion. We developed a new multi-frame stimulus that allows direct comparisons between two psychophysical measures of two-stroke motion, namely direction discrimination and motion after-effect (MAE) duration. Our results show that direction discrimination and MAE duration have the same dependence on ISI duration, rapidly reaching a peak at an ISI of 30-40 msec and declining slowly at longer ISIs. To investigate whether two-stroke apparent motion can be explained by current computational theories of motion processing, we extended the original Adelson & Bergen (1985) motion energy model to incorporate recent developments, including half-squaring and divisive normalisation. The model correctly predicts the occurrence of two-stroke motion. The effect can be decomposed into two components, a 'forward' signal generated by the frame transition without an ISI (Frame1-Frame2), and a 'reverse' signal generated by the frame transition with an ISI (Frame2-ISI-Frame1). In a physically oscillating two-stroke display these two signals are in the same direction, resulting in a unidirectional motion response. At long ISIs the 'reverse' signal disappears from the model output, leaving only the 'forward' signal which is independent of ISI, thus explaining the ISI effect seen in the psychophysical data. The 'reverse' signal is strongest using filters with a biphasic temporal response, and this explains why the effect disappears at scotopic luminance (Mather & Challinor, 2008).

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52.25, *12:00 pm*

Reducing contrast improves direction estimation at low speeds

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Under low visual contrast conditions, sensitivity to stimulus features is generally thought to be reduced. However, a number of studies have revealed complex deviations from this intuitive view. For example, Tadin et al. (2003) showed that direction discrimination of large, briefly presented, drifting gratings improves as contrast is reduced, and they interpreted their results as a perceptual correlate of the contrast dependence of surround-suppressed neurons in the visual cortex (Pack et al., 2005; Polat et al., 1998; Sceniak et al., 1999). Contrast dependence has also been demonstrated in cortical neurons for speed tuning (Pack et al., 2005; Livingstone & Conway, 2007), but no clear psychophysical correlate of this result has been found. Here, we investigated the ability of human subjects to estimate the direction of moving dot fields at a variety of spatial and temporal displacements under both low and high contrasts, and compared these results to neural responses recorded from cortical area MT of alert macaque monkeys under similar conditions. We observed that the estimation of motion direction depended both on the stimulus contrast and on the amount of spatial displacement undergone by the stimulus dots on each monitor refresh. Surprisingly, subjects were better at determining the motion direction of stimuli with small displacements at low contrast than at high contrast. For larger displacements this effect reversed. This result was mirrored in the activity of MT neurons. Additional experiments replicated the above interaction between contrast and spatial displacement for a variety of conditions, including those in which the mean luminance was matched between both contrast conditions. These data link contrast-adaptive responses in area MT with behavioral performance, and demonstrate that higher contrast is not better for motion direction processing at low speeds.

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52.26, *12:15 pm*

Motion-grouping deficits in both eyes of patients with strabismic amblyopia

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Grouping in the Lorenceau and Shiffrar occluded diamond illusion depends on stimulus factors such as the presence or absence of an occluder and the configuration of the moving elements (Lorenceau and Alais, Nature Neuroscience, 2001). The occluded diamond stimulus is bistable even when the occluder and inducer configurations are favorable --- the moving elements can either appear to move independently or they can group together. We used this property of the illusion to study form-contingent motion grouping in patients with strabismus. We measured the relative proportion of time that 11 normal vision observers reported coherent versus independent (incoherent) motion of the elements and compared this to the same proportions in a group of 8 patients with mild to moderate strabismic amblyopia (20/25 to 20/63). Each eye was tested. Two different pairs of oscillation frequencies were tested, a faster pair (2.0 and 3.6 Hz) and a slower pair (1.5 and 2.0 Hz) because we had noted in pilot testing that coherence is easier to obtain at slower speeds. Choices were indicated via button presses during trials that lasted 17.5 sec for the faster pair and 14 sec for slower pair of oscillation frequencies. The proportion of coherent vs incoherent reports was larger at the slower speed in all eyes tested. Of greater interest is that the proportion of coherent vs incoherent reports was higher for normals than for either eye of the patients at both speeds. The normal acuity fellow eyes of the strabismus patients had the same durations of coherence as did the amblyopic eyes and therefore the decreased grouping is not due to amblyopia, per se. The presence of grouping failures in both eyes of the patients suggests that normal binocular experience is necessary for complete development of mechanisms that integrate form and motion information for scene layout.

Acknowledgement: Supported by EY015790

52.27, *12:30 pm*

Reverse correlation reveals the limits of observers' ability to solve the aperture problem in translating natural scenes

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Natural scenes contain areas of high and low local orientation variance corresponding to texture and edges, respectively. While direction selective neurons in V1 are well suited to signalling the motion of edges, the motion signals arising from such regions will be ambiguous due to the aperture problem. In contrast, high variance textured regions will drive V1 neurons poorly, but can be used unambiguously to determine direction. Here we used a novel reverse correlation paradigm to determine whether contour- or texture-defined structure determines the perceived global direction of natural scenes. Subjects indicated the absolute direction of a translating natural scene, viewed through a series of randomly positioned static apertures, allowing us to relate, on a trial-by-trial basis, subjects' performance (bias and precision) to the statistical properties of the exposed image. We report that edges provide the most reliable direction signal when they are oriented parallel or orthogonal to the direction of motion (unbiased performance, ~20% better precision than that for texture). In contrast edges oriented oblique to the direction of motion lead to precision ~20% worse than for textures and typically bias observers towards reporting directions orthogonal to the edge-orientation. Differences in bias across subjects suggest that they pursue a stable but individual response strategy in the face of high uncertainty. Finally, all the effects noted (including the classic oblique effect), are invariant to random image rotations; thus effects are the result of the observers' interpretation of the scene, rather than being stimulus-dependant. In summary (compared to performance with texture) edges produce both the best and the worse performance, indicating vulnerability of our observers to the aperture problem under the conditions tested and

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that observers are equally able to use the orientations orthogonal or parallel to the direction of motion in judging the direction of complex natural scenes.

Acknowledgement: This work was funded by the Welcome Trust

Object Recognition: Objects and Visual features

Tuesday, May 12, 8:30 am – 12:30 pm
Poster Session, Royal Palm Ballroom 6-8

53.301

Object identification in scene background of different spatial frequencies

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Observers could categorize objects in natural scenes in 30 ms (Schyns & Oliva, 1994, Psychological Science). Yet, Davenport and Potter (2004, Psychological Science) had found that participants were more accurate in identifying objects without scene background than with background after viewing the scenes for 80 ms. We postulated that such discrepancy might be a result of a difference in the spatial frequency content of the background image. We investigated how object identification performance changed with spatial frequency spectrum of the image and viewing time.

Photos of 24 possible target objects were presented either alone or on one of 13 possible background of natural scenes. The targets and the background were thematically consistent. The spatial frequency of objects and scene backgrounds were processed by either low-pass or high-pass filters with six different cutoff frequencies (1, 3, 5, 7, 9, and 11cpd). The viewing duration was either 36 ms, 100 ms or until response. The task of the observer was to name the target object. The identification accuracy increased with information content in all background and viewing durations. The presence of scene background decreased the identification accuracy for all cut-off spatial frequencies with short viewing durations but increased accuracy for low cut-off frequencies with long viewing durations. This result is consistent with the hypothesis that the background effect on target identification is influenced by the richness of information in the images.

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53.302

Effects of spatial frequency bands on perceptual decision: it is not the stimuli but the comparison

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Are there optimal spatial frequencies for different perceptual decisions? We had observers perform 3 between- and 2 within-category perceptual decisions with hybrid stimuli comprising low and high SF images. Responses were to one SF band and the information carried by the other SF could be congruent (same category), incongruent (opposing category) or neutral to the response (either noise or a task-irrelevant stimulus category). Processing efficiency for the different SF bands varied across tasks, with house-flower, face-house and expression-valence decisions more efficient when based on high SF components, while flower-face and gender categorizations were more efficient when based on low SF components. In addition, there was asymmetrical interference from the more efficient SF components onto decisions based on the less efficient components. Strikingly, we also demonstrated that SF efficiency responses for identical hybrid stimuli were affected by the task context rather than the stimuli components. These results demonstrate that perceptual decisions are affected by an interaction between task and SF range; and that differences between task relevant categories determine the efficiency of one SF range for a given task. An exploration of the stimuli statistics aimed to reveal potential diagnostic attributes suggested that performance in the between-category tasks were associated with differences in orientations and overall energy levels at each SF band, while performance in within-category discriminations were associated with the number of visual features in each SF band. We conclude that the diagnostic values of each SF range can be associated to low level differences in visual features, and the larger these differences are the more efficient the perceptual decision.

53.303

Magno- and Parvo-Pathway Contributions to Masked Priming by Form: Effects of Contrast and Wavelength

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Masked response priming relies on the influence of nonconsciously processed information on the response to a visible probe stimulus. The question we address is to what extents the magno- (M) and parvo- (P) cellular pathways contribute to masked priming by form. To address this issue, we exploited the facts that 1) M contrast sensitivity is higher at low contrasts and saturates at contrasts of 0.2-0.3, while P contrast sensitivity increases monotonically up to 1.0; and 2) long-wavelength backgrounds suppress the M response. We used a metacontrast paradigm to render the target, acting as the prime, invisible, while the following mask served as the probe. Choice reaction times to the shape of the probe, whose form could either be congruent or incongruent relative to that of the prime, were used to assess priming effects. In Experiment 1, using dark on white stimuli, we varied the contrast of the prime from 0.05 to 1.0, while the mask's contrast was set at 1.0. In Experiment 2, for the same contrasts, prime and probe stimuli consisted of luminance increments on either equiluminant red or green backgrounds. Our results showed 1) that the strength of the priming effect was a nonmonotonic function of prime contrast, however, in a direction opposite to that predicted by M-pathway contribution and 2) that wavelength had no overall effect on priming effects. Although the M pathway has been implicated in nonconscious processing of visual information, our results indicate that it does not contribute to the nonconscious priming by form.

53.304

Examining the coding of colour-motion conjunctions in human visual cortex using pattern classifiers

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Colour and motion serve as the prime examples of segregated processing in the visual brain, giving rise to the question how conjunctions of these features are represented. This problem has been termed the 'binding problem'. Human volunteers viewed visual displays containing coloured dots rotating around a central fixation cross. The dots could be red or green, and rotate clockwise or counter-clockwise, leading to four possible stimulus displays. Superimposed pairs of such stimuli provided two additional displays, each containing both colours and both directions of motion, but differing exclusively in their feature-conjunctions. We used fMRI and multivariate classifier analysis to examine voxel activation patterns obtained whilst subjects viewed such displays. Our analyses confirm the presence of directionally specific motion information across visual cortex and also provide evidence of spatially structured hue representations in all early visual areas except V5/MT+. Within each cortical area, the most informative voxels coding for colour and for motion appeared to be spatially separate and to exhibit a high degree of invariance to changes in a corresponding secondary feature. Notably, our results also demonstrate the explicit representation of feature conjunctions in primary visual cortex and beyond. The results show that conjunctions can be decoded from spatial activation patterns already in V1, indicating an explicit coding of conjunctions at early stages of visual processing. Our findings raise the possibility that the solution of what has been taken as the prime example of the binding problem engages neural mechanisms as early as V1.

53.305

Binding object identity and orientation in brief displays

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Corballis (1988) speculated that recognition of rotated shapes could occur on the basis of viewpoint-invariant information, while viewpoint-dependent information may be used to double check the initial identification and determine the orientation of the object in space. Recent experiments using rapid serial visual presentation (RSVP) support this idea. Harris and Dux (2005) and Corballis and Armstrong (2007) have shown that processing of object identity, as indexed by repetition blindness, is largely orientation-invariant, but that object orientation is also extracted rapidly and can modulate the ease with which objects are individuated. The findings of these RSVP studies suggest that object identity and orientation are initially processed independently, but are then bound together into a conscious percept. In the present study, participants viewed short RSVP streams consisting of two line drawings of familiar objects, presented sequentially for 70 ms each in different orientations (all possible pairs of 90, 180 and 270 deg), which were preceded and followed by pattern masks. Before each trial, participants were cued with an object and had to decide whether that object was present on the trial and then report its orientation. The results indicate that object identity was extracted more reliably than object orientation and that correct judgement of object orientation was contingent on correct identification of the object. The more interesting observation is that when participants gave an incorrect orientation response, they were significantly more likely to report the orientation of the other object presented on that trial than an orientation that was not present. Thus, it appears that object identity is determined independently of orientation and that establishing the object's orientation is a later process that can be prone to incorrect conjunctions between the features of competing objects.

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53.306

The effect of transparency on recognition of overlapping objects

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How does transparency of overlapping objects affect object recognition? Two studies are presented that compares recognition of overlapping transparent objects to recognition of overlapping, non-transparent objects. The first study gauges the minimum time a picture of two overlapping objects must be presented in order to identify both objects correctly. The second study looks for differences in gaze patterns while inspecting the same kind of pictures presented for unlimited time. Recognition of objects rich in detail helpful for identifying the objects are compared to recognition of objects with many fewer identity-relevant details. Results have implications about how objects in a scene are segregated when relative depth is or is not apparent.

53.307

Disrupting Surface Features Disrupts Established Object Representations

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A recent study using the object-reviewing paradigm of Kahneman, Treisman, and Gibbs (1992) found that although spatiotemporal continuity consistently yielded object-specific preview benefits, surface features including color, luminance, topology, size, and contrast polarity, even in combination, did not (Mitroff & Alvarez, 2007). This finding is consistent with the hypothesis that spatiotemporal continuity plays a prioritized role in the establishment and maintenance of persisting object representations (Scholl, 2007). Using the same object-reviewing procedure as Mitroff and Alvarez, we found that introducing abrupt changes to surface features (e.g., color) during the motion trajectory eliminated the object-specific preview benefit. In contrast, making the object disappear for three frames of motion (approximately 40 ms), a manipulation that was at least as disruptive to the spatiotemporal continuity of the motion trajectory as was the surface-feature change, did not eliminate the object-specific preview benefit. Assuming that object-specific preview benefits reflect a good operationalization of object representations, the following conclusion can be drawn: Although surface features may be insufficient to establish object representations without supporting spatiotemporal continuity, they do play a role in the maintenance and updating of established object representations.

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53.308

Using Surface Features to Disambiguate What Went Where in the Perception of Causality

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It has been hypothesized that the representation of object persistence is determined entirely on the basis of spatiotemporal continuity, and that surface features play no role in this aspect of representing objects as persisting over time and space (e.g., Scholl, 2007). A recent phenomenon reported by Scholl and Nakayama (2002) in the context of studying the perception of causality is consistent with this hypothesis. A red disc, for example, moves across the screen and completely overlaps a second stationary green disc. A green disc then continues on while a red stationary disc remains at the point of overlap. Participants tend to perceive a single moving disc, passing over a stationary disc, regardless of the color change that this percept implies. A natural alternative perception might be that the red disc "launches" the green disc into motion. Here we show that this "passing" perception is stronger when the two discs are identical in color than when they are differently colored. If surface features were irrelevant in determining what went where in this example of passing rather than causal launching, the effect should have been unaffected by this manipulation. We suggest that although spatiotemporal continuity may play a primary role in determining object persistence, surface features play a role as well.

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53.309

Canonical Visual Sizes for Real World Objects

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Real-world objects vary in their physical size and can be viewed from a range of distances, thus they can subtend a range of angles in the visual field. Akin to studies on canonical viewpoint, we present a series of studies supporting the existence of a canonical visual size for objects using subjective norming, mental imagery, and reconstructive memory paradigms. In Experiment 1, observers resized images of 100 real-world objects and selected the best visual size to see each object. Observers were consistent in their responses, preferring visual sizes that were proportional to the log of the physical size of the objects in the world. When a different set of observers were told the images were pictures of toys, the selected visual sizes were smaller on the screen, implying that the conceived physical size of the object influences the preferred visual size, independent of information content in the stimulus. In Experiment 2, observers imagined real-world objects on the computer monitor. The visual sizes of imagined objects also scaled with the log physical size of the real-world object and matched the visual sizes found in Experiment 1. In Experiment 3, we examined the reconstruction of objects from memory using a drawing paradigm. To understand the impact of the frame of space around the object, three different paper sizes were employed. The drawn objects scaled with the paper size, such that the ratio of the object within the frame was equivalent across all three experiments and all paper sizes. These results demonstrate that conceptual knowledge about the physical size of objects in the world influences the visual size at which objects are preferentially viewed, imagined, and reconstructed.

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53.310

Examining object representation via object memory: exemplar and state-level object properties are supported by the same underlying features

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The properties of any given image of a real-world object (e.g., a phone) are determined both by the particular exemplar of the category it represents, and by which state or pose the exemplar is in. For example, there are many different kinds of phones (exemplar-level information) and any given phone can be on or off the hook (state-level information).

Here, we use an object memory paradigm to examine the separability of these object properties in memory. If object properties can be encoded or decay independently, then we can infer that different high-level features underlie their representations.

12 observers were shown 120 briefly presented objects, and judged the physical size of the objects. Following this task, we gave observers a surprise memory test. To probe which properties of each object were incidentally encoded, a 4-alternative forced choice test display was presented for each object, consisting of two exemplars (one familiar, one novel), each in two states (one familiar, one novel). By modeling these data, we examined how often people remembered only the exemplar-level information or only state-level information.

Using both goodness of fit measures and Bayesian model selection, we examined whether the data were better fit by a model in which these kinds of information were represented independently or together.

Both methods support a model in which these two types of object information are bound together, suggesting that memory for both exemplar- and state-level object properties is supported by the same underlying high-level visual features.

Thus, as both visual long-term memory and object recognition depend on the same high-level object representation, memory errors can usefully inform models of object recognition by elucidating the underlying object representation.

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53.311

Averaging independent estimates improves pattern recognition

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Vul and Pashler (2008) reported that the average of two guesses from the same observer was more accurate when guesses were made weeks apart versus when they were made in immediate succession. As these results suggest that an observer's guesses become more independent with a greater delay, we wondered whether the same may be true for multiple samples of a visual percept. To this end, we investigated whether averaging multiple glances improves pattern recognition. In an n-back paradigm, observers estimated the density of a briefly presented texture display, which repeated one-, two-, three-, four-, or at a random number of trials after its initial presentation. To measure the degree of dependence within response pairs, we computed the average of two density judgments of the same display as a function of the number of intervening trials. Overall, the average of two judgments of the same stimulus became more accurate as judgments occurred farther apart in time, indicating that multiple perceptual samples of a pattern become more independent, and thus more useful, with greater intervening delay. Given that participants were not asked to explicitly report whether a display was repeated, but only to report the perceived density of the pattern on each trial, and generally reported not noticing that displays repeated when questioned after the experiment, this paradigm may provide a new, implicit measure of visual short term-memory decay.

53.312

How is quantity bound to specific objects?

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At an early stage of perception, simple features of the scenery such as colors or shapes are processed separately. Each feature processing (e.g.: color) can be performed independently from the processing of other features (e.g.: shape), (e.g., Treisman & Gelade, 1980; Treisman & Schmidt,1982). Numbers or quantities also appear in all kinds of natural scenes and potentially can be perceived as such. A scene that contains for example 2 cups and 4 plates can theoretically activate in the observer's brain the quantities "2" and "4". In contrast to other features such as colors or shapes, the information "2" and "4" depends partly on the processing of other features (e.g.: if we fail to distinguish between the shape of a plate and the shape of a cup, we are also unlikely to perceive the quantity "2" or "4"). Does this make the processing of feature quantity special?

To address this question we performed fMRI experiments using the adaptation technique and examined three hypotheses concerning the way feature quantity is represented. Hypothesis-1: simple features are processed separately. Accordingly, only the number area identifies the specific quantity of each feature (e.g.: the number area is activated by the appearance of the quantities "2" and "4"). Hypothesis-2: the specific feature area identifies also the quantity of each feature; since no other area needs to be sensitive to the specific quantity of each feature, the number area is not sensitive to this kind of information. It identifies only the overall number of objects. Hypothesis-3: feature quantity is unique- it is represented twice: once in the number area and once in the specific feature area.

The results from the current fMRI study in which participants adapted to different numbers of letters (Experiment 1) and of faces (Experiment 2) best fit this last interesting hypothesis.

53.313

The Pervasive Influence of Position on Object Processing: From Brain to Behavior

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Despite behavioral evidence suggesting that object recognition is position invariant (e.g. Biederman and Cooper, 1991), recent studies in humans and non-human primates have reported strong effects of position in anterior regions of the ventral visual pathway thought to be critical for object recognition. Here we show, both behaviorally and with fMRI, that object representations are tied to limited ranges of retinotopic positions.

In an event-related fMRI paradigm we presented 24 line drawings (5° from fixation) in each of the four quadrants (for a total of 96 stimulus conditions) while participants performed an orthogonal color-matching task. In separate runs, we localized two ventral stream regions thought to be critical for object recognition, Lateral Occipital (LO) and Posterior Fusiform Sulcus (PFs). We then used multivariate pattern analysis to establish the similarity of response between each pair of conditions.

Position was the primary determinant of the spatial pattern of response in both regions, with patterns always more similar within a position than between positions. These profound effects of position were also present in category selective regions for the preferred category (e.g. faces in FFA). Consistent with physiology, effects of position changes were strongest between hemifields and there was a bias for contralateral stimuli. Further, LO showed a bias for lower field stimuli, while PFs showed a bias for the upper field, consistent with their anatomical proximity to the upper and lower field representations in early visual cortex. The position effects were largely impervious to task with the same participants showing the same effects of position when scanned a second time with a categorization task.

Our behavioral results mirrored our imaging findings with greatly reduced object priming with shifts in position, particularly shifts between hemifields. We conclude that even high-level visual object representations are position-dependent.

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53.314

At What Stage in the Human Ventral Pathway is the Greater Sensitivity to Nonaccidental over Metric Properties First Manifested?

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Non-accidental shape properties (NAPs) are those that are invariant under rotation in depth, such as whether a contour is straight or curved. Metric properties (MPs), such as the degree of curvature of a contour, can vary continuously with depth rotation. NAPs allow facile recognition when an object is viewed at an orientation not previously experienced. At what stage in the ventral pathway is the greater sensitivity to NAPs over MPs first manifested? In a single block, subjects viewed five brief animations of single geons that either cycled (through 8 frames/animation) between a NAP or an MP change or a Rotation in depth (around both the X and Y axis). For example, a NAP animation could be a cylinder with an axis cycling between being slightly curved to straight. The MP animation could be the slightly curved axis cycling with a more curved axis. Pixel energy changes were equated for the three kinds of animations. Subjects were to detect, by key press, whether there was a repeat of an animation within a block. BOLD signals were consistently and reliably greater for NAP than MP differences in LOC (both in LO and pFs) with Rotation magnitudes falling, on average, in between those of the NAP and MP conditions (in pFs). These effects were not apparent in earlier cortical stages, e.g., V1. Insofar as macaque IT cells show a greater modulation of NAP over MP differences, these results support the interpretation that human LOC is a functional homologue to macaque IT.

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53.315

Integral versus separable perceptual dimensional pairs are reflected in conjoint versus independent neural populations

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Some visual properties of shapes are apprehended separately, others as a composite; these are termed separable and integral dimensions. We hypothesize that integral dimensions are represented by populations of neurons representing dimensions conjointly, while separable dimensions are represented by independent populations.

Using a carry-over fMRI design (Aguirre, 2007) we measured recovery from neural adaptation associated with shape changes along a single perceptual dimension or combined across two. Changes along both dimensions produce recovery from adaptation that is the sum of the recovery for each dimension in the case of separate representation, but is subadditive in the conjoint case. We studied two sets of shapes that varied along two parameterized dimensions. For a set of ineffable "popcorn" shapes, the two dimensions were behaviorally integral; while for "lens" shapes the dimensions of curvature and thickness were separable (replicating Op-de-Beeck, et al. 2001, 2003).

Five participants were studied using fMRI while they viewed a continuous stream of these shapes. Two covariates modeled linear recovery from adaptation proportional to shape changes within the two stimulus spaces. We identified voxels in ventral temporal cortex in each subject that demonstrated a linear recovery from adaptation along both of the "popcorn" dimensions and both of the "lens" dimensions. A "Euclidean Contraction" covariate modeled variance attributable to sub-additive recovery from adaptation for combined changes in the shape space. The "lens" shape space had substantially reduced loading upon this covariate as compared to the "popcorn", indicating that the shape space defined by behaviorally separable dimensions was associated with a more "feature" based neural representation within ventral extrastriate cortex. This suggests that integral and separable dimensions are represented by neural populations which differ in their tuning for stimulus properties. More generally, this approach may be used to characterize tuning of neural populations for stimulus features using fMRI.

Binocular Vision: Rivalry and Bistability

Tuesday, May 12, 8:30 am – 12:30 pm
Poster Session, Royal Palm Ballroom 6-8

53.316

Binocular Combination in Anisometropic Amblyopia

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Using a suprathreshold binocular summation paradigm developed by Ding and Sperling (2006, 2007) for normal observers, we investigated suprathreshold cyclopean perception in anisometropic amblyopia. In this paradigm, two suprathreshold sinewave gratings of the same spatial frequency but different spatial phases are presented to the left and right eyes of the observer. The perceived phase of the binocularly-combined cyclopean image is measured as a function of the contrast ratio between the two eyes. Contrast sensitivity functions were also measured. We found that both eyes contributed equally in normal subjects. However, stimulus of equal contrast was weighted much less in the amblyopic eye relative to the fellow eye in binocular combination. For the Five amblyopes, the effective contrast of the amblyopic eye in binocular combination is equal to about 11%-28% of the same contrast presented to the fellow eye, much less than the ratio of contrast sensitivity between the two eyes (0.73 - 1.42). A modified Ding-Sperling contrast-gain control model yielded very good accounts of all the data. The results from the current study have many important implications in amblyopia research and treatment.

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53.317

Effects of mask-to-target energy ratio on cyclopean metacontrast masking

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In metacontrast masking, perception of a brief stimulus (the target) is reduced or eliminated under some conditions by a second, non-overlapping brief stimulus (the mask). In Type-A masking, target visibility is low when mask and target onset simultaneously (stimulus onset asynchrony [SOA] is 0) and improves as SOA increases. Type-B masking is a u-shaped function of SOA. Target visibility is poor at intermediate SOAs (50-150 ms) but good at shorter and longer SOAs. Mask-to-target energy ratio (M/T) can often determine which type of masking will occur. Type-A masking occurs when the mask is stronger (i.e. larger, greater contrast, or longer duration) than the target (M/T>1). Type-B masking occurs when M/T≤1. Type-B metacontrast has been reported in monocular, binocular, and dichoptic viewing conditions. In cyclopean conditions only Type-A metacontrast has been observed until recently (Krueger, Dobelbower & Phinney, Society for Neuroscience, 2006). We varied mask duration, holding target duration constant, to determine the effect of M/T on metacontrast with cyclopean stimuli. Stimuli were dynamic random dot, red-green anaglyphs (320x240 pixels, 50% density) viewed with red-green glasses. Observers viewed a three-target array (3x9° horizontal bars) and judged which display quadrant lacked a target (4 AFC) with SOAs of 0 to 800 ms for mask onset (8 bars vertically flanking the 4 target positions). Type-B masking functions were observed when the masks were shorter than or equal to target duration (16, 50, and 83 ms mask duration [MT≤ 1]), or slightly longer (150 and183

Tuesday Sessions

ms). Type-A masking functions were observed when the masks were of much longer duration (316 ms). These results are similar to those in masking with luminance stimuli where Type-B masking occurs with M/T near 1, and Type-A masking with M/T greater than 1. They may also explain past failures to demonstrate Type-B masking with cyclopean stimuli, which typically involved M/T>1.

53.318

Visual processes selective to both color and orientation contribute to the determination of perceptual dominance of rivalrous chromatic gratings

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The present study investigated whether visual processes sensitive to the combination of color and orientation contribute to the determination of dominance/suppression of dichoptically-presented chromatic gratings by using visibility modulation of rivalrous stimuli. Visibility modulation (VM) refers to the phenomenon in which the visibility of rivalrous stimuli can be affected by presenting a preceding stimulus. In Experiment 1, the test stimulus was fixed as green/black right-tilted vs. red/black left-tilted gratings and how color and orientation were combined in the binocular preceding stimulus was manipulated. The results showed that, when the preceding stimulus was identical to one of the test stimulus, a stimulus-based VM was observed; i.e., the test stimulus of different attributes from the preceding stimulus became dominant. In contrast, little effect was found when the preceding stimulus consisted of the combination of color from one of the test stimulus and orientation from the other. These findings suggested the contribution of color-orientation selective processes, but they could also be interpreted by an alternative hypothesis that the preceding color and orientation separately affected the dominance of rivalrous stimuli and that the effect of the preceding color was counterbalanced by that of the preceding orientation when color and orientation were combined differently. To test this hypothesis, the effects of an achromatic preceding grating were investigated in Experiment 2 with two types of rivalrous gratings; one was the same red-green gratings as in Experiment 1 and the other was isochromatic orthogonal gratings (e.g., green/black right-tilted vs. green/black left-tilted gratings). The results showed that an orientation-based VM found with isochromatic rivalrous gratings was attenuated when red-green rivalrous gratings were used and thus color and orientation competitions coexisted. Overall, the present findings suggest that the dominance/suppression of rivalrous chromatic gratings is at least partly determined by visual processes which respond selectively to both color and orientation.

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53.319

Does color misbind to achromatic regions or chromatically similar regions?

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PURPOSE: Misbinding of color occurs when the neural representation of color from a suppressed form is expressed within some region of the dominant form. In previous work, misbinding of color always was perceived within achromatic (gray) regions of the dominant form (Hong & Shevell, 2006). Misbinding of perceived gray into red or green regions never was seen. Are colors (e.g. red and green) misbound only to achromatic regions that represent the absence of color (achromatic hypothesis), or instead to regions with a stimulus chromaticity most similar to the misbound color (similarity hypothesis)?

METHOD: For 60 seconds, an equiluminant 2 cpd square-wave vertical grating was presented to one eye and a tooth-shaped vertical grating (top half of grating phase-shifted by one-half cycle relative to bottom half) to the other eye. Conditions included (A) a red/gray grating in one eye and green/gray grating in other eye (as in previous work) or (B) a red/orange grating in one eye and green/orange grating in the other eye. Measurements were made of the amount of time with the percept of one eye's stimulus alone (dominance), and with a two-color-grating percept with color misbinding seen in an achromatic stimulus region (e.g. green misbound to gray stimulus region in A), or in a chromatic stimulus region (e.g. green misbound to an orange stimulus region in B).

RESULTS & CONCLUSIONS: Misbinding was perceived within both achromatic regions and within chromatic orange regions. Further, with red/orange and green/orange rivalrous gratings, red more often than green was misbound to an orange region. This is consistent with the similarity hypothesis. However, misbinding of perceived orange into red or green regions, to form a uniform orange field, never was seen; one possible explanation is that the edge structure must be preserved after misbinding of color to form.

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53.320

Dissociation between Figure and Ground During Binocular Rivalry

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Binocular rivalry has been explained alternatively in terms of local inhibition between monocular cells (eye rivalry) or in terms of higher-level integration of stimulus features (stimulus rivalry). We used dichoptic displays consisting of clear figure and ground regions that were each composed of conflicting versions across the two eyes (e.g., a red-horizontal figure on a green-vertical ground in one eye and a green-vertical figure on a red-horizontal ground in the other eye). In some blocks, observers reported on the dominance of a given version of the figure. In other blocks, they reported on the dominance of a given version of the ground. Reports indicated that the figure appeared to oscillate between views at a faster rate than the ground. This dissociation conflicts with the eye-rivalry account of binocular rivalry. Under that hypothesis, the images should have oscillated in their entirety such that one of the original images would dominate at any given time, and figure and ground would therefore oscillate together. In contrast, the results are consistent with a stimulus-rivalry account. Under that hypothesis, different components of the scene compete for dominance, and rivalry can therefore reflect the organization of the scene, as asynchronous rivalry for figure and ground does. We speculate that binocular rivalry reflects an object-based processes that act on perceptually organized representations of the retinal image.

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53.321

Binocular rivalry between a sharp image and a low-pass filtered version of itself: Low-pass dominance increases with eccentricity

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Purpose. New corrective techniques ("monovision") for presbyopia correct one eye for near vision and the other for distance vision, creating two different focal distances. Our aim is to investigate relative dominance between a sharp (S) image in one eye and a blurred (B) version of S in the companion eye, mimicking monovision. Casual long observations (>8s) under steady fixation reveal that B's dominance increases as eccentricity increases.

Methods. We tested possible binocular rivalry as a function of eccentricity E using two paradigms: (1) We rendered the grey-level images S and B in red-black and green-black (counterbalancing color and spatial frequency content across trials). Observers reported the color of a circular patch at various eccentricities. This effectively indicated the relative dominance of S and B because of the correlation of color and spatial frequency content in the stimuli. (2) Using grey-level images for both eyes, observers detected a probe presented with equal probability to either S or B at various eccen-

tricities. Their performance indicated the relative dominance of S and B, because probes are harder to detect on suppressed images and thresholds increase.

Results. As a rule, S dominated B almost exclusively in the fovea (>80%). Paradigm (1): As E increased, the probability of reporting the color of B increased. Paradigm (2): As E increased, it became significantly more difficult to detect the probe on the S image, whereas detectability did not change significantly with E for the B image.

Conclusions. The results in both paradigms are consistent with the following pattern of dominance: The dominance of S and B decreases and increases, respectively, with increasing E. We normally have the illusion of a sharp focused image throughout the visual field. S/B binocular stimulation is a rare case where we are made aware of the low-frequency dominance in the periphery.

53.322

Interaction between crowding and binocular rivalry

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Both crowding and binocular rivalry impede the perception of target stimuli. In our pilot experiment, we first measured the decrement of Landolt C's orientation discrimination performance due to crowding at 8 difference locations. We then measured the amount of decrement from interocular suppression using the same task and in the same locations. We found positive correlation between the two measurements, suggesting that binocular rivalry and crowding are related to each other. In this study, we investigated the nature of this interaction between crowding and binocular rivalry. Specifically, we tested whether the depth of binocular rivalry suppression was increased by surrounding distractors. Participant's task was to decide whether a vertical grating (target) was tilted towards clockwise or anticlockwise. In the crowding-only condition, a vertical grating (target) with five different orientations was presented in a dominant eye and we measured proportion of clockwise responses at these five different orientations. After fitting a cumulative Gaussian function to these data, we measured orientation discrimination thresholds and they were served as baseline. When four vertical gratings were additionally presented around the target, orientation discrimination thresholds were increased. However, the additional presentation of four horizontal gratings did not make any difference. In the binocular rivalry condition, we also presented a horizontal grating to the corresponding location of the target in a non-dominant eye. When vertical distractors surrounded the target, the orientation discrimination thresholds were increased regardless of the positions of distractors (dominant or non-dominant eye). This increment of thresholds was more than increment due to crowding only. However, the orientation discrimination thresholds were not increased regardless of the positions of distractors when horizontal distractors surrounded the target. These results suggest that crowding deepens the depth of suppression due to binocular rivalry.

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53.323

On Boundary Contour and Center-Surround Factors in Binocular Rivalry

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Boundary contour information that defines surface regions can affect binocular rivalry (BR). A vertical grating disc surrounded by a horizontal grating half-image competing with a horizontal grating half-image leads to a high predominance for seeing the disc. This is attributable to either the monocular boundary contour (MBC) defining the disc, or the feature difference (vertical vs. horizontal) between the center (disc) and surround regions. Experiment-1 investigated this by measuring contrast threshold of a Gabor probe in three conditions with variously specified MBC. (1) MBC-condition: one half-image had a vertical MBC disc (1.5deg) created by a 90deg phase-shift relative to the surrounding vertical grating and the other half-image had a homogeneous vertical grating (2.2cpd, 1.5log%, 60cd/m2). (2) Ring-condition: a white ring (121.2cd/m2, 0.045deg thick), instead of the phase-shift, defined the MBC. (3) MBC+Ring condition: the same white ring encircled the phase-shifted disc. For all three conditions we found thresholds were lower on the half-image with the MBC than on the homogeneous grating half-image, indicating binocular suppression. Critically, since the Ring-condition carries only MBC, this suggests that MBC alone can lead to dominance. Experiment-2 measured BR predominance of a vertical grating disc surrounded by horizontal grating in one half-image and a horizontal grating disk created by phase-shifting it relative to the surrounding horizontal grating in the other half-image. Confirming our previous findings (Xu et al, 2006), the predominance for seeing the horizontal grating disc increased with increasing phase-shift that strengthened the boundary contour of the horizontal disc and enhanced the center-surround difference. We then added a white ring (35 cd/m2, 0.04deg thick) to encircle the phase-shifted horizontal disc. We found that with the ring, the predominance for seeing the horizontal grating remained unchanged with increasing phase-shift. This suggests that the center-surround factor contributes less to BR than the boundary contour factor.

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53.324

Saliency in a perceptually suppressed image determines the spatial origin of a perceptual alternation during binocular rivalry

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When dissimilar images are presented to corresponding retinal locations, perception will alternate between the two. This phenomenon is called binocular rivalry. Perceptual alternations during binocular rivalry will typically start at isolated locations and continue in gradual, wave-like fashion termed 'traveling waves of perceptual dominance'.

Recently, Paffen, Naber and Verstraten (2008) showed that local stimulus features influence the starting point of a traveling wave. It was suggested that perceptual alternations start at the location where saliency of the suppressed image is higher than that of the dominant one. Here we investigate this suggestion.

Two images containing 81 Gabors aligned on a grid were presented dichoptically. One of the images contained vertically oriented Gabors (the suppressor); the other image obliquely oriented Gabors (the target). In order to vary local saliency, one of the Gabors in the target image contained an orientation orthogonal to its neighbors in 50% of the trials. At the start of a trial, the suppressor was presented at full contrast, while the contrast of the target was gradually increased from 0 to 100% contrast. The task of the observer was to click a mouse button as soon as the target became visible. Next, the observer indicated at what location the target became visible. Prior to a perceptual alternation, subjects were unaware of the location of the orthogonal Gabor in the target image.

The results show that perceptual alternations most often started at the salient location in the suppressed image. These results suggest that saliency information determines the starting location of perceptual alternation. Furthermore, our results are in agreement with the claim that saliency information is available at a monocular level, outside of perceptual awareness.

53.325

Rivalry in tri-stable stimuli: Dominance durations predict the upcoming perceptual state

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When confronted with incomplete or ambiguous information, the visual system has to choose a stimulus interpretation from several alternatives. Rivalry, the situation in which all perceptual alternatives show a similar degree of veridicality, provides an ideal psychophysical test bed for such vision under ambiguity. Typical rivalry paradigms, however, involve only two alternatives, either between two eyes or two interpretations of a single figure. During continuous viewing of such a bi-stable stimulus, the probability of a particular perceptual state to occur cannot be disentangled from its average dominance duration. Here we use a tri-stable stimulus, a moving plaid with 3 perceptual alternatives (A, B, or C). We find that whether a second switch goes back to the initial percept (A-B-A) or to the third percept (A-B-C) depends on the preceding dominance durations. The relative duration of B as compared to A predicts the following percept (either A or C) with up to 81% accuracy. Our results do not only imply that the transition probability between perceptual states depends on the perceptual history, but also rule out single-process adaptation accounts of rivalry.

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53.326

Task demands can affect binocular rivalry dynamics

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It has been shown previously that stimulus driven attention can modify the temporal dynamics of binocular rivalry (Ooi & He, 1999). In addition, observers can voluntary control binocular rivalry dominance to some extent (van Ee, 2005). Here we investigate whether the task in which the observer is engaged in could influence binocular rivalry dominance.

To explore this question, we presented binocular rivalrous images composed of eight Gabor patches all oriented to the left in one eye and to the right in the other. On alternating trials, observers either reported the perceived orientation of the Gabors or searched for the location of a Gabor whose contrast was lower. The first task is the traditional binocular rivalry task to measure the dynamics of rivalry. The second task was introduced as an attempt to influence this dynamics. The experiment consisted in four blocks of trials, and unknown to the observers, the monocular target Gabor was always at the same orientation in the middle two blocks. Therefore, should the observer spend more time interpreting the stimulus in the biased orientation, she would increase her chances to detect the target. Thus, if the visual system can determine the usefulness of scene interpretation during rivalry, one would expect a bias in rivalry dominance in favor of the orientation associated with the target. We found that the biased orientation was indeed more often dominant in the first few seconds compared to baseline. This result is remarkable when one remembers that rivalry dominance was measured in absence of the target. Consistent with this result, the biased orientation sustained over the last block of trials where the target could take either orientation with equal probability. Therefore, our results illustrate task-driven effects on perception, namely that perception is partially determined by how useful the current interpretation is for the task.

53.327

Fear Processing during Binocular Suppression

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In general, stimuli that are familiar and recognizable dominate during binocular rivalry, and this is usually thought to be due to superior processing during the dominant phase. Recent research has demonstrated that familiar and recognizable stimuli and fear related stimuli such as fearful facial expressions also have an advantage of breaking suppression during binocular rivalry. In the current study, animate images from the IAPS database were introduced to one eye and competed against a standard high-contrast dynamic noise pattern presented to the other eye. We measured how long it took for fear-related images (snakes and spiders) to break out of suppression and compared the timing to a non-fear related control images (dogs, cats, birds, etc) breaking from suppression. We also measured participants' general fear levels on the Klorman Snake and Spider Phobia Questionnaire. Preliminary results show that fear-related images are faster to gain dominance, but only for those who reported a high level of fear to the specific images. That is, suppression times negatively correlated with individual differences in fear scores for both snakes and spider suggesting that stimuli relevant to individual ecological importance have preferential access to conscious awareness.

53.328

Binocular rivalry favors naturalistic stimuli in space and time

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The spatiotemporal structure of natural images has characteristic amplitude and phase spectra. For example, the distribution of spatial and temporal frequency information is proportional to $1/f\alpha$, where f is frequency and α has a value near unity. The visual system seems optimized to these properties, with discrimination performance and gain control mechanisms most efficient when $\alpha \approx 1$ (e.g. McDonald & Tadmor, 2006, Vision Res, 46: 3098-3104). Here, we ask if binocular rivalry is sensitive to properties typical of natural scenes. We used filtered 2D noise (tinted red or blue to aid identification) and varied the value of α in either the spatial or temporal domain in two separate experiments. All stimuli were equated for RMS contrast and presented dichoptically in counterbalanced, pairwise factorial combination (2 experiments, 15 unique pairs each, 4 observers, 5 repetitions, 1-min trials). We found that stimuli for which $\alpha=1$ showed the greatest predominance in both the spatial and temporal domains. We compare these findings to perceived contrast measurements for the same stimuli, and the total contrast energy in each image after passing through a model contrast sensitivity function. We conclude that the strong contrast dependency of rivalry is the mechanism by which binocular vision is optimized for viewing natural images. Additionally, we compared rivalry between natural and phase-scrambled images. With stimuli equated for total energy, images with natural phase structure were dominant for 70% of the trial duration (averaged over 8 images and 6 observers for a total of 576 1-min trials). We ruled out the effects of bias using a simulated rivalry condition, which produced an average natural image dominance of 50% (i.e. no bias). This evidence indicates that binocular rivalry is preferentially sensitive to the properties of natural images across space, time and phase.

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53.329

Binocular Suppression in the Monocular Boundary Contour Display Starts Early (≤80 msec)

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Boundary contour signal, elaborated at the surface representation level, affects binocular rivalry. We introduced an MBC-stimulus display where both eyes see the same vertical grating, but with a central circular area of one half-image's grating phase-shifted relative to the surrounding grating (Su et al, VSS 2008). The phase-shift creates a (monocular) boundary contour (MBC) defining the circular area as a vertical grating disc. With this display, the contrast threshold of a probe measured on the homogeneous grating is higher than that measured on the disc, indicating binocular suppression. This was surprising since the early feature (vertical grating) in each half-image is the same. Experiment-1 sought to confirm that the suppression of the MBC-stimulus is unaffected by binocular fusion at the early visual level. We changed the contrast of the MBC grating disc (2.2 cpd, 1.5 deg, 60cd/m2) from 0.9 to 1.7 log%, while keeping the contrast of the contralateral homogeneous grating at 1.5 log%, and measured the contrast thresholds of a monocular Gabor probe (FWHM: 0.43deg x 0.25deg) in each half-image. We found that while thresholds increased in the eye viewing the MBC disc as the contrast of the MBC disc increased, thresholds of the eye viewing the homogeneous grating were higher but did not change significantly. This indicates that the homogeneous grating was consistently suppressed and little affected by binocular fusion. Experiment-2 investigated the dynamic of the binocular suppression. We measured performance in detecting a suprathreshold Gabor probe presented on either half-image at various SOA (80-410 msec) between the MBC-stimulus onset and probe. We found suppression occurred as early as 80 msec after stimulus onset, and the magnitude of suppression (difference in percentage detection between the two eyes) is quite constant across SOA. This suggests that binocular suppression triggered by MBC is functional soon after stimulus onset.

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53.330

Non-local effects of perceptual memory in ambiguous figure perception

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Bistable perception arises when a single stimulus provides two plausible, yet mutually exclusive perceptual interpretations from which the brain must select one. Examples include binocular rivalry (BR) and bistable structure from motion (SFM) cylinders. During intermittent presentation, stabilisation can occur; perception becomes 'stuck' such that the same interpretation (e.g. a rightward rotating cylinder) is seen on every presentation for up to several minutes. This regularization of perception based on prior experience has been termed "perceptual memory". We investigate whether these memory effects spread across disparate visual locations, or are spatially specific, as reported by Chen & He (2004).

In separate sessions, observers viewed BR oriented gratings or SFM cylinders. Stimuli were presented alternately at fixation and at one of a number of eccentric locations. Thus, every second stimulus appeared at fixation, causing robust stabilization in that location. Importantly, with both BR and SFM stimuli, there were strong interactions between perception at fixation and perception at subsequent peripheral locations. In other words, perceptual stabilisation is not local, but spreads to other regions of the visual field. These perceptual interactions were not uniform across space, however, but gradually decreased as spatial separation between stimuli increased. Furthermore, by manipulating fixation position between successive presentations, we established that this spreading of perceptual memory occurs in a retinotopic frame of reference; perceptual memory is not re-mapped in response to saccades.

In summary, in stark contrast to previous findings, we found that the effects of perceptual memory do spread across the visual field; a perceptual decision at one retinal location biases the interpretation of similar stimuli at non-contiguous spatial locations. The retinotopic nature of this spread suggests that stabilisation is a low-level process mediated by facilitatory connections in low-level cortical areas.

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53.331

Genetic contribution to the rate of switching in bistable perception

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Under normal viewing conditions, a person's left and right eyes are presented with very similar visual input. When the input provided to the two eyes is so different that they cannot be combined into one coherent picture of visual space, input from each eye competes to be perceptually dominant over the other. Such a perceptual competition is called binocular rivalry. The rate of perceptual switch seems to vary based on many extrinsic factors including the perceptual strength and context of the stimuli presented to the observer. However, when the stimulus conditions are fixed, the rate of switching is relatively stable for a given individual, but varies much more between individuals. Despite extensive research on extrinsic factors that can influence rate of binocular rivalry switch, relatively little has been done to investigate intrinsic (individual biological differences) factors that may be involved. Previous research has shown that factors such as bipolar disorder may slow binocular rivalry switch, indicating that intrinsic factors may be involved, however little information is available about the contribution of heritability to rivalry rates in normal populations. In the current study, rate-of-switch was recorded in a population of monozygotic and dizygotic twins under the same binocular rivalry conditions. Rate-of-switch when viewing a bistable Necker Cube was also recorded for each subject. Results suggest that there is a very strong heritability component related to switch rate in the case of binocular rivalry, but a much weaker genetic contribution to the switching rate of pictorial bistable images (Necker Cube).

Attention: Tracking

Tuesday, May 12, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

53.401

Extrapolation vs. individuation in multiple object tracking

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A central task of perception is not only to segment the visual environment into discrete objects, but also to keep track of objects as persisting individuals over time and motion. Object persistence can be studied using multiple object tracking (MOT), in which observers track several featurally identical targets that move haphazardly and unpredictably among identical distractors. How is MOT possible? One intuitive idea is that this ability is mediated in part by a form of automatic trajectory extrapolation. Some previous studies attempted to support this view by demonstrating that subjects are better able to recover targets following a gap — the momentary disappearance of the entire display — when the gap was preceded by a coherent motion trajectory rather than a static array of objects. Such demonstrations are susceptible to a simpler interpretation, though: perhaps the pre-gap motion simply serves to better individuate the objects, rather than supporting trajectory extrapolation. To address this, we studied MOT using four conditions, each involving gaps after which the objects appeared in the same locations across conditions. In the Move condition, objects moved continuously before the gap, such that the final locations were at the 'correct' extrapolated locations. In the Static condition, objects remained stationary before the gap. In the Vibrate condition, objects oscillated in place before the gap. And in the Orthogonal condition, objects moved continuously before the gap at a 90° angle from their post-gap positions. Compared to the Static baseline, performance was equal in the Vibrate condition, much better in the Move condition, and significantly worse in the Orthogonal condition. This provides decisive evidence that extrapolation occurs during MOT, and perhaps cannot even be ignored — since unreliable trajectories yielded worse performance than no trajectories at all. These and other conditions begin to elucidate the underlying processes that effectively 'implement' MOT.

URL: http://www.yale.edu/perception/

53.402

Altering the number of targets during multiple-object tracking

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Previous research in multiple-object tracking has provided evidence that the endogenous selection of targets to be tracked requires serial selection and engagement of attention (Pylysyn and Annan, 2006). However, this work was conducted entirely via manipulations of the static pre-trial cues. This raises the possibility that reallocation of attention during task performance is distinct from selecting targets from a static set. To explore this question, a task that required participants to add and remove objects from the currently tracked set was created. Dynamic modifications of the tracked set of objects were accomplished via color cues: previously monochromatic dots were flashed equiluminant red or green to cue that a target was to be removed or added to the tracked set, respectively. While the change in color produces an exogenous shift of attention, processing the target required an endogenous association of color with action to be taken. If this processing requires serial selection, then attention would be predicted to be diverted from the previous set and performance would suffer. In contrast, the results obtained via an ideal-observer analysis suggest that there was

Tuesday Sessions

little to no penalty on overall performance due to processing the changes in the tracked set, and thus engaging and disengaging attention can happen rapidly and efficiently even when endogenous processing is required.

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53.403

Attentional prioritizations based on spatial probabilities can be maintained on multiple simultaneously moving objects

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Previous research has shown that the visual system prioritizes attention to locations based on the probabilities of a target appearing at those locations. Feria (Perception & Psychophysics, 2008) found that when tracking several moving objects, attention can be prioritized to high-probability locations on the objects, if the observer is informed of the location probabilities. The present study investigates whether prioritizations within moving objects can be learned and maintained over time, if the observer is not given information about the location probabilities. On each trial, observers viewed two long white moving lines. Small gray circular probes appeared briefly on the lines, and observers' performance at detecting the probes was used to measure the distribution of attention. In one block of trials, the probes appeared with probability .9 on the center of each line, and with probability .05 near either of the ends of each line. In another block of trials, probes appeared with probability .9 near one end of each line, with probability .05 on the center of each line, and with probability .05 near the other end of each line. When probes appeared with high probability on the centers of lines, probe detection was much more accurate at centers than near the ends of lines. However, when probes appeared with high probability near one of the ends of each line, accuracy was more similar for centers and ends. These results indicate that the distribution of attention within the objects was biased toward the centers of the objects, but was also affected by spatial probabilities. These findings suggest that observers are capable of learning spatial probability distributions, and prioritizing attention based on these distributions, in multiple independently moving reference frames.

53.404

Do multiple object tracking and letter identification use the same visual attention resource?

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Humans can track 3-5 independently moving objects among identical moving distractors (multiple object tracking). This has been taken as a demonstration of simultaneous parallel attention. Does this distributed attention facilitate letter identification, or do tracking and letter identification employ separate attentional resources?

Eight participants tracked 2, 3, or 4 out of 8 disks for 5-10 seconds. Two trial types were randomly intermixed. On tracking probe trials, one disk turned white and participants made a 2AFC target-distractor discrimination. On letter probe trials, pre- and post-masked letters were flashed on one target and three distractors locations for 80 ms. Participants made a 13AFC decision about the letter presented on the target disk (possible letters: ABCDEHLNSTXYZ).

Tracking accuracy was good: .92, .88, and .82 for 2, 3, and 4 targets, respectively. Letter accuracy was .69, .55 and .45.

We used data from 2-target trials to predict letter accuracy for 3 and 4 targets using two models. The separate resource model assumes that not all tracked objects are attended but any letter flashed on an attended object is perfectly identified. Conversely, the unlimited unified resource model assumes that all tracked objects are attended but that letters flashed on attended objects are not perfectly identified. The separate model estimated 1.3 items simultaneously attended, predicting letter identification accuracy of .48 (3 targets) and .38 (4 targets), significantly underpredicting performance. The unified model estimated letter identification accuracy for letters on attended targets to be .71, predicting letter identification accuracy of .65 (3 targets) and .62. (4 targets), significantly overpredicting performance. The best explanation for the data is an (admittedly ad hoc) limited capacity unified resource model in which all tracked items are attended but the probability of identifying a letter on a tracked object declines as the number of tracked items increases.

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53.405

Distinguishing between parallel and serial accounts of multiple object tracking

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Humans can attentionally track multiple moving objects. Is this accomplished by attending to all the objects at the same time or do we attend to each object in turn?

We addressed this fundamental question using a novel application of the synchronous-asynchronous paradigm. Participants viewed four groups of dots, each group containing four dots, each group located in its own quadrant. During the trial, which lasted seven seconds, each group of dots would rotate around the center of its quadrant, 90 degrees at a time, with a pause between rotations. The direction of successive rotations was random. Participants tracked one dot in each group. In one condition, all groups rotated synchronously. In the other condition, the groups rotated asynchronously so that at any given time only half the groups were rotating. If observers track dots serially, then the asynchronous condition should yield superior performance since fewer dots move simultaneously. Conversely, a standard parallel account predicts comparable performance in the two conditions. Surprisingly, we found that performance was actually better in the synchronous condition than in the asynchronous condition, disconfirming a serial account. We speculate that the motion onset transients in the asynchronous condition involuntarily switched attention between dots, thereby disrupting the parallel tracking mechanism.

There is evidence that tracking occurs independently in each cerebral hemisphere (Alvarez & Cavanagh, 2005, Psychological Science, 16, 637). While this might explain why dots in different visual hemifields can be tracked in parallel, when we confined all the dots to just one visual hemifield, performance was still greatest in the synchronous condition. In fact, when all the dots were confined to just one quadrant, performance was still inconsistent with a serial account. We conclude that multiple object tracking is achieved in parallel across the visual field.

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URL: http://search.bwh.harvard.edu/new/

53.406

Tracking objects with moving textures

Rebecca St.Clair[1] (rebecca.l.st.clair@vanderbilt.edu), Adriane E. Seiffert[1]; [1]Department of Psychology, Vanderbilt University

People can keep track of target objects as they move among identical distractors using only location and motion information. We investigated how observers use motion information to track objects by adding motion to the texture of moving objects. Observers tracked 4 of 10 squares filled with a random-dot texture as they moved at 1.1° per second in a box filled with random-dot texture. The squares did not have borders and the average luminance of each square was the same as the background, so the squares were defined only by motion. The texture within the squares either remained static or moved relative to the square's direction of motion. Across conditions, the texture of each square moved either in the same direction, the opposite direction, or orthogonal to each square's trajectory. When it moved, the speed of the texture also varied by condition such that the relative speed of the texture to the background was always 2.2°/sec. Tracking performance was worse when the texture moved in the opposite direction of the object (58% correct) compared to the orthogonal direction (71%; $t(18)>4$, $p<.05$). Tracking was also better when the texture moved in the same direction as the objects (81%) compared to the orthogonal direction ($t(18)<4$, $p<.05$) and was no different from the static textures (81%). This suggests that observers may use local motion information to help track targets. Further experiments will examine whether texture motion influences tracking by affecting the perceived velocity or position of the targets.

53.407

Shape influences target recovery after a blank in multiple object tracking

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People can keep track of target objects moving among identical distractors. If all objects momentarily disappear during tracking, observers have more difficulty recovering targets that move during the blank than objects that do not, suggesting observers tend to track without motion prediction (Keane & Pylyshyn, 2006). Is tracking always non-predictive or can object features assist observers' predictions of object positions? Here we test whether an object's shape can assist target recovery when its orientation corresponds to the object's direction of motion. Observers tracked 3 of 10 isosceles triangles whose orientation was either aligned or misaligned with their trajectories. All triangles moved in linear, predictable paths inside a square box and bounced off the walls of the box. All triangles moved for 4.2 sec before disappearing for 400 ms and then reappearing and continuing to move for 1 sec. During this blank, all triangles either paused or continued to move. Triangles reappeared in the same orientation that they had before disappearing. Results replicated previous work showing better target recovery when objects paused relative to when they moved during the blank. When triangles paused during the blank, tracking accuracy was significantly higher for aligned orientations (85±2%) relative to misaligned orientations (83±2%; $t(24) = 2.12$, $p < .05$). This effect of orientation was even larger when the triangles continued to move (interaction $F(2,48) = 3.357$, $p < .05$), with accuracy for aligned triangles (70±2%) significantly higher than for misaligned triangles (63±3%; $t(24) = 3.357$, $p < .001$). Target reacquisition after a disappearance improved when triangles were oriented toward their directions of motion. This suggests that, while object tracking primarily recruits position-tracking mechanisms, tracking can be predictive when an object's shape indicates its direction.

URL: http://www.psy.vanderbilt.edu/faculty/seiffert/

53.408

Self-motion influences multiple-object tracking in a virtual environment

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Investigations of multiple-object tracking aim to further our understanding of how people perform everyday activities such as playing team sports, driving down the interstate, or interacting with others in action video games. However, tracking tasks in the laboratory have largely overlooked a crucial component of real-world multiple-object tracking: self-motion. That is, as we dribble a ball down the basketball court, we must not only keep track of other players, but also plan and execute our own movements. Is our ability to track moving objects affected when we are also moving? In order to investigate the role self-motion plays in multiple-object tracking, we fitted participants with an immersive virtual reality head-mounted display. Participants tracked one to three moving target balls amidst identical distractors in a three-foot square area on the ground. On some trials, as the balls moved, participants walked in an arc from one side of the square area to an adjacent side, translating their viewpoint by ninety degrees. On other trials, participants maintained a constant viewpoint by walking in place as the balls moved. Participants were able to track multiple moving targets at an above-chance level even when they had to simultaneously translate their own viewpoint (tracking accuracy for three targets = 65%; $t(12) = 4.93$, $p < 0.005$). However, when participants changed position, their tracking accuracy suffered relative to when they stayed in the same position (tracking accuracy for three targets = 77%; $t(12) = 3.68$, $p < 0.005$). These results show that there are tracking costs associated with self-motion. Further experiments will determine the relative influence of viewpoint change and observer action. These experiments demonstrate the potential usefulness of virtual reality as a tool for studying the ways in which self-motion influences our ability to track multiple objects.

53.409

Surface features facilitate target recovery after a momentary disappearance during multiple object tracking

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When multiple-object tracking, participants attend to several, identical targets moving among distractors. If all objects disappear for a moment, participants are poor at recovering targets when all the objects continue to move during the blank (Keane & Pylyshyn, 2006). This result revealed a difficulty in making a correspondence between different locations of a target before and after a blank, based on motion information. We asked whether a surface feature, namely color, would facilitate target recovery because color is another cue to object correspondence. In addition, we investigated whether such facilitation was more effective when objects moved during the blank compared to when objects paused during the blank. Participants tracked 3 out of 9 colored dots for 6 seconds. Each target dot shared color with two distractors, but did not share color with the other targets. At a random point during tracking, all the dots disappeared and either continued moving or paused while out of view for 350 milliseconds. When the dots reappeared, the target dots either retained their original colors or swapped colors. All dots continued moving until the end of the trial, at which point, all dots stopped moving and turned white. Participants, then, attempted to select the three targets. The results showed impaired tracking when dots moved during the blank (53% correct) compared when they did not (80%), $F(1,9) = 59.9$, $p < 0.001$. However, tracking performance improved when the targets retained their colors upon reappearing (73%) compared to when they swapped colors (60%), $F(1,9) = 17.4$, $p < 0.01$. This benefit was similar whether the dots moved or paused during their disappearance (interaction, $F(1,9) < 1$). These results indicate that consistent surface features benefit object correspondence that is based on either position or motion information. Object color helps us continue tracking multiple objects after a momentary disappearance.

53.410

Why don't people look at targets during multiple object tracking?

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Multiple object tracking measures the ability to covertly attend to multiple locations over time. Previously we demonstrated that participants tracking multiple targets often look at the center of the target group (Fehd & Seiffert, 2008), a strategy we label "center-looking". This is intriguing because participants are not always looking directly at targets or saccading between them, a strategy we label "target-looking". The current experiments investigated whether people engage in center-looking only when target-looking is too difficult. Participants tracked 4 targets moving randomly amidst 6 distractors while we measured the amount of time they viewed the targets or the center of the targets. To increase the demand for foveation and hence increase target-looking, Experiment 1 manipulated dot size from 0.3 to 0.06°, which pushed participants to their perceptual limits. On correct trials, however, no change in average viewing times was seen across dot sizes, suggesting that the need to foveate targets influences neither center-looking nor target-looking. To make target-looking more difficult, Experiment 2 increased the dot speeds from 3 to 24°/s. This manipulation examined whether center-looking reflects a reluctance to move gaze during tracking to avoid losing targets during saccades. While target-looking moderately decreased with increasing speeds ($F(4,32)=2.49$, $p=.06$), center-looking was consistent across speeds ($F(4,32)<1$), indicating that center-looking was not a result of avoiding time-consuming eye movements. To make target-looking easier, Experiment 3 yoked targets to move in the same direction. Strengthening common target motion increased target-looking ($F(3,27)=12.78$ $p<.05$), but had no influence on center-looking ($F(3,27)=1.60$, $p=.21$). These results show that center-looking persists regardless of the ease with which targets can be foveated. Center-looking is not the default

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alternative to target-looking, but instead may reflect a different cognitive process. It seems that the time spent looking away from targets is not determined by the difficulty of looking at them.

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53.411

Contour interpolation automatically directs attention in multiple object tracking

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Multiple object tracking (MOT) is a task wherein observers attempt to track multiple targets among moving distractors. Contour interpolation is an early process that represents non-visible edges on the basis of how surrounding edges (inducers) are spatiotemporally related. Although MOT is usually employed to study attention, here we show that one version of the paradigm—what we call multiple vertex tracking—also reveals interpolation effects. In a typical trial, a target disk and distractor disk orbited within each screen quadrant. During a portion of the movement phase, all disks transformed into pac-men that could either interpolate with one another or not. In Experiment 1, when targets and distractors formed illusory contours with each other, tracking performance was worse than in a control condition having the same edge relations but no interpolation. Experiment 2 showed qualitatively the same outcomes when interpolated contours were occluded. In Experiments 3 and 4, when interpolation strength was decreased by either decreasing support ratio (disk diameter) or increasing inducer rotation angle, interpolation effects on tracking decreased. Across all experiments, performance was best when all four targets interpolated with one another, although the strongest interpolation effects occurred between targets and distractors. These data strongly suggest that contour interpolation automatically directs attention. They further suggest that—contrary to recent theories of tracking—the specific shape of tracked objects can be relevant to MOT, at least when those shapes contribute to unit formation.

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URL: http://keane.bol.ucla.edu

53.412

Multiple Object Tracking through temporal gaps created by the fading of objects

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In three experiments, we examined whether the encoding of object location is used in Multiple Object Tracking. Observers were asked to track four target discs among eight identical distractors on a display where the same random-dot texture was used for object surfaces and display background. Stereoscopic glasses were used to create two display conditions: 3D (where objects appeared to float in front of the background texture) and 2D (where objects appeared on the background texture). In the 2D displays, disks were only visible while they moved and became indistinguishable from the background when they stopped. In 75% of the trials, the objects halted movement mid-trial for one, two, or four seconds.

Experiment 1 used textured discs with no borders. During the pauses, the discs would appear to dissolve into the background in the 2D condition but remained distinct in the 3D condition. This produced significantly lower tracking performance only in the 2D trials with the longest pause; no decline was observed in the 3D condition.

Experiment 2 was identical to Experiment 1, except the discs had a white border during the entire trial, allowing the discs to remain distinct during the pauses. In this case there was no effect of pause duration.

Experiment 3 used the same 2D display as Experiment 1, except that in half of the trials object borders flashed "on" before halting. Here, there was an effect of pause duration in both flash and non-flash conditions (decreased performance with longer pauses).

These experiments found that objects that disappear without an abrupt offset are more difficult to track, indicating that object locations are not encoded and used to continue tracking after a gap in visibility. This suggests that the tracking mechanism does not encode location information unless cued by abrupt changes in the visual scene.

53.413

Eye-blinks and Tracking

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Visual Indexing Theory proposes a referential mechanism that tracks objects in a visual scene without necessarily encoding object properties, as demonstrated through Multiple Object Tracking experiments. The encoding of location information during object tracking, however, remains a possible exception. In the current studies, we tracked eye movements during a standard MOT task and employed a blink-contingent methodology in which objects stopped moving or disappeared during eye-blinks. Because this halting is synchronized with eye-blinks, we were able to examine natural, intrinsically generated disruptions of the visual scene without inadvertently cuing the object change.

Experiment 1 examined the effect of changes in object motion that occurred during spontaneous eye-blinks. Subjects performed a standard MOT task (4 targets, 8 non-targets). In half the trials, the objects halted for the duration of all blinks; these trials were randomized among trials where objects continued their movement. The results indicate that a blink-contingent halting of objects produces fewer tracking errors, but this effect diminishes with practice. Also, fewer fixations were correlated with better tracking performance in the last block.

Experiment 2 tested for location-encoding during MOT when objects disappeared during more natural interruptions (instead of occlusions or abrupt disappearances). We replicated the main features of Keane & Pylyshyn (2006) except we replaced occlusions with blink-contingent disappearances. We used a simple sound to signal subjects to blink once during each trial. This voluntary blink induced a change in object motion (halting or continuing along trajectories) and disappearance (150, 300, 450, or 900 ms). The results revealed superior tracking performance in the halt conditions, with lower performance as disappearance duration increased in both conditions.

Overall, our results suggest that location information and trajectory extrapolation are not crucial for tracking. When abrupt changes in a scene are visually detected, the most recently sampled location may be retrieved.

Acknowledgement: We thank Allan Kugel for his contributions.

53.414

Tracking invisible objects across viewpoint changes: The role of scene information

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Research on dynamic attention has shown that object-based attention can remain allocated to temporarily invisible objects (e.g., Flombaum, Scholl, & Pylyshyn, 2008). Does this hold even if objects in scenes are displaced by scene motion? In two experiments we examined the role of information about scene motion in multiple object tracking (MOT). In brief intervals of object invisibility, we introduced mid-trajectorial smooth and abrupt viewpoint-changes. In control conditions, all objects were visible. Smooth viewpoint-changes provided continuous information about scene motion, which supported in tracking temporarily invisible objects. However, abrupt and therefore discontinuous viewpoint-changes during object-invisibility strongly impaired tracking performance. Retained object locations that are linked to scene elements can account for attentional tracking that follows

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invisible objects through continuous scene motion. In control conditions, we replicated previous findings: If objects were visible throughout the trial, abrupt but not smooth viewpoint-changes disrupted MOT performance. Not surprisingly, abrupt viewpoint-changes disrupted performance as well if objects were temporarily invisible.

The novel evidence obtained in the reported experiments pertains to smooth viewpoint-changes that occurred while objects were invisible. Performance was superior than with abrupt viewpoint-changes suggesting that continuous information about scene motion supported in updating the retained locations of invisible objects. Current theories of MOT remain silent about the use of scene information in tracking (e.g., Pylyshyn, 2007). We suggest a tracking mechanism for temporarily invisible objects in scenes undergoing viewpoint-changes with foci of split attention following targets. These foci are linked to scene elements. Thus, they remain in place when objects disappear and follow continuous scene motion. Multi-focal attention may be pictured as peaks on an attentional map overlaying the visible scene and following scene motion if motion is continuous.

URL: http://www.iwm-kmrc.de/cybermedia/invisible-objects/

Attention: Feature- and Object-based

Tuesday, May 12, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

53.415

The spatial gradient of the spread of feature-based attention

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Attending to a feature in one location can produce feature-specific modulation in a different location. This global feature-based attention effect has been commonly studied with two stimulus locations, one in each hemifield. With such a stimulus configuration, it is impossible to study the spatial profile for the spreading of feature-specific modulation.

We examined the spread of feature-based attention by measuring attentional modulation of motion aftereffect (MAE) at remote locations (Boynton, Ciaramitaro, & Arman, 2006). Observers viewed a stimulus composed of two overlapping dot fields that moved in opposite directions in the center of the screen (adapter). They attended to one of the dot fields by performing a two-interval forced choice task on its speed. Following the adapter, a single-direction dot field (test) appeared at one of six possible locations along the horizontal meridian (eccentricity: ±5, ±10, ±15 deg). The adapter and test did not spatially overlap. A nulling technique was used to measure the perceived stationary point (PSP). We also measured the baseline MAE effect for each location by presenting a single-direction adapter and test in that location. Attentional effect was quantified as a fraction of the baseline effect, to normalize against variation in adaptability across locations. Consistent with prior work, we found a global effect of feature-based attention (the PSP depended on the direction to which subjects attended to during adaptation). Importantly, the size of this effect was not spatially uniform, but showed a reduction with greater eccentricity.

These results show that the spreading of feature-specific modulation is not uniform across the visual field but has a measurable spatial gradient. Thus feature-based attention can be global, but is not completely location-independent.

53.416

Global feature-based inhibition for a task-irrelevant feature of an unattended stimulus

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Experiments on the neural mechanisms of feature-based attention suggest that features are selected in parallel across the visual field (Treue & Trujillo,1999). Moreover, feature-based attention not only spreads to the task-relevant feature in an unattended location, but it also spreads to a task-irrelevant feature in the unattended location by virtue of it being bound to the same object as the task-relevant feature (Sohn et al., 2005). In all these experiments, however, the unattended location contained the task-relevant feature. We asked whether a similar mechanism is at work when the unattended location does not contain the task-relevant feature, and instead contains a task-irrelevant feature that matches the task-irrelevant feature in the attended location. Specifically, we asked whether attending to the color of moving dots in one visual field (VF) would influence the neural response to achromatic moving dots in the other VF. Subjects were instructed to attend to red or cyan dots (both present at the attended location and moving in opposite directions) and respond when the target dots dimmed. Critically, the achromatic dots in the opposite VF could either match the direction of the attended dots (same), match the direction of the unattended dots (opposite), or match the direction of neither the attended or unattended dots (neutral). Preliminary analysis revealed that, relative to the same and neutral conditions, BOLD activity in human MT/MST corresponding to the unattended location was suppressed when the direction of motion matched the direction of the unattended dots in the attended location. This result suggests that just as the attended color is selected in parallel across the VF, the task-irrelevant motion of the dots in the unattended color can be inhibited across the VF. This was true even though the dots in the unattended location did not contain either the attended or unattended color.

53.417

Working memory and feature-based attention independently modulate the perception of coherent motion in human observers

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Attending to a visual stimulus feature selectively modulates activity in visual neurons, resulting in a space-independent perceptual enhancement of the attended feature (feature-based attention, FBA). We investigated whether holding the representation of a visual feature in working memory (WM) produces a similar effect. We further asked whether the effects of WM and FBA occur independently of each other. In three different experiments, seven subjects fixated a dot in the middle of a computer monitor while they identified the direction of a brief pulse of coherent motion in a random dot pattern (RDP) with 0% coherence located eccentrically. Simultaneously, they performed another task that required them to either: a) attend to the motion direction of a second RDP co-occurring with but far from the pulse (FBA-only Experiment); b) remember the motion direction of a previously presented RDP (WM-only Experiment); or c) both (a) and (b) concurrently (WM-FBA Experiment). We found that mean performance in the pulse direction identification task was significantly higher when either the attended direction (FBA-only Experiment, p=0.05, paired t-test), or the remembered direction (WM-only Experiment, p=0.004) was the same as the pulse direction, relative to when it was opposite. This suggests that visual features held in WM (likewise attended features) are preferentially perceived. In the WM-FBA Experiment, mean identification performance was highest when both the remembered and the attended directions were the same as the pulse direction, lowest when both were opposite, and intermediate when one was the same and the other opposite. A two-factor ANOVA revealed significant main effects of WM (p=0.04) and FBA (p=0.03), and a non-significant interaction between these two factors (p=0.25). Our results suggest that WM and FBA can independently modulate motion perception in humans.

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53.418

Neural Mechanisms of Color and Speed Integration

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Objects are comprised of multiple features that are processed in different areas. While these features need to be bound together to create a stable object representation, it is unknown at which stages of visual processing

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such binding occurs. However, features that are bound together should affect each other's processing. We investigated the relationship between color and motion in an object representation. We recently found that isoluminant color differences can mediate bottom-up selection, similar to previous reports of contrast effects. We performed two experiments to elucidate the underlying neural mechanisms of this color-based salience. In experiment 1, subjects were asked to fixate on a central dot and an aperture with a single surface of dots moving left or right appeared in the periphery. We varied both the color and the speed of the surface on a trial by trial basis. After a random period of time, the fixation spot disappeared which was the prompt for the subjects to saccade to the aperture. Saccading to the surface resulted in an automatic pursuit of that surface. The speed of pursuit was modulated by both the color and speed of the moving surface. The results suggest that color modulation of motion processing occurs via multiplicative gain. In experiment 2 we investigated object-based selection by placing a second surface superimposed on the first surface to control for spatial mechanisms. The two surfaces moved in opposite directions and also varied in color and speed between trials, such that the effect of color and the effect of speed could either compete or cooperate. Again, we find color modulation of speed processing. We discuss these findings in relation to biased competition and multiplicative gain models of attention.

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53.419

Perception of global statistics of color-motion correlation requires surface-based attention to a single motion

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A transparent motion display comprised half of dots moving leftward, half moving rightward, half red, and half green. 100% consistency: all leftward-moving dots were the same color, and all rightward-moving dots were the other color. 0% consistency: half of dots of each motion were red, and half were green. When the color-motion pairing of all the dots is suddenly reversed by swapping dot colors, humans are remarkably poor at detecting this change when consistency is low (Saiki & Holcombe, VSS 2008). This indicates lack of representation of any particular dot's pairing. Here we explore availability of global statistics. If feature attention is completely effective, then attention to a color (say, red) should make detection of the pairing swap easy under high consistency, as the marginal mean (proportion of red dots with a particular direction) changes dramatically with the swap. The same applies to motion attention. We suspected that motion attention would be more effective than color attention because the display is subjectively organized as two surfaces moving in different directions, which attention can select. Observers monitored for the swapping of the colors of all dots, with a concurrent task of localizing a transient size change of a dot. In the "diffuse attention" condition, any dot might change size. In the "motion attention" and "color attention" conditions, observers knew the size change would occur in a dot of the specified direction and of the specified color, respectively. With low consistency displays (0-20%) attention had no effect, suggesting it did not access individual feature pairings. Only under high consistency (60%), motion attention significantly improved detection performance (relative to diffuse attention), whereas color attention provided negligible improvement. The marginal mean provides some knowledge of the overall feature pairing proportion, but apparently this can only be computed via surface-based (here, motion) attention.

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53.420

Contributions of Feature-based attention to Closure and Object Perception

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We have previously shown that perceiving contour-defined loops is better when attending to objects with congruent features relative to attending to incongruent features. At which level does this feature-based attention influence object perception? A key step of object perception is object closure, and recent electrophysiological studies suggest that closure is associated with negativity at ~320 ms over latero-occipital electrodes, termed Ncl. Here we investigated whether the Ncl and other, relatively late perceptual components are modulated by feature-based attention. While recording high-density event-related potentials (ERP's), we presented random arrays of gabors to the left and right of a central fixation point. Either on the right or the left side the gabors formed a loop that was either contour-defined or motion-defined, and afterwards participants guessed the side on which the loop appeared. To cue attention to contours or motion, in separate blocks 80% of the trials showed contour- or motion-defined loops, respectively, and only 20% of the trials showed the other feature. We found that people were more accurate in perceiving contour-defined loops when they expected contours and they showed an equivalent cueing effect for motion, thus, confirming the role of feature-based attention in object perception. Our ERP results showed more pronounced negativity for contours than for motion at ~380 ms over latero-occipital recording sites, consistent with previous reports of the Ncl. Furthermore, cueing attention to contours resulted in a stimulus-specific modulation of the ERP from ~300 ms. Surprisingly, however, the influence of attention was opposite to that of the Ncl. Valid cues resulted in relatively greater positivity, not negativity, compared to invalid cues. Our data suggest that the Ncl is independent of mechanisms conveying feature-based attention. Further research is required to clarify the stimulus- and attention-based mechanisms of later processes of object perception.

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53.421

Attention spreads to unattended features of an object

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There is increasing evidence that attention selects objects as integrated feature ensembles (O'Craven, Downing, & Kanwisher, 1999). However, little is known about the neural mechanisms that allow object features, often represented in dispersed cortical areas, to become bound together into a unified object percept. Schoenfeld et al., (2003) investigated this question using moving dot-arrays in which a task-irrelevant color feature would sometimes appear. That study demonstrated attentional selection of the color feature within 40 – 60 msec, in brain regions that represent color information, thus providing a potential mechanism for the binding of features across a multi-feature object. The present study was aimed at investigating whether the irrelevant color processing demonstrated in the Schoenfeld et al. study would generalize to a different type of object. Event-related potentials were recorded while subjects observed a grid of horizontal and vertical lines. During each block, participants were asked to attend to either the horizontal or vertical lines and to respond when a line of the attended orientation was thicker than usual. On two-thirds of the trials, vertical or horizontal lines were colored red instead of gray, and color was irrelevant to the task. Unattended red stimuli elicited a prominent sensory response beginning about 100 msec post stimulus onset relative to gray stimuli. Attentional selection of the task-irrelevant color feature (color on the attended orientation vs. color on the same orientation when unattended) occurred at about 300 msec, similar to the finding of Schoenfeld et al. (2003). These findings suggest that attention generally operates in an object-based manner and provides timing information for the binding of color to line orientation.

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53.422

Attention Cannot Spare Task-Irrelevant Locations on an Attended Object

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Reaction times for detecting the onset of targets on attended objects are faster than reaction times for detecting the onset of targets on unattended objects. Such findings suggest that spatial attention selects objects and not just locations. Some theories posit that visual attention acts on perceptual surfaces, such that once attention is drawn to one location on an object's surface it spreads obligatorily to other locations on that surface even when the observer is performing a task unrelated to those other locations. We used steady-state visual evoked potentials (SSVEP) to study object-based attention in the absence of task demands for target detection or action planning with respect to the attended object. Attention has been shown to modulate SSVEPs, and unlike transient flashes used in classical event related potential (ERP) studies, SSVEP procedures do not draw bottom-up attention and can be used to study attention over extended periods of time. Our stimuli consisted of a "plus sign" configuration in which a horizontal bar either partially occluded the vertical bar (in On-object trials) or appeared partially occluded behind it (in Outside-object trials). We presented task-irrelevant, concentric semi-circular flickering stimuli on the two ends of the horizontal bar while subjects fixated the center of the plus sign. We "locked" attention to the central (intersecting) region of the bars by asking observers to spend several seconds counting the randomly-timed occurrences of low contrast "target" flashes in the central region. No target ever appeared on the ends of the bars. SSVEP power was higher in On-object trials compared to Outside-object trials. Consistent with prior findings on attentional modulation of SSVEP, this differential effect was seen only with some frequencies and contrasts of the flicker. Our results show that attention spreads across the entire attended object even when there is no task benefit for doing so.

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53.423

Attentional Tracking of Spatially Extended Objects: Evidence for Object-based Competition Between Lateralized Attentional Systems

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Previous studies have demonstrated that observers can select and track objects independently in the left and right visual field, as if separate attentional systems were engaged in each hemifield (Alvarez & Cavanagh, 2005). Like most attentional tracking experiments, this previous work required observers to track small objects, which always were contained completely within one half of the visual field. However, in real world viewing conditions, objects are often spatially extended, and some parts of an object will appear simultaneously in each hemifield. We tested how attention selects and tracks such spatially extended objects using lines that spread between the left and right hemifields (the bilateral condition) versus lines that spread across the top and bottom of either the left or right visual field (the unilateral condition). On each trial 4 bilateral lines or 4 unilateral lines were briefly presented, and 2 of them were highlighted as targets for tracking. Then all of the lines began to move. At the end of the trial, all of the lines stopped, and observers clicked on the target lines. We measured the proportion of trials on which both targets were accurately tracked. Observers tracked targets less accurately in the bilateral condition (64%) than in the unilateral condition (76%, $p < .01$). The number of target lines, and the spatial extent of the lines were equal in the two conditions. Thus, these results suggest that the critical factor is whether the targets were contained within one half of the visual field, or extended across the left and right hemifields. The difficulty of tracking objects that extend across the left and right hemifields could reflect object-based competition between the attentional systems engaged in the left and right hemifields.

53.424

The Focus of Expansion in Optical Flow Fields Acts as a Strong Cue for Visual Attention

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During walking or driving, the optical flow field FOR an observer expands from a singular point, called the focus of expansion (FOE; assuming negligible rotation). Does this point in the field of view attract significant amount of task-independent attention? We reported last year at VSS that observers' overt attention (i.e., eye movements) was strongly drawn to the FOE, both when viewing natural scenes as well as in visual search. The effects were stronger and remained longer than any other cues tested (intensity, color, flicker, perspective, contractive motion). We here further investigate these effects. (1) Using an exogenous cueing paradigm, we found that convert attention was also attracted by the FOE, but not by a focus of contraction (FOC; zooming out). The FOE effects on covert attention was observed early on (SOA = 0) and remained strong (up to SOA=750 msec), without showing the typical time course for "inhibition of return". (2) Using a natural scene change detection paradigm, we found that the distribution of attentional monitoring of objects was strongly biased by the FOE; when the FOE was near a changed object, the RT was > 3 sec faster than when the FOE was far from the change ($p<1e-9$, KS-test). Such effect was not seen for the FOC ($p>.9$, KS-test). (3) We compared the performance of the saliency model of visual attention (Itti & Koch, 2001) with or without the FOE component. By incorporating the FOE component, the model predicted the human eye movements significantly better. We conclude that the FOE guides visual attention and eye movements in our daily life.

53.425

Separating attentional reference frames: Contributions of space- and object-based representations to attentional guidance

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Recent evidence suggests that object-based attentional selection is primarily guided by spatial uncertainty of target location (Shomstein & Yantis, 2002, 2004; Drummond & Shomstein, 2008; but see Chen & Cave, 2006, 2008; and Richard, Lee, & Vecera, 2008). What remains unclear, however, is whether certainty enhances a spatial location (i.e., space-based representations) or a surface that occupies that spatial location (i.e., object-based representations). Dynamic displays (or rotating displays) provide a useful tool for separating the otherwise overlapping representations. The use of such dynamic displays in prior studies has been limited almost exclusively to the use of inhibition of return (IOR) as a measure (Becker & Egeth, 2000). The current study, however, aimed to examine the contribution of each representation while measuring attentional facilitation. In our paradigm, the two rectangle outlines rotated 90° or 180° clockwise or counter-clockwise, resulting in non-matching space and object locations, which separated the spatial and object-based reference frames. Results suggest that in dynamic displays, both space-based and object-based representations are abandoned under conditions of target location certainty, which provides further evidence for the prioritization account of object-based attention. Under conditions of uncertainty, space-based attention is inefficient for guiding attention, while the object-based reference frame becomes more stable and dominant, thus guiding attentional selection (i.e., attention tracks rotated objects). In addition, the same dynamic display paradigm was adopted for use with an IOR approach in order to investigate the extent to which certainty affects IOR.

53.426

Hierarchical organization influences on object- and location-based Inhibition of Return

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The Inhibition of Return (IOR; Posner et al, 1988) effect reflects a mechanism that biases attention from re-examining previously attended regions (Posner & Cohen, 1984) or objects (Jordan & Tipper, 1998; Tipper, Jordan & Weaver, 1999). A previously attended object, if moved to a novel location, also carries with it an inhibitory “tag”. Object-based IOR is carried both by outlined-objects (Jordan & Tipper, 1998) or surfaces defined by a field of dots, even when superimposed upon another surface (Johnson, Fallah, & Jordan, VSS 2008). We probed the level of hierarchical organization that maintains object-based IOR as the object moves across the visual field.

A modified version of the cueing paradigm, which dissociates object- and location-based IOR effects was used (Tipper et al, 1999). In the present study, we investigated whether object-based IOR is mediated at a local (individual dots) or global (surface) stage of object processing. The display consisted of a single surface of dots in the shape of an annulus. The surface was visible through three apertures in an invisible occluder. While controlling for perceptual complexity, in one display condition the dots rotated (local), while in the other display condition the aperture rotated over the static surface (global).

The location-based IOR effect was significantly larger in the local condition ($p = .003$). Despite manipulating the hierarchical organization of the objects in the display, remarkably there was no difference in the object-based IOR effects observed in the two conditions ($p = .557$). These results are discussed in light of previous research and current models of spatial and object-based attention.

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Object-based Effects on Tracking Multiple Target and Non-target Objects

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Observers are limited in the number of independently moving objects they can simultaneously track in the visual field (Pylyshyn & Storm, 1988). Yantis (1992) reported that perceptual grouping by rigid motion of to-be-tracked objects improved observer’s ability to perform the multiple object tracking (MOT) task. Given the relationship between perceptual grouping and object processing, it was presumed that a similar advantage for tracking items presented on the surface of objects would be observed.

Sixteen dots (elements) were presented in each trial. Four of the elements briefly flashed on and off to mark them as targets. All of the elements proceeded to move around the display for 5 s. When the motion stopped, one element flashed on and off, and the participants were required to report whether or not it was one of the four target dots. Unbeknownst to the participants, the dots in the display were not only MOT target and non-target elements. They also defined the surface of two superimposed structure-from-motion cylinders (formed from 8 dots on each). An object-based benefit in MOT was predicted when the targets formed part of a single (within) object, compared to when they were spread across both (between) objects.

Surprisingly, overall MOT accuracy did not differ between the within and between object conditions. However, contrasting object-based effects were observed when target and non-target trials were analysed separately. Accurate “yes” responses occurred more often in the between- compared to the within-object condition. A similar performance benefit in tracking has been reported when to-be-tracked targets were spread across two compared to a single region in depth (Viswanathan & Mingolla, 2002). In contrast, accuracy was higher for non-target conditions in the within- compared to between-object condition. Evidence for the role of motion-in-depth as a mechanism to track targets and ignore non-targets will be discussed.

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53.428

Prior entry for feature-based attention: Are objects of the attended color perceived earlier?

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Objective: “Prior-entry” refers to objects at attended locations being perceived prior to those at unattended locations (e.g., Shore et al., 2001; Schneider & Bavelier, 2003). Our goal: investigate prior-entry for objects of the attended feature (color).

Methods: Three experiments employed temporal order judgment (TOJ) or simultaneity judgment (SJ). Stimuli comprised two oriented bars equidistant from a fixation mark. One bar was presented prior to the other; stimulus-onset asynchrony (SOA) between them varied. TOJ task: report orientation of the bar shown first; SJ task: report if bars were shown simultaneously. In Experiment 1, location or feature (color) cues preceded stimuli by brief (110 ms) cue lead time (CLT). Observers performed TOJ task, not attending to cue. In Experiments 2 and 3, effect of feature cue was examined further by engaging attention to cue’s color. Three CLT conditions (250, 700, 1200 ms) were used in Experiment 2 (TOJ paradigm), and one CLT condition (700 ms) in Experiment 3 (SJ paradigm). Note: TOJ task involved reporting orientation of first bar, and orientation feature is orthogonal to color feature, thus minimizing first-order response bias.

Results: Spatial prior-entry effect was replicated in Experiment 1: bar at cued position was perceived earlier than bar at uncued position. Feature-based prior-entry effect was observed only in Experiment 2 for CLTs of 700 and 1200 ms: bar of attended color was perceived earlier than that of unattended color.

Conclusions: Prior-entry effect for object with attended feature was found in TOJ task, the most frequently used paradigm in the literature to claim the spatial prior-entry effect, but the effect was absent in the SJ task. This could be due to a second-order response bias in the TOJ task, or to the fact that the SJ task is not as sensitive as the TOJ task.

53.429

Object-based attention in patients with left and right hemisphere lesions

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Since Egly, Driver and Rafal’s (1994) pioneering study of object-based attention, their two-object cueing design has been widely used to study space- and object-based attentional orienting. Here, patients with unilateral brain injury performed target detection in a modified version of the two-object cueing task. By obliquely orienting the two rectangular objects ±45˚, we were able to measure cueing performance separately at midline, in the contralesional field, and in the ipsilesional field. Cues were 64% predictive and always appeared in an upper or lower midline location. For targets appearing at midline locations, RTs were faster at the cued than uncued locations, as expected. When targets appeared laterally to the right or left of fixation, performance was modulated by the configuration of the objects in the display, but in opposite ways on the contralesional and ipsilesional sides. Reaction times (RTs) on the ipsilesional side were in the predicted direction: faster to targets in cued objects than in uncued objects. Conversely, RTs to contralesional targets were slower in cued objects than in uncued objects. The left and right hemisphere groups did not differ from each other in this respect. In sum, both patient groups revealed contralesional object-based neglect while demonstrating the opposite, but expected, object-based facilitation effect in their ipsilesional field. These findings will

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be related to the anatomical structures lesioned in this group of patients as well as to previous studies of lateralized attentional orienting and theories of hemispheric asymmetries in attentional orienting.

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53.430

Individual differences in object based attention

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Previous research suggests that visual attention can be allocated both to locations (space-based) and to objects (object-based). Space-based attention effects are consistent across experiments, and tend to be large, especially within simple cuing paradigms. Object-based attention effects, however, are smaller and less consistent. Here, we address the possibility that variability in object-based attention effects across studies can be explained by variability across individual observers. We tested 60 observers in each of two configurations of a common object-based attention paradigm (Moore, Yantis, & Vaughan, 1998). In one configuration, two vertically oriented rectangles were presented to the right and left of fixation; in the other, the rectangles were horizontally oriented above and below fixation. Theories of object-based attention predict responses to targets in uncued locations should be faster on trials when the target and cue are presented on the same object than on trials when they are presented on different objects. Using ANOVA and t-tests, we found a space-based cuing effect in both configurations. However, we found the anticipated pattern of object-based results only in the horizontal configuration, and the opposite pattern in the vertical configuration. We then used bootstrapping methods to estimate effect sizes for individual subjects. The analyses found that 99% of observers exhibited significant space-based attention effects, but only 26% of observers exhibited significant object-based attention effects. Furthermore, another 26% of observers exhibited significant effects in the direction opposite to predicted object-based attention effects. This individual variability accounts for the contradictory findings of the two experiments, reveals a potential source of the small and inconsistent findings across the object-based attention literature, and suggests that object-based attention may not be as robust as previously assumed. These results highlight the importance of using techniques like bootstrapping to analyze experimental data at the individual observer level.

Eye Movements: Saccade Selection

Tuesday, May 12, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

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Saccadic eye movements to Gaussian luminance and color blobs

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In the past several paradigms were used to investigate the influence of an additional target on saccade latencies and end points. If a second target is presented far away of the actual saccade target, latencies are increased, which is called the remote distractor effect. If the second target is presented closer to the actual target, saccade amplitudes are directed to the center-of gravity of both targets, the global effect. In all of these paradigms two distinct targets are clearly visible. Here we investigated how saccades are influenced if two overlapping targets are present.

To this end we measured saccades to pairs of Gaussian blobs of luminance or DKL color contrast, which were presented on a uniform gray background. The blobs were presented at an eccentricity of 10 deg at a randomized angle, their standard deviation was 0.5 deg of visual angle and they were separated by 0.5 deg. This way two largely overlapping blobs were visible. One blob (reference) always had a fixed contrast of 20%, the contrast of the other blob (comparison) took values of 8, 10, 40 and 50%. The subjects were instructed to move their gaze toward the blobs, as soon as the fixation point vanished.

We observed that saccades land closer to the blob with higher color or luminance contrast. Moreover the latency decreased with increasing contrast of the comparison blob. In general latencies in the color condition were larger than in the luminance condition.

The results indicate that even when the spatial layout is constant, the visual system puts a larger weight on features with a higher contrast.

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53.432

Saccade planning is dissociated from pre-saccadic attentional facilitation after damage to the posterior parietal cortex

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Numerous studies have suggested that saccades to a location trigger an automatic attentional shift to the saccade goal, which enhances perceptual processing at that location. Here, we argue for a functional dissociation between pre-saccadic perceptual enhancement and saccade planning. A patient with a lesion in the right posterior parietal cortex participated in a dual saccade and letter discrimination task. The patient made saccades to the left or right visual field. During the saccade latency a letter was briefly presented at the saccade goal and the patient was asked to discriminate the letter after he completed the saccade. The patient was able to make the normal saccades to the left, impaired visual field that could not be distinguished from saccades to the right, healthy, visual field. However, he was unable to discriminate the letters presented at the saccade goal on his left visual field whereas his performance was excellent in his right visual field. By presenting letter changes at locations that were either closer to or further away from to the saccade goal location, we also tested whether this inability to discriminate a letter at the saccade goal in the impaired visual field was attributable to a distorted attentional shift. The patient performed at chance for all letters presented in the contralesional visual field. We conclude that the leftward saccades were made without an anticipating attentional shift, whereas the rightward saccades were accompanied by a normal attentional shift.

53.433

Saccades are planned using spatial memory information as well as current retinal position

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Purpose: When people make an eye movement toward an object, they can use both the current retinal image of the object and spatial memory to plan the saccade. Recent work has shown that people use memory in their estimate of object location when planning finger movements, and they give a higher weight to memory when there is greater uncertainty of the current visual estimate due to low contrast (Brouwer & Knill, JOV, 7(5):6, p1-12) or greater retinal eccentricity (Issen & Knill, VSS Abstract 2008). We asked whether people would show a similar pattern when issuing eye movements. Methods: In a virtual environment, two objects appeared on the right side of the screen: a “weapon” and a circular “target” region. Subjects had to move the weapon to the “reload station” located 30 degrees to the left, then touch the circular target. While subjects moved the weapon to the reload station, they typically fixated that area, and thus the circular target was in the periphery. In a third of the conditions, the position of the circular target

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shifted by about one degree during this transition. Eye movements were recorded with an Eyelink using corneal reflection. Results: We regressed the saccade endpoint on the remembered and updated visual locations of the target. Although the target was visible in the periphery when subjects planned their eye movements, the saccade endpoints fell between the visual and remembered locations, as evidenced by a significant regression term for memory. Conclusion: This is evidence that eye movements, like other motor commands, are not issued based entirely on the current retinal map, but rather a more complex integration of cues including the updated visual information and the remembered target location.

53.434

The role of context and feature information in fixation search

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To evaluate the relative influence of target feature information and spatial context information in visual search, human eye movements were measured in a task where a small Gabor search target was randomly positioned at one of four pre-cued locations (the context) within a circular background of 1/f noise. All cued 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. Each trial began with the pre-cue display. In the "context-plus-features" condition, subjects maintained fixation until they initiated the onset of the search display with a button press, giving them the opportunity to extract target feature information before making a saccade. In the "context-only" condition, subjects also maintained fixation until the button press, but the search display did not appear until an eye movement was initiated. The duration of the search display was fixed at 500ms. Interestingly, the results suggest that in both conditions subjects planned two saccades prior to initiation of the first saccade, and thus in this task the eye movement strategy was largely determined by the context. The human eye movement patterns were compared with the predictions of several model searchers including the Bayesian ideal (Ideal), expected entropy minimization (EEM) and random (Ran). Both the Ideal and the EEM were found to predict the direction of human saccades relatively well; however, humans tended to fixate closer to the arc on which the targets lay than did the models.

53.435

Suboptimal selection of initial saccade in a visual search task

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Purpose. We investigated how the visuo-motor system plans saccades in an economic task analogous to visual search.

Methods. The subject saw two visual squares (tokens) displayed along a horizontal "base" line through the bottom of a screen 57 cm from the subject perpendicular to his line of sight. On each trial, the subject could freely saccade to any point along the base line. During the saccade, one of the two tokens would change slightly. The subjects then judged how the token changed, responding by keypress. If the subject's response were correct he received a reward. Prior to the main experiment, we mapped subjects' visual sensitivity to token change at different eccentricities. 4 subjects participated in the task.

Analyses. The key independent variable was the spacing between the two tokens. The token change was chosen to be difficult to see outside of the foveal region. If the tokens were near each other the subject could reliably identify token change from a fixation point midway between the tokens. If the tokens were far apart, then this middle strategy would lead to little reward; a stochastic strategy where the subject could saccade to one target would perform better. The key prediction of the experiment is the critical separation where the ideal subject should switch from the midpoint strategy to the stochastic strategy in order to maximize expected gain.

Results. We found that subjects were suboptimal in this task. With increasing separation of tokens, subjects switched to the stochastic strategy too soon, consistent with the possibility that they underestimate their visual acuity in periphery. As a result subjects earned only 83% of the expected gain had they switched at the correct point.

Conclusion. Even in simple displays with only two tokens and after training, subjects do not plan saccades that maximize expected gain.

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The Control of Fixation Duration: Time-Course of the Response to Stepwise Changes in Processing Difficulty

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Eye movements are among the best measures of ongoing cognitive processing. The principles governing the cognitive control of fixation durations, however, are unclear. While the direct-control hypothesis assumes that fixation durations reflect processing demands at the fixation location, the indirect-control hypothesis assumes that fixation durations predominantly reflect current task demands and are unaffected by the processing load at the current fixation. We studied the adjustment of fixation durations to stepwise changes in processing difficulty. Participants searched for a target symbol in an array of stimulus elements. The target symbol was a closed ring, while distractors consisted of rings with a small gap. We manipulated processing demands by varying the similarity between target and distractor stimuli. Difficulty was controlled by gap size. In a first experiment, we prevented preview of the next symbol by gaze-contingent masking. During each fixation, the fixated symbol was shown while the remaining symbols were masked by Xs. Participants searched the array sequentially from left to right. There was no response to decreasing processing difficulty on the first symbol. For increasing processing difficulty, we observed an immediate but disproportionate prolongation of fixation durations on the first symbol. In both conditions, fixation durations on the second symbol matched the new processing needs. In a second experiment, we permitted preview of the entire stimulus. We replicated a delayed adjustment to easy symbols and an immediate prolongation on difficult symbols. Our results demonstrate that (i) direct control of fixation durations is limited to the situation of a sharp increase in foveal processing difficulty and that (ii) direct control can only prolong fixation durations. Moreover, there is an (iii) indirect control mechanism for the shortening of fixation durations, which unfolds over subsequent fixations following a change in processing difficulty.

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Testing processing mode within single visual fixations: Saccadic modulation of the distractor effect

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In view of a variety of everyday tasks, it is highly implausible that all visual fixations fulfil the same role. Earlier we demonstrated that a combination of fixation duration and amplitude of related saccades strongly correlates with the probability of correct recognition of objects and events both in static and in dynamic scenes (Velichkovsky, Joos, Helmert, & Pannasch, 2005; Velichkovsky, Rothert, Kopf, Dornhoefer, & Joos, 2002). It has been variously reported that the presentation of sudden (visual) distractors influences not only the saccadic latency (e.g. Walker, Deubel, Schneider, & Findlay, 1997) but also the fixation duration in free visual exploration (e.g. Graupner, Velichkovsky, Pannasch, & Marx, 2007). In three experiments we investigated the amount of the distractor effect in relation to amplitudes of the preceding saccade. In Experiment 1, it is shown that retinotopically identical visual events occurring 100 ms after the onset of a fixation have significantly less influence on fixation duration if the amplitude of the previous saccade exceeds the parafoveal range (set on 5 deg of arc). Experiment 2 demonstrates that this difference diminishes for distractors of obvious biological value such as expanding motion patterns. In Experiment 3, we show that saccade amplitudes influence visual but not acoustic or haptic

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distractor effects. These results suggest an explanation in terms of a shifting balance of at least two modes of visual processing during a free viewing of meaningful visual images.

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53.438

Trial history biases the spatial programming of antisaccades

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The context in which a saccadic eye movement is made is known to influence saccadic latency and error rate. Much less is known about contextual effects on saccadic metrics. We previously showed that both expectancy (prior probability) and trial history may bias the actual endpoint of an antisaccade (Rodriguez et al, Previous saccades to other locations affect the programming of current antisaccade coordinates, but not those of prosaccades. VSS 2008). In this report we studied the temporal parameters of the historical bias.

Subjects performed antisaccades to a stimulus randomly located either on the horizontal meridian, 40° below, or 40° above the horizontal meridian, with all three locations equally likely and equally frequent in each block, and all locations within the same horizontal hemifield. We analyzed the endpoint of antisaccades to the location on the horizontal meridian, contrasting the effects of preceding trials in which the target was above the meridian with trials in which the target was below the meridian. We analyzed several historical effects: not just that from the immediately preceding trial (n-1), but also the penultimate (n-2) and (n-3) trials. We also compared the historical effects on short-latency versus long-latency antisaccades, using 250ms as a latency criterion.

We found that antisaccades were significantly displaced towards the preceding saccadic endpoint at all three levels (n-1, n-2, n-3). The historical effect was present only in short-latency and not in long-latency antisaccades. We conclude that the location of prior antisaccades can bias the spatial programming of upcoming antisaccades, that this historical effect persists over many seconds, and that it influences mainly rapidly programmed eye movements.

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53.439

The influence of a visuomotor set on express saccades: Coordinate frames and contingency

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Express saccades are the shortest latency eye movements known (70-110ms). However, previous work in our lab has shown that when elicited by the appearance of a spatially extended visual stimulus, express saccades have vectors influenced by a visuomotor set. In this case, the visuomotor set was established by an instruction to make a saccade to the left or right side of the stimulus array (Edelman et al, 2007). Remarkably, such a spatial "Cartesian instruction" does not increase saccade latency. Here, we extend these experiments in two ways. First, we examined whether a visuomotor set expressed in polar coordinates, established by an instruction to make a saccade to the nearer or farther of two visual stimuli arranged along an iso-directional line, is as effective as an instruction expressed in Cartesian coordinates. Second, we examined whether Cartesian instructions are effective when they are contingent, such that, for example, saccades are instructed to be made to the leftmost of two spots of light separated horizontally if they appear in the upper visual field and to the rightmost spot if they appear in the lower visual field. Subjects viewed a CRT display controlled by Vision Shell software routines while eye position was monitored by videooculography at 500 frames/s (Eyelink II, SR Research). A traditional gap task (gap duration: 150-200 ms) was used to facilitate express saccade production. First, we found that a visuomotor set established by a polar coordinate instruction influenced express saccade vector almost as much as Cartesian instructions, though there was a strong bias to make a saccade to the closer of the two targets. Second, we found that contingent Cartesian instructions had much less of an effect on saccade vector as non-contingent Cartesian instructions.

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53.440

Does saccadic space compression mean size shrinking?

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Stimuli flashed around the time of saccades may be mislocalized, shifting towards the saccade target. The mislocalization pattern has been interpreted as peri-saccadic space compression (Ross et al., Nature 1997). To investigate the deforming effect of such "compression of visual space" on object size, we directly tested if objects would be perceived as smaller along the direction of saccades.

Horizontal bars of 1°, 5°, or 10° in length with centers at -15°, 0°, +9°, or +15° were flashed in a random order, when subjects (n=2) made saccades from a fixation on the left (-10°) to a saccade target on the right (+10°). Subjects reported the perceived location and size of bars by indicating the end-points with a mouse. Locations of the perceived bar centers followed the classic mislocalization pattern. Mislocalization occurred approximately within a time interval from -40 to 40ms relative to saccade onset, and localization error peaked (up to 10 degrees) near saccade onset time.

A piecewise linear model of mislocalization was established based on the data, with which the localization error for a point at any position and any onset time can be interpolated. The model was verified to be valid against mislocalization patterns from vertical flashing bar experiments. Predicted lengths of perceived bars were calculated by determining the mislocalization of end points based on the model. For 1 and 5° bars, actual perceived lengths were not correlated with predicted lengths ($r<0.12$, $p>0.36$). Perceived lengths of 10° bars were correlated with prediction ($r=0.39$, $p<0.001$), but only shrank by about 27% of the predicted amount.

While perceived bar length could shrink under certain conditions, it seems that mislocalization of points might not imply a corresponding change in perceived object size.

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53.441

Stimulus exposure and gaze bias in visual decision tasks

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Recently, Glaholt & Reingold (in press) reported biases in looking behavior during eight-alternative forced-choice (8-AFC) decision tasks. We found that throughout the entire decision period, dwell duration (where a dwell is a run of consecutive fixations on an item) is longer on the chosen item than on not-chosen items. In the current study we investigated the ways in which this dwell duration bias depends on stimulus exposure. Eye movements were recorded while participants selected from a display of eight photographs the photo that they preferred the most, or the photo that was the most unusual (control task). In Experiment 1, we manipulated stimulus exposure by pre-exposing four of the eight photos, for one second each, prior to each 8-AFC decision. In Experiment 2, stimulus exposure was manipulated within-trial using a gaze-contingent methodology that limited viewing time during each dwell to either 200 ms or 400 ms. Experiment 1 revealed a larger dwell duration bias for items that were not pre-exposed

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compared to items that were, which suggests that the bias involves the selective encoding of task-relevant information. In Experiment 2 we found that a dwell duration bias is present even when stimulus exposure is equated between the chosen and not-chosen items, indicating that post-perceptual factors also contribute to the bias. In addition, we examined the component fixations within each dwell and discovered that the bias in dwell duration is the result of both an increase in the number of fixations per dwell as well as a lengthening of individual fixation durations. A similar pattern of results was present in both the preference and control tasks. Implications of the present findings are discussed in the context of the Gaze Cascade model of preference decision making (Shimojo, Simion, Scheier & Shimojo, 2003).

53.442

Remembering the old, preferring the new: Memory for old and new items in repeated visual search

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Körner and Gilchrist (2007) had subjects search the same 10-letter display twice, consecutively for different targets. Their participants found the target faster in the second search when they had recently inspected it while it was a distractor in the first search. In Experiment 1 we tested whether search for the second target is faster even if the target had not been inspected previously. We presented a target letter in the second search which had either been inspected during the first search or not. Additionally, when the target was absent in the second search, we measured the time until a specific distractor (so-called secret target) was fixated. Likewise, this secret target could have been either fixated during the first search or not. This allowed us to study memory not only for distractors which became targets but also for distractors which stayed distractors throughout. Results showed that the target was found faster even if it had not been fixated previously. In addition, the secret target was fixated later on when it had been fixated as compared with when it had not been fixated. Some of these effects may be due to the variable amount of time needed to complete the first search. Therefore, in Experiment 2 we used a gaze-contingent technique to control for the duration of the first search. We also varied display size (5, 11, and 17 items, respectively). Replicating the findings of Experiment 1, there was a benefit for both inspected and non-inspected targets independent of display size and a preference for fixating non-inspected distractors earlier during the second search. These results provide evidence for a flexible memory mechanism which generally guides search away from old items and towards new items. If, however, a recently inspected (old) item becomes a target memory can also guide search back to it.

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53.443

Gaze behaviour in the natural environment: Eye movements in video versus the real world

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How do people distribute their visual attention in the natural environment? This question is often addressed by showing pictures, photographs or videos of natural scenes under controlled conditions and recording participants' eye movements as they view them. In this experiment, we investigated whether people distribute their gaze in the same way when they are walking around the real world as when they view video clips taken from the perspective of a walker. We hypothesized that, due to being immersed in the real environment, people would look at different items and change their scanning strategy when actually walking around the scene as opposed to passively watching a video of it.

In the first session, participants walked at their own pace between two points on a university campus, and their point of gaze was recorded using a discrete portable eye-tracker. In a subsequent session, both these and a new set of participants viewed video clips of the walk that were captured by the eye-tracker. These clips showed the first-person perspective of someone walking around campus, and participants were asked to watch the videos as if they were walking the route themselves, while sitting at a computer monitor. The most inspected items were other people, obstacles and the path ahead. This was particularly the case when people were actually walking, although the tendency to look at people was modified by the social situation. These results provide important evidence that gaze behaviour is determined by an interaction between individuals and their environment, and our findings help to bridge the gap between attention in the laboratory and in the real world.

53.444

Adaptive Distribution of Gaze in the Real World

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In the real world, humans must allocate limited perceptual resources to ensure that gaze is in the right place at the right time. How is this achieved? We suggest that humans are very sensitive to contextual attentional demands and rapidly learn to deploy gaze proactively on the basis of the learnt statistical structure of the environment. Subjects walked along an oval path in a large room, for 12 laps, in the presence of other pedestrians who behaved in characteristic ways. One pedestrian (Rogue) walked on a collision course with the subject for a brief period (1sec) whenever they neared the subject. Another pedestrian (Risky) walked on a collision course with 50% probability, and another (Safe) walked normally. In another block of trials, subjects had the added task of staying a constant distance behind a lead pedestrian. The latency with which the pedestrians were fixated after appearing in the field of view changed rapidly for Rogue and Safe pedestrians. Latencies for Rogues shortened, and for Safe increased, by over 200msec. This was true whether on not the Leader was present. Subjects were nearly always fixating the Rogue pedestrian proactively, in advance of the path deviation. With no Leader, fixations durations changed with a similar time course, becoming longer for Rogues, and shorter for Safe. However, when subjects had the added task of following the Leader, fixations on all pedestrians were 100msec shorter and durations did not change across time. Thus Subjects handle the added load by reducing time spent fixating all pedestrians, but they maintain the same gaze priorities on first appearance and reduce latencies on Rogues even with the added task. Individual subjects behave similarly, despite the unconstrained context, suggesting that rapid gaze adaptation reflects a stable and lawful property of natural gaze behavior.

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53.445

Saccades and microsaccades during visual fixation, exploration, and search: Foundations for a common saccadic generator

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Microsaccades are known to occur during prolonged visual fixation, but it is a matter of controversy whether they also happen during free-viewing. Here we set out to determine: 1) whether microsaccades occur during free visual exploration and visual search, 2) whether microsaccade dynamics vary as a function of visual stimulation and viewing task, and 3) whether saccades and microsaccades share characteristics that might argue in favor of a common saccade-microsaccade oculomotor generator. Human subjects viewed naturalistic stimuli while performing various viewing tasks, including visual exploration, visual search, and prolonged visual fixation. Their eye movements were simultaneously recorded with high precision. Our results show that microsaccades are produced during the fixation periods that occur during visual exploration and visual search. Microsaccade dynamics during free-viewing moreover varied as a function of visual stimulation and viewing task, with increasingly demanding tasks resulting in increased microsaccade production. Moreover, saccades and microsaccades had comparable spatiotemporal characteristics, including the presence of equivalent refractory periods between all pair-wise combinations of saccades and microsaccades. Thus our results indicate a microsaccade-saccade continuum and support the hypothesis of a common oculomotor generator for saccades and microsaccades.

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URL: http://www.neuralcorrelate.com/smc_lab

53.446

Predictive eye movements in gaze and action observation

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Eye movements often precede the motor behavior towards an object: we tend to first gaze at the object with which we intend to interact. Eye movements can thus reveal an individual's focus of attention and predict subsequent actions. Determining the direction of seen gaze toward a particular object in space (triadic eye gaze) is especially crucial in establishing joint attention. When an individual points to an object after having gazed at it, the availability of the cues indicating the chosen object dynamically changes over time. Initially, gaze direction is the only accessible cue, but as soon as the arm starts moving also the kinematic cues are available.

To investigate the temporal involvement of different cues we examined the eye movements of observers while they were watching videos of an actor performing gazing and pointing movements towards several target objects. Observers had to look at the target object as soon as possible. Two factors were manipulated: the presence of gazing behavior and the visibility of the target objects. The gaze triggered a rapid and accurate response on the target object. Observers were able to identify the target objects when the arm was still at the beginning of its trajectory, with fewer saccades and more accurately. When gaze information was not available, observers' gaze still led the hand movements of the actor, but was comparatively slower in identifying the target objects. The visibility of the target objects had an ameliorating effect on the spatial accuracy.

These findings suggest that other's gaze direction is an essential predictive cue about the final location of a pointing movement. Observers thus activate action plans based on the actor's gaze direction and kinematic cues to produce proactive eye movements.

Acknowledgement: Research supported by EU grant (FP7-ICT-217077-Eyeshots).

Perceptual Organization: Grouping

Tuesday, May 12, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

53.447

The dwell time for the whole is LESS than for the sum of its parts

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The grouping of image parts into a perceptual whole can help to deduce an objects' shape when it is only partially visible. Here we studied the temporal characteristics of the process of grouping parts into wholes by measuring eye movements during visual search. Visual search for an occlusion-defined surface among non-surface stimuli can proceed efficiently across the visual field, that is search times show little dependence on the number of items (Davis & Driver, 1994). However, search for a target surface among other surfaces is inefficient (Gurnsey, Poirier & Gascon, 1996). We asked whether the grouping of parts into wholes might speed visual search compared with a condition that contained identical local parts that could not be grouped into wholes.

We measured reaction times and eye movements while participants (n=12) were searching for the odd-one-out target (singleton) among a field of uniform distracters (4, 8, 12 items). Search items were Varin inducers of illusory contours that were either properly aligned (whole condition) or outward pointing (part condition). The target-defining feature was a difference in the inducers' openings (+/- 10° from 90°) which corresponded to a difference in the perceived shape enclosed by aligned inducers.

Search was inefficient for both, a whole among wholes, or a part among parts, but the time required to find the singleton increased at only half the rate in the former condition. However, the dwell times per item – as estimated by the slopes of linear fits to individual reaction times – slightly overestimated the difference in fixation duration between the whole and part condition (~140 vs. 260ms). Fixation durations that were calculated directly from the eyes' scan path yielded a difference of 60ms between fixations of wholes (140ms) and parts (200ms). Therefore processing of the perceptual whole did indeed need less time than processing of the individual parts.

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53.448

Grouping thresholds are several times larger than detection thresholds - a new approach toward the psychophysics of Gestalten

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Two experiments were performed to compare detection thresholds for spacing or size with thresholds for grouping. Stimuli were horizontal chains of 12 black dots or circles that were varied either in inter-dot distance or size. Three naïve observers served as subjects. In the first experiment, the distance after the 3rd, 6th, and 9th dot was increased in random steps to determine the threshold at which the observer detected the difference in spacing. Thereafter, spacing was increased further to find the threshold at which the observer perceived 4 groups of 3 dots each. The method of constant stimuli was used with "regularly vs irregularly spaced" as response criteria. Each condition was repeated 5 times. Dots had a diameter of 27.50 arcmin, a spacing of 34.38 arcmin and were presented for 1 s. Fixation was in the center slightly below each chain. Results: The detection threshold for the cumulated data was 38.16 arcmin, while the grouping threshold was 48.26 arcmin. This difference translates into a factor of 3.7. In the second experiment, a chain of empty circles was used and the size of the 4th - 6th and 10th - 12th circle randomly increased to measure the threshold for either detection or grouping. The method was the same as before. Circles had a diameter of 27.50 arcmin and were spaced at 82.50 arcmin. Results: Here the detection threshold was 28.32 arcmin, while the grouping threshold was 33.55 arcmin. This difference translates into a factor of 7.4. Conclusion: The results of both experiments demonstrate that the threshold for perceiving stimuli as irregularly spaced or dissimilar in size is not the same as the threshold for grouping. In order to perceive stimuli as grouped, stimulus differences had to be approximately 4 times (for dot spacing) and 7 times (for size) larger than for detection.

53.449

The role of Gamma oscillations in binding ambiguous visual input into coherent percepts

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The question as to how isolated features are bound into coherent object percepts presents a challenge to contemporary neuroscience. Several theoretical and experimental accounts have suggested that oscillatory neural activity in the Gamma range is functionally related to such object integration. Typically, however, such studies cannot fully disentangle stimulus-related (bottom-up) from higher cognitive (top-down) factors. Here we overcome this issue by using an ambiguous figure, whose perceptual interpretation - in the absence of any stimulus changes - alternates between a bound object (moving diamond) and individually moving apertures. Participants indicated these endogenously generated switches, while we recorded high-density EEG. We find a decrease of Gamma power in a narrow band around 40 Hz starting about 500ms before the report of perceptual switches, clearly

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preceding any motor-related (alpha, mu) activity. This implies a tight temporal coupling of Gamma activity to the process of top-down object binding under ambiguity. This is in line with the purported role of Gamma oscillations in object binding, and additionally suggests a function of Gamma activity in resolving perceptual ambiguity.

53.450

Spatial overlap of collections affects the resolution of ensemble features

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Goal: Collections of visual objects can be grouped and statistical properties of the group encoded as ensemble features (e.g., average orientation, centroid, approximate number of items). While features from multiple salient groups may be stored (Chong & Treisman, 2005; Halberda, Sires & Feigenson, 2006), spatial separation between groups may affect group selection (Watson et al, 2005). We investigated the effects of degree of spatial overlap between two groups, specified by color, on the discrimination threshold for the ensemble features of average size and approximate number.

Methods: Subjects (N=44) performed either an average size or approximate number discrimination. Trials varied the ratio of both average size and number across two briefly flashed collections (blue and yellow dots) while trial blocks varied the degree of spatial overlap between these two collections, the density of items, and the size of the display area. Accuracy and RT were recorded and the discrimination threshold for each subject was determined for each block.

Results & Conclusions: For number discrimination, analyses revealed a significant effect of overlap ($p < .0001$), and no effects of density or display area for both accuracy and RT. Weber fraction remained fairly constant across blocks as the two sets moved close to one another and then rapidly decreased when the two sets became completely overlapping. Results for average size were similar to number for RT measures ($p < .01$), but showed no effects for accuracy. One possibility is that subjects could adopt strategies focused on individual item sizes for computing the average size of dots (Myczek & Simons, 2008) while such strategies are not possible for computing approximate number. These results suggest that, while encoding features from more than one collection may be possible, features encoded from spatially localizable collections are more accurate than those from spatially overlapping collections.

53.451

Grouping oranges affects their overall appeal

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As we go about our grocery shopping, items are often grouped together, such as cans of soup or bunches of oranges. Does this grouping influence the perceived desirability or attractiveness of the objects? In an experiment, we examined the influence of grouping oranges on their overall appeal. Specifically, we compared whether a group of oranges appeared more or less attractive than individual oranges that comprise the set. Observers rated the appeal of briefly presented single oranges, and heterogeneous and homogeneous groups of 4 to 32 oranges. Individual oranges were drawn from a set of images ranging from “ripe” to “moldy.” When the average rating of a set was compared to the averaged ratings of the set members, the averaged ratings of individual set members were generally perceived to be more appealing than the overall average rating of the set. Further, ratings became compressed as sets became more heterogeneous, such that “ripe” sets were rated less appealing than their individual counterparts, and “moldy” sets were rated as more appealing than their individual counterparts. Our results suggest that the perceived attractiveness of a group is less than the sum of its parts, such that presenting objects in groups rather than isolation can bias their perceived attractiveness.

53.452

Perceptual Grouping During Multiple Object Tracking

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Previous research has suggested that perceptual grouping may significantly aid performance in Multiple Object Tracking (MOT) tasks. That is, observers may track multiple items by spontaneously grouping disparate items into a single “virtual object”. According to this hypothesis a virtual polygon is initially created and then updated during tracking, with the vertices of the polygon consisting of the tracked elements (Yantis 1992). Recently our lab has demonstrated an ERP component, the CDA, sensitive to the number of successfully tracked items in a MOT task such that the amplitude of the component increases with increasing set size up to the individual subject’s tracking capacity (Drew & Vogel 2008 J. Neuroscience). Here, we investigated whether a real or virtual polygon between targets in a tracking task would enhance behavioral performance and reduce tracking load (as indexed by a reduction in amplitude of the CDA). We found that the the presence of actual grouping lines connecting the three targets in a MOT task reduced tracking load when the lines were present as compared to when they were absent. These results suggest that perceptual grouping does indeed play a role in tracking, but this role may be primarily restricted to situations when there are strong bottom-up cues for grouping the objects together.

53.453

The functional asymmetry of the lower and upper visual fields in attention and perceptual grouping

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Evidence from monkey and human studies reveals two functionally distinct cortical streams in processing visual information: a dorsal attention pathway (‘where pathway’) and a ventral object perception pathway (‘what pathway’). Anatomically, the ventral pathway receives inputs mainly from the upper visual field (UVF), whereas visual information in the lower visual field (LVF) is largely projected to the dorsal pathway. We therefore hypothesized a functional asymmetry between LVF and UVF as the shape analysis was more efficient when stimuli presented in the UVF whereas attentional modulation was more prominent in the LVF. To test this hypothesis, we used fMRI to measure subjects’ neural activity in the primary visual cortex retinotopically corresponding to Gabor patches presented in the UVF and LVF respectively while they judged the Vernier alignment between one pair of Gabor patches presented in a 45 or 135 degree titled axis and ignored the other pair orthogonal to the first one. Irrelevant to the task, a centrally-presented Gabor patch was either in line with or orthogonal to the Gabor patches to be judged. As expected, we found retinotopically corresponding regions of a Gabor patch in the primary visual cortex showed a higher response when the patch was either attended (versus ignored) or aligned with (versus orthogonal to) the center patch, suggesting that the primary visual cortex is involved in both attentional modulation and perceptual grouping. However, the attention effect was significantly larger when the patch was presented in the LVF than in the UVF, whereas the grouping effect showed an opposite pattern as the grouping effect was larger in the UVF. This asymmetry suggests that attention and grouping are indeed two separate functions, although they both manifest similar characteristics in processing visual information.

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53.454

Dynamic Visualization of Perceptual Organization

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Gestalt psychologists described Perceptual Organization as a dynamic process in which features of the visual world are grouped and structured (Wertheimer, 1923; Kohler, 1920). Modern-day perceptual organization

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experiments infer the operation of perceptual organization by asking observers to judge features of static displays (e.g., Palmer, 2003; Kubovy and Gepshtein, 2003; Kimchi, 1998). The experiments in this paper explore the generative aspects of perceptual organization. To do so, 72 observers participated in an on-line experiment in which their task was to actively manipulate the nodes of a network diagram until the structure of the visualization they created captured the structure in the data. The data sets for the network diagrams each contained two clusters, that is, groups of nodes that were highly inter-dependent. If perceptual grouping is a dynamic process, then observers should actively uncover the clustered structure within the data and accurately organize the nodes into two subgroups. To study the strength of this process, we varied the difficulty of the task by introducing 1, 2, 3, or 4 "masking" edges connecting the subgroups. We found that, independent of the level of masking, observers were able to recover the grouped organization of the data, and created network layouts that accurately separated the two subgroups. Observers further organized the nodes to reduce line-crossings, thereby reducing clutter and increasing clarity about node connections. Moreover, 80% used the edges in their constructs to create an encircling convex hull around the clustered groups, reinforcing the perception of two separable structures. This active-manipulation paradigm provides insight into the dynamic process of perceptual organization, and offers a promising tool for future studies.

Temporal Processing: Mechanisms

Tuesday, May 12, 8:30 am – 12:30 pm
Poster Session, Vista Ballroom

53.501

The Unveiling of Transient Channels at High Spatial Frequencies by Contrast Masking and Contrast Adaptation

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The lowpass spatio-temporal contrast sensitivity function (CSF) of the visual system for high spatial frequency signals has led some authors to posit that a single spatio-temporal channel is able to explain visual perception when testing at the higher spatial frequencies. We have re-examined this assumption through contrast masking and contrast adaptation experiments. When masking, the contrast of the mask as a function of temporal frequency (TF) was inversely scaled to a proportion of the CSF in an attempt to whiten the spatio-temporal masking response of the visual system's spatio-temporal processes. The detection contrast of 1 Hz and 10 Hz probes whose mean spatial frequency was 16.0 cpd, was then measured using a 2AFC paradigm. The mean luminance of the display monitor was 400 cd/m2. At low mask contrasts (multiples of 2 times threshold), and after inverting the contrast scaling of the masks, the masking functions for both probes were found to be lowpass functions of TF. For maskers whose contrast was set at a multiple of 16 times threshold contrast, however, the probes exhibited sustained and transient masking functions. In examining threshold contrast elevations as a function of adaptor (0-38 Hz) and test (0-19Hz) TFs for one-dimensional highpass spatial frequency signals, we further demonstrate the presence of an adaptable transient TF tuned channel whose peak lay around 12.0 Hz. Collectively, our results unveil significant transient but hidden characteristics of the visual system that we explain as an emergent property of an adaptable system in which transient and sustained processes lie in cascade.

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53.502

Spatial tuning of adaptation-induced temporal compression

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Adaptation to high temporal frequency reduces the perceived duration of sub-second intervals. Here we explore the effects of changing spatial scale and configuration. To measure perceived duration, a grating (10Hz, 600ms) was presented at one side of fixation and the duration of a comparison, presented on the other side, varied over trials (10Hz, 350 – 850ms) to generate a psychometric function. The 50% point provided a measure of the perceived duration of the standard. To investigate small-scale lateral interactions, the standard was preceded by a mixed adaptor (20Hz interleaved with 5Hz to avoid changes in perceived temporal frequency) placed at the same position or completely above or below (0.75º, 1.50º, 2.25º). We found that the spatial tuning of the temporal compression at fine scales was a good fit to a Gaussian and remarkably tight (mean of 3 subjects; $\sigma = 0.59^\circ$, R2 = 0.996). We also investigated adaptor size. The adaptor and stimulus height was 0.05º, 0.25º, 0.50º and 1.50º while the width was fixed at 5º. The standard was always completely overlapped the adaptor. We found little difference in compression across conditions. Even very thin adaptors produced significant duration compression. Finally, we measured the amount of temporal compression for a centre-surround spatial configuration. The adaptor was always presented in a central disc. The standard was located in an abutting annulus. We either changed the diameter of the adaptor (2º, 5º, 8º) keeping the outer diameter of the test stimuli at a fixed value (9º) or fixed the adaptor 5º and varied the outer diameter (6º, 7.5º, 9º). We found that the adaptor produced a reduction in the perceived duration for thin annuli. This effect disappeared or even induced a small temporal expansion in thicker annuli. The fine spatial tuning indicates an early locus for the temporal compression effect.

53.503

Distinct spatial association fields for harmonic motion and harmonic contrast

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Background: Spatial association fields (SAFs) describe perceived grouping strength between texture elements as a function of their joint position and orientation/direction. However, SAFs have only been measured in the "sustained" regime with cues such as static or constant-motion elements. Here, I investigated properties of SAFs in the "transient" regime using harmonic motion and harmonic contrast.

Methods: Stimuli consisted of two texture elements, each of which was composed of a static grating and a dynamic (5-Hz counterphasing) grating. Manipulating the spatial phase of the static grating produced time-varying oscillations either in motion or in contrast while sparing properties of the dynamic grating. Observers performed a two-interval forced-choice task and reported the element pair with greatest harmonic coherence (i.e., maximum synchrony). Coherence thresholds were measured at the 75%-correct level for all combinations of 3 inter-element distances, 3 orientation/direction angles for the first element, and 8 orientation/direction angles for the second element.

Results: When both elements underwent harmonic motion, the SAF was highly direction selective and tuned for direction similarity regardless of relative element position. When both elements underwent harmonic contrast, the SAF was nonselective for orientation. For both harmonic types, grouping strength decreased with inter-element distance. When elements of a pair underwent different harmonic types, observers were strictly unable to judge element coherence. This finding is surprising given that dynamic gratings are physically unaffected by harmonic type.

Conclusions: Unlike grouping across sustained cues, grouping across transient cues requires exquisite sensitivity to the relative timing of events across the visual field. Correspondingly, SAFs for transient and sustained cues have markedly different properties that may reflect distinct underlying neural mechanisms. The inability of observers to integrate across harmonic motion and harmonic contrast supports the notion of distinct grouping pathways in the transient-cue domain.

Acknowledgement: This work was supported by COBRE grant P20 RR20151-02 from the National Institute of Health (NEI) to the Center for Visual Neuroscience at North Dakota State University.

53.504

Spatial aspects of perisaccadic chronostasis

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Visual perception is modulated during saccadic eye movements. The threshold for luminance contrast is increased and the perceived location of briefly flashed visual stimuli is shifted or compressed in space. Recent studies showed that also temporal perception is massively influenced perisaccadically. The duration of stimuli presented at the endpoint of saccades is overestimated when presented near saccade offset. This effect, termed chronostasis, does not occur for stimuli presented at the midpoint of the saccade trajectory.

It is currently discussed whether different perisaccadic effects on visual perception might be more directly related than previously thought. This could imply similar spatial dependencies across different perceptual effects. We recently showed that perisaccadic contrast thresholds are modulated by the stimulus position, with the weakest threshold elevation occurring near the midpoint of the saccade trajectory. We hence explored whether saccadic chronostasis, like saccadic suppression, does occur at positions other than the saccade target.

Eye movements were recorded in subjects with an infrared eye tracker running at 500 Hz. Subjects initially fixated a target on the horizontal meridian. A variable time after trial onset subjects were cued to make a 25° saccade towards a saccade target. A low luminance stimulus was constantly shown at the fixation point or at the saccade target throughout a trial. The luminance of the stimulus was perisaccadically increased for a variable duration (test stimulus). After a delay an otherwise identical probe stimulus was shown for 500ms at the same location. Subjects indicated whether or not the test stimulus was longer than the probe.

Perceived duration was prolonged peri- and postsaccadically at both the saccade target and the initial fixation point as compared to fixational controls. We conclude that saccadic chronostasis is not restrained to the saccade endpoint and hypothesize that the duration of visual intervals is perisaccadically overestimated across space.

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53.505

Phantom flashes caused by interactions across visual space

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Studies have shown that the perceived value of some feature of a target stimulus, such as its color or orientation, can be modulated by stimuli around it. We wondered if such interactions were limited to modification of features, or if there are conditions under which these interactions can cause one to see a stimulus when none, in fact, occurs. Two disks were presented in two separate locations directly below fixation—a “central” location closer to fixation and a “peripheral” location farther away. Each disk was flashed a variable number (0-4) of times on a given trial. In separate blocks of trials, observer reported either the number of central or peripheral targets perceived. The near-foveal and peripheral visual signals influenced one another: when the target flashed once and the distracter more than once, observers often perceived two or more target flashes. The perceptual bias was asymmetric: A single flash in the center accompanied by multiple flashes in the periphery was perceived as multiple flashes, but multiple flashes in the center accompanied by a single flash in the periphery was not perceived as a single flash in the center. The asymmetry argues against an explanation based on cue integration, a framework often used to explain the audio-visual flash illusion that inspired this study. Moreover, whereas an auditory stimulus affects visual perception only when the numbers of flashes and beeps differ by one, here the peripheral flashes affected the perception of visual stimuli near the center even when the numbers of flashes in the two locations differed by two. The findings indicate that a) different locations in visual space interact in complex ways to radically alter visual perception, and b) the interaction between visual stimuli in different locations is of an inherently different nature than that between vision and other modalities.

53.506

Contrast gain not contrast change induces apparent temporal compression

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The apparent duration of an interval containing a 50% luminance contrast grating drifting at 20Hz is compressed when preceded by a 90% contrast interval as compared to when preceded by a 10% contrast interval (Bruno & Johnston, 2007, Journal of Vision, 7(9): 376a). We linked this effect to contrast gain control mechanisms that are known to shorten the primate temporal impulse response in M cells, but not in P cells (Kaplan & Benardete, 2001, Prog Brain Res, 134:17-34). If true, we should not expect an effect of a static inducer on duration perception. Indeed, a 10% or 90% contrast static inducer had no significant effect on the perceived duration of a 50% contrast test drifting at either 5 or 20Hz. Also, we measured the perceived temporal frequency of a 50% contrast interval containing drifting motion when it followed either a 90% or a 10% contrast interval containing oscillating motion. We observed no significant difference in apparent speed for 20Hz drift, which induces temporal compression, as compared to 5Hz drift, which does not, indicating changes in temporal frequency are not critical for time compression. We also found a significant reduction in apparent contrast followed the 90% contrast interval, but no change after a 10% contrast inducer for both 20Hz and 5Hz drift. Thus changes in apparent contrast per se do not induce changes in duration. Finally, we asked the subjects to directly compare the duration of a 10% contrast interval with a 90% contrast interval containing drifting motion. No significant difference in apparent duration between 5 and 20Hz was observed. Our results show that contrast gain, but not contrast per se, has an effect on duration. This effect is limited to moving stimuli implicating the magnocellular pathway and is not mediated by changes in perceived temporal frequency or perceived contrast.

53.507

Perception of Temporal Structure is Distorted Early in the Visual System

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Previously, we reported that human observers misperceive the temporal order of briefly presented adjacent visual stimuli that differ in duration. Our manipulation used ramped temporal envelopes (Gabor and Gaussian) to present the stimuli, and the induced temporal asynchrony (~100 ms) was orders of magnitude larger than known thresholds for detecting temporal order with visual stimuli of equal duration (~ 4 ms). We suggested that this sizable effect could be a direct result of early visual processing in the magnocellular visual pathway.

Here, we present new experiments investigating the perceived temporal structure of brief visual events. In support of our hypothesis, we present evidence that the magnitude of induced temporal asynchrony of ramped stimuli increases when energy is shifted to lower spatial frequencies. This finding is predicted by the temporal processing characteristics of early visual mechanisms that prefer different spatial frequencies. We also investigate perceived temporal order with stepped stimuli and a slightly different task, in which observers must judge the temporal order of a stimulus onset or offset relative to an ultra-brief flash. We find that step onset is delayed and step offset is advanced as compared to the flashed stimulus. These non-veridical temporal percepts are described in terms of a model of temporal processing in pre-cortical visual pathways.

53.508

Top-down modulations in perception of simultaneity

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The claim that temporal aspects of perception are sensitive to top-down influences is supported by several pieces of evidence regarding perception of temporal order. This evidence includes modulations of temporal displacements by attention (the prior entry effect; Titchener, 1908) and by schemata obtained from experience (Pechenkova, 2008; Caldwell-Harris & Morris, 2008). Would there be similar evidence in perception of simultaneity and succession? To answer this question, we tested potential effects of two methods of top-down stimuli grouping.

In the first experiment, left and right halves of 6-letter strings (Russian nouns and nonword anagrams of the same words) were presented for 25 ms each with SOAs from -59 to +59 ms or simultaneously. Participants performed a 2AFC task, indicating whether they saw two parts of a string as simultaneous or successive. 75% threshold for perceived simultaneity and difference thresholds were measured by method of constant stimuli. The results showed that when letters form a word, subjects tend to report 'simultaneity' on larger SOAs than for nonwords. Comparison of difference thresholds shows that this effect is not just a response bias.

The second experiment tested whether biasing the perceptual organization of a bistable figure (Rubin vase) would affect the perception of simultaneity or succession of its component parts. Bias to see either a central vase or two faces was created within two separate blocks of trials by both verbal instruction and introducing real vases or faces as filler images. The presentation timing and task were identical to the first experiment. There was a slight tendency for more 'simultaneity' reports in face than vase condition.

Results from both experiments indicate that top-down modulations can change perception of simultaneity vs. succession. However, different materials and ways of grouping produce controversial effects. Possible explanations of these effects and reasons of the discrepancy will be discussed.

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53.510

The perceived duration of a stimulus depends on temporal context

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We here report a new class of duration illusion in which the subjective duration of a flash is modulated by up to 30% as a function of its temporal relation to a longer flash. When a brief flash occurs in the presence of a longer flash, its perceived duration is expanded for longer stimulus onset asynchronies (SOAs) and contracted for shorter SOAs. This pattern of perceived duration distortion appears to be related to the hazard function, which describes the probability of an event occurring given that it has not yet occurred. To test this possibility, we varied the probability distribution function of SOAs presented in an experiment session and compared the measured duration distortion to the duration distortion predicted by a model based on the hazard function. Our findings parallel a previous demonstration that perceived brightness is modulated by temporal context (Eagleman et al., 2004), suggesting the possibility of a common mechanism for continuous magnitude comparisons. Other stimulus attributes related to magnitude, such as size and numerosity, may also exhibit illusory changes in perceived magnitude as a function of temporal context.

53.512

Style follows content revisited: Evidence from an ERP study

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To find out what characterizes art from a vision scientist's point of view, it seems important to contrast the processing of style and content in art. While the perception of content (motif) presumably shows strong similarities to normal object and scene perception, style is an aspect that is art specific and that may thus trigger art-specific processing (Augustin, Leder, Hutzler, & Carbon, 2008). Results from a recent study (Augustin et al. 2008) suggest that the processing of content precedes the processing of style, with judgments of similarity for picture pairs reflecting differences in content at shorter presentation times than differences in style. The current investigation tried to find out whether this result is also supported by brain correlates of motor preparations related to explicit classifications of style and content.

We adapted a Dual Choice- Go/No Go paradigm (van Turennout, Hagoort, & Brown, 1998), in which one stimulus dimension determines whether to react or not to react (Go/No Go) and the second dimension determines which hand to react with in Go-trials (left/right). We assessed lateralized readiness potentials (LRPs) as brain correlates of hand-specific response preparation. The results suggest information about content to be available earlier than information about style: There was a significant LRP for No-Go trials in cases where style determined the Go/No Go decision and content determined the left/right-decision, but not in those cases where the task assignments of style and content were switched. These results support the finding that style follows content in the processing of art (Augustin et al., 2008), probably reflecting the optimization of the visual system for object and scene perception as opposed to style perception.

53.513

When an effect precedes its cause in consciousness

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An optimal correspondence of temporal information between the physical world and our perceptual world is an important factor for survival. It is generally agreed that the perceived temporal order of events is linked to our concept of causality: by Nature's law, the cause precedes the effect in time. Does the same temporal order necessarily hold in our perceptual awareness? Previous studies have revealed specific discrepancies between physical time and time perception. However, the relationship between the perceived time of events and the dynamic state of their neuronal representations remains largely unexplored. In the current psychophysical study, we demonstrate a striking phenomenon in which the cause of a perceptual event is perceived after the event itself. We used a paradigm referred to as motion-induced blindness (MIB) in which a static visual stimulus presented on a constantly rotating background disappears and reappears from awareness periodically, with the dynamic characteristics of bistable perception. A sudden stimulus onset (e.g., a flash) presented during a period of perceptual suppression (i.e., during MIB) is known to trigger the almost instantaneous reappearance of the suppressed stimulus. Surprisingly however, we report here that although the sudden flash is the cause of the reappearance of the static target (the corresponding effect), it is systematically perceived as occurring after this reappearance. In other words, the distinct neural signatures of conscious and unconscious events in the brain result in a perceived temporal order that contradicts the causal relation between the two events. This illusion thus sheds important light on the neural mechanisms of time perception and visual awareness.

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53.514

On the perception of temporal visual events

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Introduction and Motivation. In the mid-20th century while attempting to determine the development of the concept of time in children, Jean Piaget demonstrated that children under eight years of age are unable to perceptually discern the speed and time traveled of simple objects. For instance,

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when viewing two simultaneously moving objects (A and B), where both objects start and stop at the same time but A is moving faster than B, the child will report that A traveled longer due to the perceptual entanglement between space and time. Indeed, there is a multitude of instances in which conscious visual experience can be demonstrated to deviate significantly from the actual course of events, such as perisaccadic mislocalization, multi-modal visual illusions, and the misperception of object size in 3D scenes.

Methods. Following Piaget's example, in the present study, we explore the ability of healthy adults to discern differences in speed and travel duration of two simple cartoon cars presented on a standard monitor (100 Hz refresh). Ten speed levels and ten travel durations in both sequential and simultaneous presentation conditions were tested. At the end of each trial, subjects were asked to indicate which car had traveled faster and which had traveled longer. Subjects were also tested in a cross-modal version of the experiment in which the pitch and duration of an engine sound attempted to mislead subjects' perception.

Results. Preliminary results demonstrate that during trials in which both cars travel simultaneously, subjects perform with a high degree of accuracy. However, during sequential presentation, subjects' perception of relative speed is degraded in relation to perception of relative travel duration. Furthermore, both sound pitch and sound duration significantly degraded subjects' perception of both speed and travel time, with sound pitch inducing a greater distortion in perception than sound duration.

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53.515

Auditory dominance in time perception

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Visual stimuli are judged to be shorter than auditory ones. We used this well-known phenomenon to understand how auditory and visual signals contribute to perception of duration. Specifically, what duration is perceived when auditory and visual stimuli coincide (the visual or the auditory perceived duration?), and to what degree does selective attention modulate the influence from each modality? Visual and auditory stimuli of different durations (0.2 to 1 s) were either presented coincidentally or separately, and observers judged their durations in a 2AFC temporal-bisection task (typically used in the time-perception literature). Regardless of whether the auditory stimulus was stronger, subjectively matched, or weaker compared to the visual stimulus, perceived durations of auditory-visual stimuli were always the same as those of auditory stimuli presented alone. This refutes the hypothesis that auditory stimuli are perceived to be longer because they are more salient than visual stimuli, and also indicates that auditory signals dominate in time perception when a stimulus is redundantly presented through auditory and visual modalities. Can selective attention overcome this auditory dominance? We made the durations of the auditory and visual stimuli different in the bimodal condition and asked observers to judge durations of the visual stimuli. Only when the auditory stimuli were weaker (although strong enough to dominate time perception in the absence of selective attention) and were temporally embedded within the visual stimuli were observers able to filter out the auditory modality and correctly judge visual durations. Our results thus suggest that time perception predominantly depends on auditory signals regardless of the relative salience of the auditory and visual signals, attention to the visual modality is only effective under limited conditions. These limitations may be accounted for by differential use of auditory and visual modalities in naturalistic object perception.

Perception and Action: Decisions and Frames of Reference

Tuesday, May 12, 8:30 am – 12:30 pm
Poster Session, Vista Ballroom

53.516

Comparison of perceptual and motor decisions via confidence judgments and saccade curvature

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A major challenge in cognitive sciences is the appraisal of the relationship between perception and action and of the subtending biological processes. Here we address this general issue by investigating the link between the subjective visibility of close to threshold distractors and the trajectory parameters of saccades directed to a highly visible target. This study investigated the effects on perceptual and motor decisions of low-contrast distractors, presented 5° on the left and/or the right of the fixation point. Perceptual decisions were assessed with a Yes/No (distractor) detection task. Motor decisions were assessed via these distractors' effects on the trajectory of an impending saccade to a distinct imperative estimulus, presented 10° above fixation 50 ms after the distractor(s). Results show that saccades curve away from distractors only when observers report them to be present(perceptual Hits and False Alarms). Furthermore, saccade deviation is correlated (on a trial-by-trial basis) with the inferred internal response associated with the perceptual report: the stronger the distractor-evoked perceptual response, the more saccades deviate away from the distractor. Also, in contrast with a supersensitive motor system, perceptual sensitivity is systematically higher than the motor sensitivity derived from the distributions of the saccades' curvatures. When both distractors are present (and straight saccades are expected), the sign of saccades' curvature is correlated with observers' perceptual bias/criterion. Overall the results point to a strong perceptual-motor association and demonstrate that saccade trajectories betray observers' perceptual state.

53.517

Switching from reactive to intentional responses

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How does one switch from a reactive to a proactive/intentional response mode? An annular 'gauge' fills in within time T. Subjects must press a button in synchrony with the completion of the filling in. Equivalently, they have to press a button in synchrony with the last of a series of 3 equally paced light-flashes (pairs of Gaussian blobs displayed so as to form a hexagon) of period T. T is random across trials (from 0 to 500 ms). Response Time (RsT) – measured from the onset of the gauge or of the second event in the sequence of 3 – is T-independent up to E = RsT(T=0)+K and equals T thereafter. E is the 'elbow' of the RsT(T) function. It reflects the timing of the operations performed for deciding to switch from the reactive to the proactive response mode including subjects' introspective estimation of their Reaction Time, RT (assessed in independent experiments) to the gauge and to the 3-events stimuli. RsT(T=0) is RsT at T = 0 and is about 70 and 16 ms longer than the RT to these two stimulations, respectively. K ≈ 30 ms in both experiments. Based on a simple sequential processing model, these data allow the inference of the 'time-to-impact'/velocity computation (in the gauge experiment; ≈ 60 ms), the bias of the introspective RT estimation (≈ +30 ms) and the decision time to switch from the reactive to the intentional response mode (≈ 20 ms). This paradigm unveils the introspective nature of deciding between re-acting and postponing action.

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53.518

Interactions between decision criteria estimated using external noise methods

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In simple detection tasks observers presumably use a subjective decision criterion based on their noisy internal response, setting a boundary between "yes" and "no" responses. The variability of this decision criterion cannot be directly assessed in a fixed stimulus paradigm. Here, we used external noise to model internal responses, so that criteria can be unambiguously identified in the stimulus space. This also allowed the direct assessment of the interactions between criteria assigned to different targets in conditions where two detection tasks were mixed in a single testing session (Gorea & Sagi, 2000).

Observers were presented with two luminance flashes, one on each side of fixation, with their amplitudes randomly drawn from either "Signal" or "Noise" Gaussian distributions. Flashes were presented within a red and a green circle whose color marked the two Signal/Noise distribution pairs that differed in their variances and/or means. Observers reported whether the flash enclosed in the circle with delayed offset belonged to the corresponding Signal or Noise distribution (partial report). Signal mean and variance differed across the two tasks by a factor of 1 to 3.5. Observers were informed about the differences between Signal means.

For naïve observers the two criteria measured within the dual task were found to be very close, deviating significantly from the close-to-optimal ones observed with a single target. Observers familiar with Signal Detection Theory and stimulus parameterization did not show such interactions. As the present unidimensional external-noise task allows for the use of a stimulus-intensity level as a decision criterion, expert observers may set their criteria in stimulus space while naïves do so internally, as is the case for all observers when only internal noise is present and suboptimal performance is observed. Our results reject a previous suggestion that in multiple detection tasks observers simply match their false alarms rates across tasks.

53.519

Dynamics of decision criterion setting in a detection task

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Performance at a detection task is characterized by signal detection theory with two standard measures: the d' measuring sensitivity and the decision criterion measuring response bias.

It has previously been shown that decision criterions interact when targets with different sensitivities are mixed. In the present study, we aimed at characterizing the variation of the decision criterion following a change in the experienced signals.

We designed a detection task where 8 subjects had either to discriminate low-sensitivity targets from non-targets (in weak target blocks), or high-sensitivity targets from non-targets (in strong target blocks). Weak target blocks and strong target blocks alternated without any noticeable transition, and we varied the length of these blocks as our main experimental factor. We modeled criterion adjustment as resulting from the leaky integration of signals in the past trials, with two parameters: λ reflecting the criterion sensitivity on past experience and τ reflecting the time constant of the leaky integration function.

The behavioral results showed that subjects' criterion varied according to the stimuli recently encountered. In the long blocks condition, criterion was higher in long blocks with strong-targets than in long blocks with weak-targets. In the short blocks condition, criterion decreased through blocks with weak targets and increased through blocks with strong targets.

Different model parameters were found to fit behavior in the long and short blocks conditions, suggesting that in the long blocks condition subjects integrated signals over a large number of trials to slowly change their decision criterion and in the short blocks condition subjects integrated signals over a small number of past trials to quickly change their decision criterion.

These results confirm that subjects adapt their decision criterion dynamically to recently experienced stimuli. Moreover, they show that the dynamics of criterion adaptation itself are modulated by the frequency of change in stimuli.

53.520

The effect of reward structure on sequential decision-making

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Human decision-making is often suboptimal in sequential tasks where the more rewarding option must be learned through the experience of successes and failures and the goal is to maximize reward. Rather than learning and exploiting the better option, humans typically persist in selecting less-rewarding options, even after thousands of trials. However, because successfully learning the better option often requires maintaining highly accurate estimates of reward over time, this raises the possibility that the fundamental nature of the given reward distribution, as well as the fidelity with which the rewards are encoded and retained may play a role in decision suboptimality. To test this hypothesis, we provided subjects with either graded (e.g. any value between 0 and 25 is possible) or discrete (e.g. only values of 0 or 25 are possible) rewards. Distributions that contribute to noisy estimates of mean reward should impair decision-making performance. Participants played a game in which they piloted a ship and attempted to destroy a target by repeatedly shooting the target with one of two types of bullets. Unbeknownst to the subject, on average one bullet type did more damage to the target than the other. Four variations of the task awarded damage points via simulated draws from binomial, normal, uniform, or beta distribution functions. The distributions were matched so that the mean damage as well as the variability in small sample estimates of the mean was equivalent for all distributions. Consistent with our hypothesis, a comparison of decision-making performance across conditions indicates that decision-making is closer to optimal when rewards are drawn from the less noisy continuous functions.

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53.521

Promoting Optimal Decision Making By Reducing Unexplained Variability in Outcome

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Human behavior in binary choice tasks is notoriously suboptimal. Given repeated choices between two options, one with a higher probability of being the correct option than the other, the obvious optimal solution is to choose only the higher probability option. Interestingly, this optimal strategy is rarely observed. The more typical finding is that subjects sample the options in proportion to their respective probabilities of being correct - a tendency known as probability matching. While standard models in the field posit that subjects in decision making tasks simply collect outcome statistics and base their decisions upon those statistics, we propose that individuals have a natural propensity to not just simply learn the outcome statistics, but instead attempt to build a causal model that can reduce unexplained variability in outcome. Only when this unexplained outcome variability is sufficiently reduced will behavior approach optimal. We tested this hypothesis by comparing subject performance in various conditions that had identical outcome statistics, but differed in the degree to which they fostered the creation of compelling causal models that could explain the statistics. As predicted, subject behavior was significantly nearer to optimal in the condition where a natural causal model existed than in conditions where no such model could be formed.

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53.522

Response demands do not influence perceived illusory motion in cognitive-based tasks

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At VSS 2008, we presented a method using illusory motion (the Duncker illusion) to study the visual pathways serving cognition and action. Subjects' responses were influenced by illusory motion when asked to report the trajectory of a target using a cognitive-based task, but were not influenced by the illusion in a motor-based task. The purpose of the present study was to determine the magnitude of the illusory effects for cognitive-based tasks that are more comparable to the motor-based task. Our previous cognitive-recall task could have been influenced by "relational momentum," defined as an over-extrapolation of displacement when a target passes behind an occlusion. To address this, we had subjects perform an additional cognitive-recall task in which they were to select the location on the display where they last saw the target before the display concluded. This is different from our previous method because rather than extrapolating to the location toward which the target seemed to be heading, the subject directly chose the last remembered location. In an additional cognitive-recall task, subjects were asked to estimate the target's trajectory. After conclusion of the display, subjects drew a line parallel to the remembered slope of the path of the target. Using this task, we examined how the subject perceived the trajectory of the target, rather than simply the remembered end position of the target. All subjects reported illusory motion for both tasks; therefore we believe our experiments allow separate examination of the visual pathways utilizing comparable methods. Given these results, we have begun to look at how each of the pathways handle extraneous noise in a display.

URL: http://tigger.uic.edu/~mikel/VSS/VSS2009_JA.pdf

53.523

Evidence for the primacy of the motor system in visual time perception

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If perception is the interpretation of sense data, a fundamental question for neuroscience is how we perceive time, because there are no time sensors on the body. A popular view is that timing information is distributed in the dynamics of brain activity and thus can be distorted for each modality independently (Ivry & Schlerf, 2008; Eagleman, 2008; Pariyadath & Eagleman, 2007). Using the visual oddball paradigm, I replicate earlier work showing a visual event's duration can be distorted by a factor of 1.5 (Tse, Intriligator, Rivest & Cavanagh, 2004) but extend the work to show crossmodal interactions with the motor system. When people view stimuli known to produce time distortion, they are reliably slower at responding to the onsets than the offsets, and furthermore they are faster at these onsets compared to the onsets for matched events that do not produce time distortion (r2=0.81). However, the motor responses alone were sufficient to eliminate the duration distortion effect (PSE≈0.923, n.s.). The distortion was unaffected by perceived onsets and offsets as measured by auditory matching. We interpret the results as evidence for the motor system's primacy in timing tasks and suggest the modality-independent view of time perception needs to be reconsidered.

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53.524

Developing a neuromimetic accumulator model of perceptual decisions

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Neurons in the frontal eye field (FEF) contribute to decisions about where and when to shift attention and gaze. Visual neurons differentiate a task-relevant stimulus from distractor stimuli. Movement neurons trigger a saccadic eye movement when activity reaches a fixed threshold. A database of FEF visual and movement neuron activity from three macaque monkeys performing a singleton visual search guided the development of an accumulator model of perceptual decision-making. Previously, we used the activity of FEF visual neurons as input to stochastic accumulator models representing hypothetical movement neuron units (Purcell, B.A., R.P. Heitz, J.Y. Cohen, G.D. Logan, J.D. Schall & T.J. Palmeri (2008) Modeling interactions between visually-responsive and movement-related neurons in FEF during saccade visual search. Vision Sciences Society 8: 1080.). These simple models successfully accounted for response times during visual search, but lacked neural plausibility. In the present work, visual neuron activity drove more complex stochastic accumulator models. The models varied on whether hypothetical movement neuron units (1) accumulated visual input independently or competitively, (2) were subject to self-inhibition or (3) tonic inhibition that acts as a gate on visual input by suppressing the accumulation of activity below a certain level. Accumulator models with different architectures accounted for the distributions of response times. However, by comparing the dynamics of model activation to the activity of FEF movement neurons, we resolved this model mimicry. Independent or competitive accumulation of visual activity with tonic gating inhibition provided the best account for behavioral and neural data. The complexity necessary to account for both response times and the form of neural activity indicates that simple diffusion or race models of sensory decision processes may be inadequate.

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53.525

Visuomotor compensation for variation in perceptual latency

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The less intense a stimulus is, the more time it takes the neural signal from the retina to reach visual cortex (Maunsell et al, 1999). Presumably because of this variation in latency, a dim moving object appears to lag behind where it would appear if it were bright (Hess, 1904). To investigate whether this flaw in perception afflicts our ability to interact with moving objects, we asked subjects to press a button at the moment a rotating bar became aligned with a stationary reference (no feedback was provided). Over a 15-fold photopic range of luminance, they did not respond later when the moving bar was dimmer. However, the results of two perceptual localization tasks with similar stimuli indicated that the bar appeared further behind when it was dimmer, relative to a reference bar that was either moving (the Hess effect) or flashed (the flash-lag effect). This suggests that the visuomotor system compensates for changes in visual latency due to luminance variation, despite uncorrected lags in conscious perception. A further experiment suggested that the divergence of perceptual latencies and motor timing is not restricted to moving stimuli: when subjects synchronized button presses with a periodically flashing bar, the effect of luminance on their errors was smaller than the effect on perceptual latency as measured by the Hess effect. However, this compensation appears to function only within a daytime range of luminance. When the tasks with

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moving stimuli were conducted again but in a lower, mesopic range of luminance, the synchronization responses were significantly delayed by decreasing luminance to an extent nearly in agreement with the perceived location of the moving bar. One possible explanation is that the adult visuomotor system has learned through life experience to trigger timed actions earlier when visual signals are weak.

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53.526

Neural correlates of visuomotor integration: an MEG study

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In this experiment we investigated the neural correlates of visuomotor integration by recording whole head MEG from 15 participants during a tracking task. On each trial participants observed a moving target on a screen, with a less than fully predictable trajectory, using stimuli adapted from Miall and Jackson (2006: Experimental Brain Research).

A 2x2 within-subjects design was used, with one factor of hand movement and one of eye movement. For the eye movement factor participants either fixated centrally or tracked the target with their eyes and for the hand movement factor either rested their hands or used their right hand to control a joystick to track the target.

Our results showed bilateral beta desynchronization and contralateral gamma synchronization in the motor cortex, in the manual tracking conditions, which was strongest in the combined manual/visual tracking condition. Gamma synchronization was also observed in the visual cortex and this was correlated with behavioural measures of performance.

We discuss these results in relation to van der Werf, Jensen, Fries, and Medendorp's (2008: Journal of Neuroscience) detection of event-related gamma synchronization in the motor cortex during delayed saccades; and we discuss further the relationship between neural activity and the behavioural strategies adopted by participants in the task.

53.527

Line By Line: Behavioural and EEG evidence for a stroke-order priming effect in letters

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Does the perception of the end-product of an action reflect the temporal sequence of the action that produced it? Human actions have distinct temporal signatures. Letter writing is a particularly prevalent form of motor action involving the production of character strokes in an invariant sequence with a common temporal order. We have previously demonstrated that the temporal order of letter strokes primes letter recognition (Parkinson & Khurana. 2007, QJEP 60(9), 1265-1274): If letters are presented dynamically as an additive sequence of constituent strokes, letter/non-letter judgments are speeded when the temporal order of the strokes is consistent with that used in writing action. This stroke order priming effect is evidence for an influence of learned writing action upon ongoing visual perception of letters.

Here we present direct evidence for the influence of the action-consistent temporal sequences on letter perception. We investigated the neural correlates of the stroke order priming effect by measuring event-related potentials (ERPs) associated with early visual processing, both when engaging in speeded letter/non-letter judgments and passively viewing identical stimuli. In accord with the behavioural results, we found that visual processing was speeded for letters that were produced by action-consistent stroke sequences, measured as significant latency shifts in early visual ERP components. Moreover, visual processing was speeded in the action-consistent sequence even prior to it becoming a letter or non-letter, implying that the action-consistent stroke sequence produces a visual prediction for letters before the onset of the letter stimulus. These effects are independent of the letter-judgment task, suggesting that the effect is not a form of response priming. Thus, if the dynamic sequence resembles the actions used to produce a letter, perceptual prediction and speeded visual processing occur for the final stimulus. This is further evidence for an action-perception link for common motor behaviours such as writing.

53.528

Sequential effects of prime-target compatibility in a masked priming task

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The purpose of the present study is to examine sequential effects of prime-target compatibility in a response priming paradigm. In the priming task a left- or right-pointing arrow (target), requiring a speeded left or right hand response, was preceded by an arrow (prime) pointing to the same (compatible) or opposite direction (incompatible). In separate experimental sessions, the prime was either masked (subliminal), or unmasked (supraliminal) and was followed by the target either immediately or after a 150 ms delay. Average reaction times to the target were affected by compatibility, masking and delay between prime and target. With no delay between prime and target, responses to compatible trials were faster than incompatible trials (Positive Compatibility Effect, PCE), irrespective of the presence of a mask. When the target followed the prime with a 150 ms delay, a PCE was observed with unmasked primes, whereas with masked primes responses to compatible trials were slower than incompatible trials (Negative Compatibility Effect, NCE). To determine if these different compatibility effects persist across trials, we recorded series of 500 consecutive responses to randomized prime-target pairs and analyzed the sequential effects on reaction times over many lags (Wiener Kernel Analysis). We compared the sequential effects in the priming task with a baseline paradigm where no prime was presented. The results so far indicate some evidence for modulations of compatibility effects extending across several trials, with implications for mechanisms of control.

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Eye, Head, and Hand Coordination in 16-to 36-Month-Old Infants

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Infants and young children learn by viewing and interacting with their world (Gibson, 1969). While previous developmental studies have used a camera to document toddlers' everyday activities from a third-person perspective, we have recently developed a new technique that allows us to collect multiple streams of data simultaneously to gain insight into the first-person perspective of a young toddler. We collected eye movements using a Tobii X120 eye tracker, head and hand movements using 6D position sensors and the first person perspective of the visual field using a mini-camera attached to the head of the toddler. The toddlers viewed balls on rods emerging from a puppet show theater to a point where they could look, touch and interact with them.

The data indicate that 59% of the time the head, hands and eyes were stationary, as compared with less than 1% of the time when all three were moving. Furthermore, eyes were moving less than 1% of the time while hands and head were still. The data provide fine-grained dynamic information about the first-person perspective of young toddlers, and provide new insights about the the multimodal organization of attention, perception and action as toddlers interact with their caregivers and the world around them.

53.530

Bimanual Interaction of Manual Heightmatching to Misperceived Elevations of a Target with Different Hand-to-Body Distances

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The perceived elevation of a visual target at an observer's true eye level changes systematically with the pitch of the visual field: it appears to be raised in a pitched topbackward visual field and lowered in a pitched top-forward visual field. However, the accuracy of manual pointing or height-matching to a perceptually mislocalized visual target increases linearly with hand-to-body distance, approaching complete accuracy at full arm extension, with errors equal to the perceptual mislocalization for the hand close to the body. In the present experiments, we investigated bimanual interaction with the two hands held at different hand-to-body distances throughout a trial on manual tasks to a common visual target under pitch induction. Observers in darkness monocularly viewed a visual target at 70 cm distance in their median plane either 12° above, 12° below, or at eye level with a 50°-long line pitched either -30° (topbackward), or 20° (topforward) at 25° horizontal eccentricity. The manual heightmatching to the target was measured by a Polhemus 3-Space search coil with the unseen hand either in the midfrontal plane or at 20 cm or 40 cm in front of the midfrontal plane. The manual heightmatch to the visual target with either hand alone changed linearly with manual distance for each inducer pitch; manual heightsetting-vs-pitch functions were parallel for different target heights. With the two hands at different distances simultaneously, the height of the manual match to the target by the second hand to make a setting was influenced by the setting of the first hand. The average bimanual transfer of a setting from the baseline independence level approximated 44%, whether the first match was with the left or right hand. Hand dominance played an important role: 68% transfer was measured for the dominant to nondominant hand, 26% transfer was measured for the nondominant hand to the dominant hand.

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53.531

A comparison of the dynamics of visually-controlled head and hand movements

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Brueggemann and Stevenson compared tracking of a randomly moving target by eye gaze and hand, using a joystick-controlled cursor (2007 OSA Fall Vision Meeting). In this study, we extended their work by comparing motor control of a tracking cursor using either the hand or the head. A Polhemus Fastrak 6-DOF space tracker was used to provide inputs; in the case of the hand, position was used to control the cursor, with up and right in space naturally mapping to up and right on the screen. In the case of the head, angular measures of pitch and yaw were used, as if a virtual laser pointer were attached to the subject's nose. The primary difference between these two cases is that, in the case of head rotations, the vestibulo-ocular reflex (VOR) causes compensatory eye movements to be made, stabilizing the scene on the retina in spite of the movement of the head. Under normal circumstances, the VOR effectively compensates for head movements, the world appears stable, and similar results are obtained for head and hand correlograms. Observed latencies are in the neighborhood of 400 milliseconds, with the head around 50 milliseconds faster than the hand. The method is expected to reveal more striking differences, however, under abnormal gravitational conditions such as those encountered during aircraft maneuvers or space flight, where lack of visual stability is often observed. We have examined adaptation of the VOR (using modified visual feedback) as a possible analog of these conditions. We have also measured period-versus-delay (PVD) functions of oscillations induced by delayed visual feedback. We have previously reported PVD slopes near 1.6 for eye movements, suggesting a control system using both position and velocity inputs. PVD functions obtained for head tracking show steeper slopes, suggesting a different weighting of visual signals is used for control.

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URL: http://vision.arc.nasa.gov/personnel/jbm/home/presentations/vss09/

53.532

Head-torso coordination and overt shifts in attention

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Background. Overt attention shifts are made through eye, head, and torso rotations or some combination thereof. Many studies have explored eye-head coordination but relatively few studies have investigated head-torso coordination. We explored head-torso coordination using a looking and pointing task. Head-torso coordination involves complex dynamics and we hypothesised that the coordinative behaviour would demonstrate hysteresis (where history influences behaviour) in common with most complex systems.

Methods. Eight right-handed adults sat in a swivel chair and both looked and pointed eight times over a 180° range to eighteen different locations in 10° increments right and left of midline (conditions counter-balanced, target locations randomised). Optoelectronic apparatus recorded head, torso, and hand movements. The positional data were subsequently filtered and differentiated to provide detailed kinematic profiles.

Results. (1) The head, torso, and hand speed profiles unfolded within a common time window enveloped by the head movement duration. Head peak speed had a linear relationship with target angle. Movement time also had a linear relationship with target angle until a plateau around 60°. (2) Even small gaze shifts (10° from the midline) involved changes in head position, which contrasts with previous studies reporting that small gaze shifts only involve the eyes. Whilst participants sometimes pointed at targets on the right hand side without torso rotation, the number of trials with torso rotation increased linearly with angle. There were twice as many trials with torso rotation to the right side targets in the pointing condition when compared to the looking condition.

Conclusion. A reliable relationship exists between speed and amplitude in head movements. A flexible task dependent coordinative relationship exists between the head, torso, and hand. The coordinative relationship cannot be predicted simply from the task – it is necessary to know the history of the system. Thus, the head-torso system exhibits hysteresis as hypothesised.

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53.533

Coordinate frames for reach to grasp in visual and haptic calibration

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Introduction: Previously we calibrated participants by preserving visual feedback using a mirror image of an object, surreptitiously changing the position of the haptic object relative to the visual object. We found generalised changes in open-loop reaching behaviour (pre versus post-calibration) which were best captured by a Cartesian coordinate system (Sheehan et al., VSS, 2008). Other studies indicate that visual space is represented by a cyclopean spherical coordinate system (e.g. Vetter et al., 1999), suggesting that the frame-of-reference in which adaptation occurs may be specific to the feedback that drives the adaptation process (see also van den Dobbelsteen et al., 2003). The current study extended previous VSS work by examining reaching behaviour before and after calibration between a visual calibration group (subjected to distorted visual feedback through prismatic viewing) and a haptic calibration group (subjected to distorted haptic feedback).

Methods: We used apparatus which allowed manipulation of differences between an object's visual and haptic location using a mirror system (Sheehan et al., VSS, 2008). All participants made pre-calibration open-loop

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reaches to nine locations. Similar to Sheehan et al. (VSS, 2008) participants in the haptic group were recalibrated at one location by changing the position of a felt object in relation to a visually specified object. In the prism group, however, participants were recalibrated by looking at the visual object through prisms while reaching to the un-displaced felt object. Thus, each group was calibrated by the same angular degree but by a different mode of sensorimotor distortion. Both groups made post-calibration open-loop reaches to nine locations.

Results: Matlab routines fitted error patterns of changes in reaching behaviour pre and post-calibration to predicted errors within Cartesian and Spherical coordinate systems, revealing differences between calibration modes.

Conclusions: The human sensorimotor system adapts to different frames-of-reference depending on the nature of feedback information.

Acknowledgement: This study was part-funded by The Wellcome Trust and Dorothy Campbell Studentship

53.534

The Rod-and-Frame and Simultaneous Tilt Illusions: Perception, Action and the Two-Wrongs Hypothesis

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Several studies have demonstrated a dissociation of the effects of illusion on perception and action, with perception generally reported to be susceptible to illusions, while actions seem immune. These findings have been interpreted as supporting Milner & Goodale's hypothesis for the existence of separate visual processing streams for perception and action. However, work from our lab (Dassonville & Bala, PLoS Biol 2004) and that of Matin (Li & Matin, Vis Res 2005) has suggested that this type of behavioral dissociation will occur for any illusion that is caused by a distortion of the observer's egocentric reference frame, without providing evidence for the existence of separate visual representations for perception and action. According to this Two-wrongs hypothesis, movements aimed at illusory targets will be accurate if they are guided within the same distorted reference frame used for target encoding, since the error of motor guidance will cancel with the error of encoding (hence, for actions, "two wrongs do make a right"). Here, we further test the Two-wrongs hypothesis, by examining two illusions for which the hypothesis makes very different predictions: the rod-and-frame illusion (which affects perception but not actions, Dyde & Milner, Exp Brain Res 2002) and the simultaneous tilt illusion (which affects perception and actions equally, Dyde & Milner 2002). As predicted, the mechanism that drives the rod-and-frame effect is a distortion of the observer's egocentric reference frame, while the simultaneous tilt illusion is caused by local interactions between stimulus elements within an undistorted reference frame. These results provide evidence for a class of illusions that lead to dissociations of perception and action through distortions of the observer's spatial reference frame, rather than through the actions of separate visual processing streams.

53.535

Actions Do Not Escape the Influence of Visual Illusions -- Even When Manual Behavior Is Accurate

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Accurate manual behavior in response to stimuli that produce errors in visual perception has often been reported. Such findings have invariably been interpreted as implying that the visual inducer has no influence on the manual behavior. We show that this assumption is incorrect in two experiments involving large egocentric visual illusions in which hand-to-body distance was systematically varied and manual behavior of the unseen hand was measured. In the first experiment, systematic changes in the physical elevation visually perceived as eye level (VPEL) were induced by changes in the pitch of a single long line and measured by the elevation of the subject's setting of a small visual target. In the second experiment, systematic changes in the frontal-plane orientation visually perceived as vertical (VPV) were induced by changes in the roll-tilt of a 2-line visual inducer and measured by the subject's setting of a short line to appear erect. For both experiments, the results showed 3 sorts of systematic effects: influences of visual inducers on the egocentric location of targets (conventional visual illusions), influences of visual inducers on the felt position of the unseen hand/arm in the absence of a visual target (manual illusions), and influences of visual inducers on manual/visual matches. The manual illusions are absent when the hand is close to the body but grow linearly with hand-to-body distance. The manual/visual matches also change linearly with hand-to-body distance. However, the matches are grossly erroneous when the hand is close to the body although the matches are veridical with the arm fully extended (the distance for which the manual illusion is greatest!). In effect, the manual illusion with the fully extended arm tended to compensate for the visual illusion. Our recently-proposed Proximal/Distal Model (VisRes2005; JOV2008) explains the apparent paradox and quantitatively fits all of the experimental results.

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Visual Search: Context and Attention

Tuesday, May 12, 8:30 am – 12:30 pm
Poster Session, Vista Ballroom

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Identifying a "default" visual search mode by operant conditioning

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Studies on attentional set and visual search have revealed that perception of a visual target is impaired by a temporally preceding distractor. The pattern of this impairment, known as the attentional capture, is contingent on the participant's attentional set. When searching narrowly for the specific target feature (the feature search mode), only the matching stimuli capture attention. When searching more broadly for an oddball (the singleton detection mode), any singleton captures attention. The present study examined which attentional set represents the "default" search mode. Unlike extant studies that provide participants with instructions to search for a specific target, the present study used operant conditioning to shape search behavior. In a training phase, participants receiving no instructions were presented with a red letter (target) embedded in a rapid stream of gray letters and heard a reward tone only when they hit a corresponding key. In this phase, observers could choose either the feature search or the singleton detection mode, because the target could be defined either as a red letter or as a singleton. In the test phase, the strategy used by observers was assessed by using peripheral distractors presented immediately before the target frame. The peripheral distractors contained one red (or green) and three gray symbols. The results showed that identification accuracy was impaired by both colors of distractors, indicating that participants adopted the singleton detection mode. Interestingly, approximately 90% of participants reported that they chose the feature search mode when asked explicitly afterwards. Identical patterns of results were obtained in follow-up spatial search experiments. These results suggest that the singleton detection mode represents a primary search mode. The dissociation between the behavioral results and the verbal reports implies that participants are not sensitive to the search mode they use, even though their choice of strategy seems highly conscious.

53.537

Temporal dynamics of the attentional template during visual search

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Extensive evidence indicates that an attentional template is used to guide attention to items that contain task-relevant features. To explore the temporal dynamics of this template, we recorded eye movements during a visual search task in which observers searched for a Landolt-C target in a 24-item array. Half of the items were red and half were blue, and we varied the probability that the target was a cued color (100%, 80%, or 50%) versus an uncued color (0%, 20%, or 50%). When the cue was 100% predictive, the first saccade was occasionally directed toward the uncued color, but almost all subsequent saccades were directed toward the cued color. The same pattern was observed when the cue was 80% predictive, except that observers switched to the uncued color if they searched most of the items of the cued color without finding the target (and then they sometimes switched back to the cued color). Thus, the template remains constant for long runs of saccades, even though this leads to long-distance saccades that skip over nearby items of the color not currently specified by the template. When the cue was non-predictive, however, observers exhibited no momentum to continue searching the same color on consecutive saccades, and they even exhibited a slight tendency to alternate between the two colors more than would be expected by chance. This is surprising from the biased competition perspective, given that the currently fixated item is presumably stored in visual working memory, which might be expected to bias subsequent saccades toward matching items. Together, these results show that the attentional template may change over the course of a single trial of visual search, and that task-irrelevant features of the currently fixated item do not have an obligatory effect on subsequent shifts of gaze.

53.538

Configural Asymmetries in visual search are robust to changes in the spatial arrangement of the search elements

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BACKGROUND: Configural asymmetries refer to differences in visual search performance caused by the orientation of otherwise identical search elements (Junge, VSS 2008). For example, bicolor elements split horizontally (up/down configuration) are searched more efficiently than identical elements split vertically (left/right configuration). This study tested the robustness of these asymmetries to manipulations of the spatial arrangement of the search elements. The spatial arrangement of the elements (pseudo-random vs. regularly positioned) and spatial separation between search elements were manipulated to influence global vs. local processing of the search displays. Specifically, we tested the hypothesis that the magnitude of the asymmetry might be attenuated with displays favoring global processing of the search elements (e.g., regularly positioned elements in close proximity).

METHODS: Three observers participated in two latency visual search experiments. Experiment 1 investigated the effects of set size and the spatial arrangement of the search elements (regularly positioned, slightly irregular, moderately irregular, and pseudo-randomly positioned) on search performance for horizontally and vertically split elements. Experiment 2 tested the effect of element separation on search performance for both horizontally and vertically split elements.

RESULTS: More efficient processing of horizontally split elements compared to vertically split elements was replicated. The overall spatial arrangement of the search elements affected search performance; regularly positioned elements were searched more efficiently than pseudo-randomly arranged elements. Surprisingly, the elements' spatial arrangement had little effect on the magnitude of the configural asymmetry. Similarly, element separation had little effect on the magnitude of the asymmetry, although a trend was observed in which displays composed of regularly positioned elements in close proximity exhibited a reduced configural asymmetry.

CONCLUSION: The configural asymmetries were remarkably robust to manipulations of the spatial arrangement of the search elements. The measurements point to a fundamental difference in how objects requiring left/right vs. up/down comparisons are processed visually.

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Contextual cost: When the target is not where it should be

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Visual search is often facilitated when the search display occasionally repeats, even though participants are unaware of the repetition. A prominent explanation of this memory-based search, known as contextual cueing (Chun & Jiang,1998), is that it is a form of top-down, associative learning of display configurations and target location. However, recent findings emphasizing the importance of local context near the target (Brady & Chun, 2007; Olson & Chun, 2002) give rise to the possibility that low-level local-repetition priming may account for the effect. This study distinguishes these alternatives by testing whether search is guided towards a target's expected location, even when the target is relocated to another location. This manipulation allows us to directly test the associative nature of contextual cueing. After participants searched for a T among Ls in displays that repeated 24 times, they completed a transfer session where the target was relocated. In Experiment 1, the target moved to a previously empty location positioned near (2.16°) or far away (4.32°) from the trained target location. Search in the near-relocation condition was faster than search in novel displays, suggesting that the contextual guidance is not spatially precise. However, the contextual cueing benefit was eliminated in the far-relocation condition. Experiment 2 used a similar design, except that the target swapped locations with a near or far distractor during the transfer session. Contextual cueing was abolished when the target swapped locations with a near distractor, and was reversed into a contextual cost (slower RT than the new condition) in the far-swap condition. Together, these findings show reduced contextual cueing when targets move away from their expected locations. We conclude that target predictability is a key factor in memory-based attentional guidance, supporting a top-down, associative learning account.

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53.540

No Target No Effect: Target Absent Trials in Contextual Cueing

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In contextual cueing, reaction times (RTs) to find a target are lower when a display has been repeated compared to when a display is new. Recent work has suggested that this benefit occurs as participants learn the associations between the target and its surrounding distractors. We ask what happens to contextual cueing when there is no target item. Can participants learn an association between a configuration of distractors and the absence of a target? If it is the target-distractor associations that are important then when there is no target (and hence these associations cannot be formed) no contextual cueing effect should emerge. Experiment 1 replicated the standard contextual cueing effect with target-present displays, but found no effect of context on target-absent displays. Suppose that a repeated configuration indicates that the target is present at a specific location 50% of the time. If not, a distractor is present at that location and the target is absent from the display. In this case no contextual cueing is found on either present or absent trials (Experiments 2 & 3). It is the intermittent presence of the distractor item at the target position that blocks contextual cueing (Experiment 4). Once a context has been learned, however, a contextual cueing effect can be observed on trials when the target is absent (Experiment 5). These data suggest that it is the relationship of targets to the configuration of distractors that is critical in the establishment of contextual cueing.

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53.541

Visual search guidance is best shortly after target preview offset

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At last year's VSS (Schmidt & Zelinsky, 2008) we reported that visual search guidance improves when a short delay is inserted between the target preview and the search display, a benefit that we attributed to consolidation of the target representation being time-locked to the preview offset. To further explore this hypothesis, we conducted a series of experiments in which a pictorial target preview was followed by a 5-item search display (all photorealistic objects). In one experiment we systematically manipulated ISI and found a guidance benefit for preview-search delays in the 300-600 msec range. In another experiment we replicated this effect with a short preview duration to show that benefits are linked to preview offset rather than better encoding. Lastly, we flashed at preview offset either a colored noise mask or a distractor item from the search display, and found that the target-related guidance benefit persisted despite the presence of this potentially disruptive visual information. Moreover, when a distractor item was flashed at preview offset, gaze was not guided to this item in the search display; indeed we found guidance away from this object in target-absent trials after an ISI, indicating an active suppression of the flashed distractor. This further suggests that preview-related guidance is more than simple obligatory visual priming, as the flashed distractor and not the target was viewed last. We interpret these data as evidence for a guidance process that begins to exert itself after attention is disengaged from the guiding stimulus (e.g., preview offset), with the process of elaborating a target template requiring ~300 msec and lasting until ~600 msec in this task. This elaborative process is highly selective to target features and relatively immune from interference related to brief visual interruptions, a necessary quality in a guidance system designed to work in the real world.

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53.542

Target Representations Guiding Visual Search for Two Colors: Two Discrete Colors, or a Single Range?

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In previous color search experiments, we found accurate guidance of eye movements by color, with high fixation probabilities at colors similar to the target color, and diminishing fixation probabilities as the similarity to the target decreases. However, this color selection becomes less accurate when participants search for two colors rather than one. As the two target colors become less similar to one another, there are more fixations to colors that are dissimilar to either target color. Dual-target search diminishes color guidance (Stroud et al, 2008).

When the two target colors are similar, there are many fixations to colors that are between the two targets in color space. At first glance, this pattern suggests that search is guided by a single target template consisting of a range of colors including the two targets and all colors in between. Nonetheless, here we explore the possibility that these results are produced by two discrete target color templates, with no specific guidance to intermediate colors. If dual-target search is accomplished by two separate searches, one for each target, then the "in-between" colors would have two chances to be fixated, because they are similar to both target colors. We generated predictions for the fixation rates of the in-between colors by combining fixation rates from colors near to each individual target. The predictions match the observed fixation rates in some conditions, supporting the claim that search is driven by two discrete color templates, but in other conditions the predictions overestimate the fixation rates. We compare the evidence for a single template selecting a range of colors against the evidence for two separate templates selecting two specific targets.

53.543

The Frankenbear Experiment: Looking for part-based similarity effects on search guidance with complex objects

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Similarity is a key concept in many theories of visual search, but the effects of object similarity on search have only been explored using simple stimuli. Given that real-world objects can be similar and different in many respects, it is unclear whether relationships obtained for simple objects will generalize to more complex search stimuli. In this experiment, the heads, arms, legs or torsos of distractor teddy bear objects (all photorealistic images) were replaced with the equivalent parts from a target teddy bear. This similarity manipulation transplanted target features to the distractors on a part-by-part and pixel-by-pixel basis. Subjects were shown a target preview followed by a 4 or 8-object present/absent search display consisting of random, unaltered bears or bears that were manipulated to have one, two or three parts matched to the target. Trials were also either distractor heterogenous, where each distractor was a different bear with different parts matched to the target, or distractor homogenous, where distractors were the same bear with the same matched parts. Consistent with previous work (e.g., Duncan & Humphreys, 1989), we found that errors and RT slopes increased with target-distractor similarity and decreased with distractor-distractor similarity. Increasing target-distractor similarity also resulted in fewer initial saccades directed to the target and more distractors fixated before the target. However, similarity did not interact with distractor homogeneity/heterogeneity in our task (contrary to previous work), and oculomotor analyses revealed minimal effects of set size or distractor heterogeneity on overt search guidance. We interpret these patterns as evidence for a dissociation between distractor-distractor similarity and search guidance; homogenous distractors may speed manual search decisions and reduce errors, but we found little evidence suggesting that distractor-distractor similarity improves search guidance. We speculate that this may be due to a reduced ability to group visually complex real-world objects.

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53.544

Optimal integration of information across space in homogeneous and heterogeneous search displays: data and neural implementation

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Human ability to detect a target among distractors is influenced by several well-investigated factors, including set size, target-distractor similarity, and distractor heterogeneity. A factor that has been ignored is the uncertainty of individual items in a single display. Intuitively, items that provide less reliable visual information should, on any given trial, be assigned less weight in the target detection judgment. In earlier work, we showed that a Bayesian model of search makes this intuition precise and accurately predicts human performance in homogeneous displays containing items of differing reliability (i.e., all distractors have the same orientation, but vary in contrast). Here, we test the Bayesian model when distractors are heterogeneous and drawn from a near-uniform feature distribution. We again find that humans integrate information across space nearly optimally. The standard MAX model from signal detection theory allows for neither differing reliabilities nor heterogeneous distractors.

Furthermore, we propose a neural implementation of Bayesian visual search using probabilistic population codes. In this framework, each item elicits activity in a population of neurons with so-called Poisson-like variability. On each trial, an entire probability distribution over the stimulus is automatically encoded by each population pattern. Since the Bayesian computations are very complex, approximations are needed for a neural network to implement them. We consider networks with one of three types of operations: 1) linear; 2) quadratic; 3) quadratic plus divisive normalization. We impose the constraint that the output is again in the Poisson-like format, to facilitate downstream computation. We find that the third type outperforms the first two, as measured by percent information loss with respect to the Bayesian observer. This is true for both homogeneous distractors and heterogeneous distractors drawn from a uniform distribution. Together, these results show that Bayesian theories of perception have great potential to be extended to complex integration tasks.

53.545

Quitting rules in visual search

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When and why people decide to stop searching for a target that they have not found is an old question. At VSS last year, we demonstrated that payoff matrices can bias observers towards responding that a target is present or absent in visual search. This year, we attempt to explain reaction time and detection rates by considering time-dependent reward-maximization models. Data come from 32 observers, performing a realistic x-ray baggage-screening task. X-ray images of empty bags were filled with semi-transparent, overlapping x-ray images of weapons and other objects. Bags contained 3, 6, 12, or 18 objects. Targets were guns and knives. Observers gained money for correct answers and lost money for incorrect answers. There were 5 possible payoff matrices crossed with two time pressure conditions. In the low pressure condition, observers completed 200 trials at their own pace. In the high pressure condition, they had 15 minutes to search as many bags as they wanted. Payoff matrices were equally effective in low and high pressure conditions. Unsurprisingly, observers became faster under greater time pressure. Moreover, they were close to maximizing expected reward under both conditions. We tested several time-dependent models of decision-making. Drift-diffusion models that decide when accumulating evidence exceeds a target-present or absent threshold failed to explain the data. Models that lack time-penalty (e.g., that decide when expected reward stabilizes) could not explain the effects of time-pressure. Models with linear time-penalty also failed to explain the data. An ideal observer model that maximizes reward rate accounts for: (i) why observers quit search more quickly when targets are rare (i.e., fast "no" responses in target absent trials); (ii) why miss errors are high for rare targets; and (iii) how changing the payoff matrix can make observers quit later and reduce miss errors.

53.546

Do summary statistics influence visual search?

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When presented with sets of similar stimuli, the visual system extracts a summary representation of the entire set. This strategy is employed not only for basic features of simple stimuli, but also for high-level object properties such as facial expression. Summary representation allows efficient access to information about the set as a whole, but how does it affect search for an individual within the set? We tested whether observers more readily detected a face that deviated substantially from the mean expression of a set of faces, versus one whose expression was close to the mean. Participants searched for a specific identity within sets of faces. The face sets could be either homogeneous or heterogeneous in expression. Critically, we varied the distance of the expression of the target face from the mean expression of the set. Search times were reduced when the expression of the target face was far from the mean expression of the set. Thus, deviation from the mean, in this case along an irrelevant dimension (expression), influenced search efficiency for the identity. These results demonstrate that the summary representation of a set property significantly impacts target detection.

53.547

Cueing Effects for Human and Ideal Searchers during Multiple-Fixation Visual Search

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Introduction: There have been decades of work studying the computations and neural mechanisms by which cues predictive of the target location improve search performance. Often in these studies, observers are instructed to maintain fixation during search in order to isolate effects of covert visual attention from the influence of eye movements (Palmer et al., 2000). However, in the real world, human search involves the deployment of covert attention and also saccadic eye movements. Here, we measure the effects of cues on perceptual accuracy of humans during multiple-fixation search and compare them to the predictions of various foveated computational models (ideal searcher, Najemnik & Geisler, 2005; saccadic targeter, Beutter et al., 2003) which plan eye movements using the prior probabilities of target presence indicated by cues. Methods: Participants performed an 800ms search for a tilted Gabor among horizontal Gabor distractors embedded in spatio-temporal white noise. The target was located at one of sixteen locations, all equidistant from the center fixation cross (eccentricity = 9.3 deg). Either two, four, eight, or sixteen box cues indicated the possible locations of the target. In the experimental condition observers were allowed to move their eyes freely. In a control condition, observers were required to maintain central fixation throughout the duration of each trial. Results: Human improvement in search accuracy with fewer cues was greater for multiple-fixation search than for single-fixation search. Observer fixations clustered around cued locations suggesting strategic eye movement planning based on cue probabilities. The difference in cueing effects across single and multiple fixation searches were predicted by both the ideal searcher and saccadic targeting model. Conclusions: Humans use cues to strategize their eye movements which give rise to performance improvements beyond those of covert attention. This additional benefit from cues can be predicted from computational models of multiple-fixation search.

53.548

Active search for multiple targets under time pressure

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Earlier studies have examined saccadic eye movements while searching for a single target in noise. Here we investigate saccades while humans actively search for multiple targets in brief displays and subsequently identify all potential target locations. Under these circumstances, saccades need to be efficient to maximize the number of correct decisions.

Methods: The search display had six potential signal locations, 3 degrees from a central fixation spot. Each location had an independent probability of having a target, so a trial could have from 0 to 6 targets. The target was a vertical string of 5 dots presented among randomly positioned noise dots at varying noise levels. Observers actively searched the brief display and then chose all potential target locations with a cursor. The display duration varied from 350 to 1150 ms.

We compared human eye movements to the prediction of a Bayesian model that determined where to look. We assumed that each location had an oriented filter selective for the target. The probability of a target at a location depends on the prior probability of a target, and on the likelihood of a particular filter response given that the location contains a target or not. The filter response tends to be high when a target is present and low when no target is present. Intermediate target responses are equally likely to be target or noise. The model predicts that for brief displays, these uncertain locations are inspected first.

 See page 3 for Abstract Numbering System

Results & Conclusion: At low and moderate noise levels, observers made few saccades, typically to likely target locations. At high noise levels observers made saccades to uncertain locations as well as to likely target locations. This finding differs from single-target search where saccades are directed to the most likely target locations.

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53.549

Virtual evolution for visual search in natural images results in behavioral receptive fields with inhibitory surrounds

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Purpose: Classification image studies reveal that the neural mechanisms driving perception and saccades during search use information about the target but are also based on an inhibitory surround not present in the target luminance profile (Ludwig et al., 2007; Eckstein et al., 2007). Here, we ask whether these inhibitory surrounds might reflect a strategy that the brain has adapted to optimize the search for targets in natural scenes. To test this hypothesis, we sought to estimate the best linear template (behavioral receptive field), built from linear combinations of Gabor functions representing V1 simple cells in search for an Gaussian target added to natural images. Methods: Statistically non-stationary and non-Gaussian properties of natural scenes preclude calculation of the best linear template from analytic expressions and require an iterative method such as a genetic algorithm (virtual evolution). Thus, we virtually evolved a behavioral receptive field built from linear combinations of Gabor receptive fields to maximize accuracy detecting the Gaussian target in one 4000 calibrated images (van Hateren & van der Schaaf, 1998). Results: We found the optimized linear template included a substantial inhibitory surround that was larger than that found in humans performing target search in white noise (Eckstein et al., 2007). Inclusion of independent internal noise to each channel during the virtual evolution resulted in an optimized template with inhibitory surrounds that were comparable to those in human observers. Finally, the inhibitory surrounds were robust to changes in the contrast of the signal and non-linearities in the model, and generalized to tasks in which the signal occluded other objects in the image. Conclusion: Together the results suggest that the apparent sub-optimality of inhibitory surrounds in human behavioral receptive fields when searching for a target in white noise might reflect a strategy to optimize detection of targets in natural scenes.

53.550

Feature-based and contextual guidance mechanisms in complex natural visual search

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Predicting human eye movements during search in complex natural images is an important part of understanding visual processing. Previously, several mechanisms have been shown to influence the deployment of attention and eye movements: bottom-up cues (Itti & Koch 2001) as well as top-down feature-based (Wolfe 1994, Navalpakkam & Itti 2005) and contextual cues (Torralba 2003). How the visual system combines these cues and what the underlying neural circuits are, remain largely unknown.

Here, we consider a Bayesian framework to study the contributions of bottom-up cues and top-down (feature-based and contextual) cues during visual search. We implemented a computational model of visual attention that combines feature-based and contextual priors. The model relies on a realistic population of shape-based units in intermediate areas of the ventral stream (Serre et al 2005), which is modulated by the prefrontal and parietal cortex. The posterior probability of the resulting locations is combined within parietal areas to generate a task-specific attentional map.

We compared the predictions by the model with human psychophysics. We used a database of street-scene images and instructed subjects to count either the number of cars or pedestrians while we tracked their eye movements. We found a surprisingly high level of agreement among subjects' initial fixations, despite the presence of multiple targets. We also found that the pattern of fixations is highly task-dependent, suggesting that top-down task-dependent cues played a larger role than bottom-up task-independent cues.

We found that our proposed model, which combines bottom-up and top-down cues, can predict fixations more accurately than alternative models, including purely bottom-up approaches. Also, neither feature-based nor contextual mechanisms alone could account for human fixations. Our results thus suggest that human subjects efficiently use all available prior information when searching for objects in complex visual scenes.

Perceptual Learning: Associations and Plasticity

Tuesday, May 12, 2:45 – 4:15 pm
Talk Session, Royal Palm Ballroom 1-3
Moderator: Ione Fine

54.11, *2:45 pm*

Effects of orientation specific visual deprivation in adults measured using altered reality

Stephen Engel[1] (engel@umn.edu), Peng Zhang[1], Min Bao[1], Miyoung Kwon[1], Sheng He[1]; [1]Department of Psychology, University of Minnesota

Environmental manipulations produce strong cortical plasticity in developing animals (e.g. "stripe-rearing"), but few methods are available to alter the environment of adult humans. We developed novel technology to allow manipulations targeted to known visual mechanisms, and demonstrated it by removing energy from the environment at a specific orientation. Eight subjects viewed the world using an "altered reality" system, comprised of a head mounted gray-scale video camera that fed into a laptop computer that in turn drove a luminance calibrated head-mounted display (HMD). Energy at a narrow range of orientations across all spatial frequencies was removed from the video images prior to their display. This filtering was done in real time on the laptop computer using a simple mask in the Fourier domain. Viewing the filtered video images through the HMD, subjects were able to interact with the world, while being deprived of input at a specified orientation. Prior to and following a four-hour period of deprived visual input, contrast detection thresholds were measured for sinusoidal patterns at the removed orientation and at the orthogonal orientation. Patterns were 6 degrees in size, had a spatial frequency of 1 cycle per degree, and were presented centered 8 degrees in the periphery. Thresholds for the removed and orthogonal patterns were equal prior to the deprivation period. Following deprivation, thresholds for the removed orientation were reliably lower (by 18% on average) than thresholds for the orthogonal orientation. Thus visual sensitivity to the deprived orientation improved, suggesting an increase in the gain of orientation selective mechanisms. The altered reality technology should be able to produce a variety of environmental manipulations useful for studying plasticity in many different visual mechanisms.

Acknowledgement: Supported by UMN Digital Technology Institute

54.12, *3:00 pm*

Changes in the understanding of visual depth cues eight years after sight-recovery

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Here we report changes in the visual performance of patient MM, who acquired sight during adulthood after becoming blind at age three. One year after sight-restoration, MM perceived 2D form and 3D form from motion but had difficulty inferring 3D structure from stationary 2D images. In particular, MM was insensitive to both shading and perspective cues, such that he did not readily perceive shaded circles as being concave or convex and was unable to identify shapes depicted by 2D line drawings. Further, he was not susceptible to the Shepard tables illusion (where perspective cues lead normal observers to misjudge table dimensions). MM

Tuesday Sessions

was also immune to the Bex illusion, where control observers overestimate the speed of expanding or contracting radial gratings. This 'radial motion bias' has been attributed to an interpretation of these stimuli as having motion in depth. MM initially exhibited no radial motion bias, in spite of otherwise normal motion processing. Follow-up tests conducted 8 years post-operatively suggest that MM has gained some fluency with perspective depth cues. For example, MM now shows similar sensitivity to the Shepard tables illusion when compared to control observers, and he displays a radial motion bias of equal magnitude to that of controls. Yet he remains insensitive to cues for shape from shading. In contrast to control observers, MM is no better at detecting targets shaded to appear convex or concave among inverted distractors. These results imply specific improvements in MM's performance and suggest some influence of adult experience on his understanding of perspective cues.

Acknowledgement: NEI 14645

54.13, *3:15 pm*

Basic visual representations are altered by rewards

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Experience routinely associates natural images with value. For instance, we may associate views of restaurants with bad or good dining experiences. Do such associations affect visual representations? To answer this question, we alternately trained participants to associate visual scenes with high or low reward, and had them categorize the same images as their brains were scanned using fMRI. On every trial of a choice task, they saw an indoor and outdoor scene, and were asked to choose between them. Choices of one image led to a higher monetary gain than choices of the other. These pairs were repeated across blocks, so that learning could lead to higher reward. Between choice task blocks, participants completed a categorization task. They saw the same images, plus novel images, randomly interleaved, and categorized them as 'indoors' or 'outdoors.' Analysis focused on categorization, when reward association was not relevant to the task. Categorization-phase results showed priming (shorter reaction times compared to novel images) for the first appearance of high-reward, but not low-reward images. By the third repetition, there were no differences in priming between high- and low-reward scenes. In fMRI analyses, we functionally localized the parahippocampal place area (PPA). The PPA showed lower activation (repetition attenuation, a measure of learning) for the first appearance of high-reward images in the categorization phase compared to novel images. In contrast, the low-reward images did not show significant repetition attenuation on the first categorization-phase appearance. Thus, basic visual representations are modified by reward associations, even when the reward is not relevant to the task at hand. Further analyses will focus on the effect of the number of appearances and strength of reward associations on visual representation.

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54.14, *3:30 pm*

Transforming a left lateral fusiform region into VWFA through training in illiterate adults

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A region in the left lateral fusiform cortex has been identified to play an important role in processing written scripts. There is evidence that this region is selectively sensitive to visual word form information, and thus has been labeled as the Visual Word Form Area (VWFA). Here we investigated the neural plasticity of this region and addressed the question of whether the specialization of this region for processing written scripts can only be formed during an individual's developmental stage. Chinese adults who were illiterate but otherwise neurologically and intellectually normal were recruited in this study. They provide a fresh blank slate to examine if extensive reading training can reshape the functional selectivity in the mid-fusiform region. The illiterate subjects were taught to read Chinese characters in regularly scheduled Chinese classes. In block-design fMRI experiments conducted before and at different stages of their training, subjects viewed Chinese characters as well as images of faces and line drawing objects. Before training, subjects showed expected activation to faces and line-drawing objects, but none of the subjects showed significant activation to Chinese characters in the mid-fusiform region. However, after moderate training (e.g., learned 100 characters or more), most of these illiterate subjects showed enhanced activity to Chinese characters in the presumed VWFA region, usually slightly lateral to the left fusiform face area. Thus the results show that the adult brain is highly adaptive and certain regions can be transformed to acquire new functional selectivity. In addition, the fact that training adult illiterate subjects lead to the same anatomical region to become sensitive to written scripts compared to people who acquired reading skills in their normal developmental stages suggests that the VWFA must have intrinsic properties that are especially suited for the processing of visual written scripts.

54.15, *3:45 pm*

Perceptual learning and the role of virtual standards in visual discrimination

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Many discrimination tasks (e.g. contrast discrimination) that normally exhibit perceptual learning when presented in blocked two-interval forced choice (2IFC) runs, cannot be learned when presented in a roving design in which one of four randomly chosen reference standards are presented on each trial. We recently reported (PLOS Biology, 2008) that learning can be restored if the levels are presented in a repeating pattern or if each 2IFC pair is preceded by a verbal pre-cue indicating the forthcoming standard, but not by a visual pre-cue of the standard. One hypothesis that could explain these findings is a floor effect whereby cases with less learning also have lower pre-training thresholds. We tested this hypothesis by measuring pre-training thresholds using a wide variety of pre-cues in the same observers. However, only by replacing 2IFC with a standard-always-first method (and compensating for the sqrt(2) factor) did thresholds change, giving us an important clue to a new hypothesis. Nachmias (2006) and Lapid et al. (2008) found that when the standard was in the first 2IFC interval, thresholds were >30% lower than with the standard in the second interval. We believe their surprising finding goes well beyond an interval bias and well beyond Nachmias' article's modest title (the last 8 words of this abstract). We propose that when the levels are closely spaced in a roved 2IFC method, the standard becomes hard to pin down. Our results indicate that perceptual learning is not possible when roving makes it difficult to learn a virtual standard, forcing the observer to compare the two 2IFC intervals (an inefficient process). Perceptual learning may well involve learning a virtual standard, usable across trials. This finding not only can explain why learning is difficult or impossible under conditions of 2IFC with roving, it could also impact the general understanding of 2IFC.

Acknowledgement: Natural Science Foundation of China and NIH

54.16, *4:00 pm*

Augmented Hebbian Learning Accounts for the Eureka Effect in Perceptual Learning

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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; 2006) 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 output 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, which has been confirmed in our lab. Another prediction is that the existence of high accuracy trials may facilitate the learning in low accuracy trials. We tested this "Eureka" effect. 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 6 groups: 2 experimental groups in which high training accuracy (85% correct) was mixed with low training accuracy (65% correct) with and without feedback; 4 control groups in which high/low training accuracy was mixed with the same high/low training accuracy with and without feedback. Contrast thresholds improved in the high-high and high-low mixture training accuracy groups independent of the feedback condition. However, threshold improved in the low-low mixture training accuracy condition only in the presence of feedback. Furthermore, the learning rates for both high and low accuracy staircases in a mixture group did not significantly distinguish from each other; nor did they differ from those of control groups. The results are both qualitatively and quantitatively consistent with the predictions of an augmented Hebbian learning model, but not with pure supervised error correction or pure Hebbian learning models. The results lend further support for the augmented Hebbian learning hypothesis in perceptual learning.

Acknowledgement: Supported by NEI.

3D Perception: Shape

Tuesday, May 12, 2:45 – 4:30 pm
Talk Session, Royal Palm Ballroom 4-5
Moderator: Manish Singh

54.21, *2:45 pm*

Three dimensional shape and the perception of physical stability

Roland Fleming[1] (roland.fleming@tuebingen.mpg.de), Manish Singh[2]; [1]Max Planck Institute for Biological Cybernetics, [2]Rutgers University - New Brunswick

Most work on 3D shape perception focuses on the estimation of local geometrical properties such as depth, slant or curvatures. However, our phenomenal experience of shape is also influenced by global properties such as part structure, center of mass, symmetry, etc. Here we study how global shape properties determine our impression of whether an object is physically stable. Physical stability is behaviourally important as it affects our expectations about object behaviour, and the planning of motor actions. Objects topple over when the gravity-projected centre-of-mass (COM) falls outside the support area (the convex hull of points of contact with the groundplane). We can use this to define a continuous measure of geometrical stability as the angle through which an object must be rotated before it will fall over. This measure depends on support area and the mass distribution that defines the shape's COM. We measure perceived stability in a series of adjustment and YES/NO tasks. Subjects were presented with computer rendered images of objects with different 3D mass distributions that were placed close to the edge of a precipitous table edge. Their task was to identify the orientation of the object relative to the groundplane at which it appeared to be critically stable (i.e., was equally likely to right itself, or fall off the table). The results show a consistently strong correlation between physical stability and perceived stability, although different subjects make different classes of systematic error (e.g., judgments of stability consistent with perceiving the COM to be lower than ground truth). We argue that perceived stability is an important, holistic property of shape that the visual system readily estimates, and analyse the contribution of mid-level shape properties (such as symmetry, curvatures and part structure) to the perception and misperception of stability across a wide range of shape classes.

Acknowledgement: RF supported by DFG FL 624/1-1. MS supported by NSF CCF-0541185 and IGERT DGE-0549115

URL: http://www.kyb.tuebingen.mpg.de/bu/people/roland/VSS09/

54.22, *3:00 pm*

Cooperative computation of shape and material from motion

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In previous work we showed that specular rotating superellipsoids of varying corner-roundedness have characteristic optic flow patterns that predict observers' shininess ratings: namely, more-rounded shapes are perceived as less shiny than cuboidal shapes. However, previous behavioral results also show a strong covariation between percepts of shape and material – shiny objects judged matte also appeared non-rigid. This suggests that material perception involves the simultaneous inference of shape and material, where material properties include both reflectivity and elasticity. In this work we investigate the computations underlying the perception of shape and material from motion.

Previous work in computer vision provides theory for estimating shape given known material properties (e.g. structure-from-motion and shape-from-specular-flow). We incorporate these results into an "analysis by synthesis" framework that postulates that the visual system has high-level models for inferring the shape of objects in matte rigid motion sequences (e.g. structure-from-motion), matte-elastic, shiny-rigid and possibly shiny-elastic sequences. We show that errors in the model fit scan be used to infer the most likely material type for the sequence. In particular, using novel measures of consistency and error of reconstructed shapes across time, we show that the pattern of fit errors, for a model assuming rigid matte objects, can be used to predict whether the object is both shiny or matte and rigid or non-rigid.

For example, an object's material and rigidity can be accurately estimated for slowly deforming matte surfaces. Interestingly, however, low curvature shiny objects generate structure-from-motion model fit errors that are more similar to non-rigid matte objects. From these results, we hypothesize that human observers may use a similar analysis-by-synthesis strategy to compute shape and material from motion. The hypothesis predicts perceptual errors on a range of motion stimuli that we compare to human judgments.

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54.23, *3:15 pm*

The role of a perceptual decision rule in development of variance reduction by cue integration

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In recent studies, children aged below 10 years did not integrate estimates from different modalities to reduce response variance (Nardini et al., 2008, Gori et al., 2008). We asked whether there is earlier variance reduction for two cues within a modality. Adults and 6 – 11-year-olds judged which of two simultaneously presented slanted planes, defined by disparity, texture, or both, was shallowest. Adults improved their thresholds given both cues rather than either one, and weighted the texture cue most for planes approaching the horizontal, in which texture provides the most reliable slant information. In children, this adaptive pattern of weighting was first seen at 10 years, and a reduction in variance at 11 years. Therefore we found no earlier variance reduction within a modality than was previously found between modalities. Whether judging single or multiple cues, it is necessary to decide when to stop collecting information and respond. In a second study we asked whether changes in this decision rule might underlie the development of variance reduction. We analysed the latency and accuracy improvements of adults, 8- and 10-year-olds, given both disparity and texture cues compared with one alone. For difficult stimuli close to threshold, adults exploited a second cue to improve accuracy. For easy stimuli already accurate unimodally, they improved latency. This implies that adults respond once they judge the probability of being correct to have reached some threshold. As before, children did not improve accuracy given a second cue. However older children exploited the second cue to improve latency, even with difficult near-threshold stimuli for which adults instead improve accuracy. We propose that one reason for children's failure to reduce variance given multiple cues is that they use a decision rule that does not take into account the quality of sensory evidence, i.e. the probability of being correct.

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54.24, *3:30 pm*

Environmental statistics influence integration of visual cues to depth

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In the Bayesian approach to perception (Knill & Richards, 1996), prior assumptions play a critical role. However, little is known about how the brain learns and adapts its "priors". It has been proposed that priors reflect environmental statistics (Geisler & Diehl, 2003). As the statistics of different environments, for example man-made vs. natural environments, vary strongly, it would be advantageous to have different priors for different environments and flexibly switch between them. To test this, we had subjects judge the 3D-orientation of planar objects containing small conflicts between the slant suggested by binocular disparities and figural compression. The informativeness of the latter, monocular cue depends on subjects' priors, because inferences from two-dimensional information to a three-dimensional interpretation require assumptions about symmetry, isotropy, and such. Consequently, when we manipulated the statistical regularities of the environment in which the stimuli were presented, subjects' reliance on the compression cue changed. In a first session, the environment in which test stimuli were presented consisted of isotropic objects, and in this regular environment, subjects relied about equally on the binocular disparity and the compression cue to slant. In the following sessions, we randomly interleaved trials with regular environments and trials with irregular environments which consisted of non-isotropic objects with random aspect ratios. The influence of the compression cue was stronger in trials with regular than in trials with irregular environment, and in both cases significantly lower than in the first session in which only regular environments were presented. This indicates that subjects generally lowered their belief in isotropy when trials with irregular environments were introduced and used a stronger prior on isotropy in trials with regular than with irregular environments. We conclude that subjects can rapidly switch between priors used to interpret a monocular cue to depth when shifting between environments with different shape statistics.

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54.25, *3:45 pm*

How is the perception of shape from shading affected by revealing the lighting properties?

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Recovering 3D shape from shading is ill-posed, so to solve the problem the visual system must use assumptions or additional information about the surface material, surface shape, and lighting. We examined whether viewers can infer the lighting properties from the shaded surface of a familiar object and then use that information while judging the shape of an unfamiliar and irregular object in the same scene. Subjects estimated local orientation for points on the unfamiliar test surface by adjusting a gauge figure until it appeared normal to the surface [Koenderink et al. 1992]. We revealed the lighting direction and ratio of directional vs ambient lighting in the scene by rendering a nearby sphere. We manipulated the reliability of this information by varying the reflectance of the sphere. The reference sphere and test surface were rendered as Lambertian surfaces with attached shadows. Observer settings were more accurate when the lighting properties were reliably revealed by the reference sphere, demonstrating that subjects are able to infer the lighting direction and the ratio of directional vs ambient lighting, and then make use of that information. The increase in accuracy was greatest when the light was coming from below and when the reliability of the reference stimulus was high. These data show that observers can use information from the lighting of a familiar object to interpret the shape of an unfamiliar object in the same scene, and that they use a light-from-above prior when lighting information is unreliable.

54.26, *4:00 pm*

The Perception of Surface Slant from Monocular Texture Gradients and Binocular Disparity

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Two experiments were performed to examine the perception of surface slant from texture gradients and binocular disparity. In Experiment 1, observers matched the apparent slant of a planar surface defined by monocular texture gradients or binocular disparity by adjusting the orientation of a line on a separate monitor. In Experiment 2, observers matched the apparent slant of a planar surface defined by monocular texture gradients with an adjustable stereoscopic planar surface. The results of both experiments reveal that observers' judgments of slant from texture are systematically biased, such that stereoscopic surfaces appear significantly more slanted than those that are defined by monocular texture gradients. In addition, the variance of observers' judgments for both sources of information increases with the slant of the depicted surfaces. These results are fundamentally incompatible with data obtained from slant discrimination studies (e.g., Knill & Saunders, Vis Res, 2003) that have consistently shown that the reliability of observers' slant estimates is higher for large slants than for small slants. 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 or the presence of 2D cues. Our results indicate that the assumptions employed for interpreting the results of prior discrimination studies may not be valid, and that the use of discrimination procedures for investigating the reliability of perceived slant is questionable.

54.27, *4:15 pm*

The 3-D Helmholtz Square illusion: more reasons to wear horizontal stripes

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The 'Helmholtz Square' illusion demonstrates that a square comprising horizontal stripes looks taller and narrower than an identical square comprising vertical stripes. Thompson (vss 2008) showed that this illusion persists when applied to 2-D female figures, challenging the popular belief that horizontal stripes make us look fat. However Taya & Miura (2007) have demonstrated that in 2-D representations of vertical cylinders the apparent depth of the cylinder correlates inversely with apparent width, i.e. the more the apparent depth the narrower the cylinder. They propose that a vertically-striped cylinder presents more cues to its 3-dimensionality than a horizontally-striped cylinder, thus it appears narrower and this effect outweighs the Helmholtz illusion. However Li & Zaidi (2000) have shown that patterns containing contours lying along the lines of maximum curvature of the surface are critical for conveying shape. That is, depth in a vertically oriented cylinder (or human body) would be best revealed by horizontal not vertical lines. We have measured the perceived widths of real 3-D cylinders covered with horizontal or vertical lines and a uniform grey colour. 15 participants matched the perceived width of a range of cylinders (varying in real diameter from 2 - 12cm) to the separation of a pair of vertical lines on a computer screen. We find that the Helmholtz illusion persists, with the horizontal cylinders appearing up to 6% narower than the vertical cylinders, a similar magnitude to the 2-D case. This contradicts Taya & Miura's expectation that vertical lines will give more depth cues in a 3-D vertical human, and hence will have a slimming effect. We suspect that our cylinders contained sufficient depth cues in both vertical and horizontal versions to eliminate any illusion from a disparity in perceived depth. Further experiments explore the influence of pattern spatial frequency and colour on the illusion.

Multisensory Processing: Brain and Behavior

Tuesday, May 12, 5:15 – 7:00 pm
Talk Session, Royal Palm Ballroom 1-3
Moderator: Laurence Harris

55.11, *5:15 pm*

On Maintaining Crossmodal Identity

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The Prakash group reported (J.Vision, 2008,8,23) that the congenitally blind person who gains sight initially fails to identify seen objects with their felt versions: a negative answer to the Molyneux question. However, s(he) succeeds in doing so after a few days of sight. We argue that this rapid learning resembles that of adaptation to rearrangement in which the experimentally-produced separation of seen and felt perceptions of objects are very rapidly reunited by the process called capture. Moreover, we hypothesize that the original ability to identify objects across modalities by the neonate is assured by the same process.

The identification of seen with felt representations and vice versa requires that both be attributable to a single object. Otherwise they are independent and unrelated. How is this unity achieved? The prime condition for unity is spatiotemporal superposition. The normally perceived object is palpable at the location and time that it is seen. For the blind person the seen aspect is of course absent. When vision is acquired the temporal superposition of seen and felt holds but not necessarily the spatial superposition. But, as in prism adaptation, the simultaneity of seen and felt activation should produce spatial superposition by capture.

Analyzing the vast number of rearrangement experiments – optical, electronic, and mechanical – the essential condition for adaptation is the production of spatial discrepancy between the two modes: visual and haptic. With a few exceptions, that prove the rule, temporal superposition of visual and haptic signals remains (simultaneity of brief signals and synchroneity of extended signals) and appears to be the engine of adaptation. Desynchronization of these signals either reduces or eliminates adaptation. Capture, which requires only brief exposure to the generating conditions, appears to be the prototype of the adaptation process.

55.12, *5:30 pm*

Two different visual encoding strategies in intra- and inter-modal 3-D object recognition

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The different pattern of recognition performance was found whether participants recognized 3-D objects in within- or cross-modality as they learned (Ueda & Saiki, 2007). The recognition performance showed viewpoint invariance in cross-modal recognition, whereas the learned viewpoint showed an advantage in within-modal recognition. In this study, we investigated eye movements to estimate strategies leading to different recognition performance between within- and cross-modal 3-D object recognition. An unfamiliar 3-D object was presented visually for 2 seconds, followed by a recognition test. Participants were told the test modality before the study phase, during which their eye movements were recorded. For the recognition test, the test stimuli were presented either visually (within-modality) or haptically (cross-modality) from various viewpoints, and participants responded as to whether or not it was the same as the object presented earlier. The patterns of eye movements during the learning phase were different depending on prespecified test modality. The distribution of fixation was significantly broader in inter-modal recognition than intra-modal recognition. Clustering of fixation data showed different patterns, possibly reflecting different learning strategies. Participants focused on connected portions of components in intra-modal recognition, suggesting that they used image features or relations among components, whereas they focused on the centroid of each component of stimuli in inter-modal recognition, suggesting that they regarded one component as one feature. The strategy in inter-modal recognition leads to viewpoint invariant performance because recognition using part shape is presumably less sensitive to object rotation. However, the strategies in intra-modal recognition lead to viewpoint dependent performance because recognition using image feature or spatial relations among components is vulnerable to the rotation of the object. These results suggest that recognition in intra-modal and inter-modal demand different information of 3-D objects, leading to different recognition performance.

55.13, *5:45 pm*

Vestibular facilitation of optic flow parsing

Paul MacNeilage[1] (pogen@pcg.wustl.edu), Zhou Zhang[1], Dora Angelaki[1]; [1]Washington University School of Medicine

Self-motion relative to the stationary environment produces a globally consistent pattern of visual motion on the retina known as optic flow. Local motion signals inconsistent with the global flow are generated by objects moving relative to the scene. The nervous system must therefore parse retinal image motion to estimate object motion and self-motion separately. Here we investigate whether simultaneous vestibular self-motion facilitates this parsing process. Experiments were conducted using a motion platform and attached visual display. There were two conditions, Visual-only and Combined (Visual/Vestibular), and trials for these conditions were interleaved. The visual stimulus consisted of a 3D starfield and a spherical object located to the left of the fixation point; both the starfield and the object were composed of randomly placed, limited-lifetime, frontoparallel triangles rendered in stereo. On each trial, the visual stimulus (and motion platform on Combined trials) simulated an earth-horizontal translation of the subject relative to the world and simultaneous vertical displacement of the spherical object upwards or downwards. Subjects were asked to discriminate the direction of object movement. Object displacement (and velocity) was varied from trial to trial according to a staircase procedure and psychometric functions (cumulative Gaussian) were fit to estimate discrimination thresholds. This procedure was repeated for forward, lateral (rightward), and two intermediate heading angles. Repeated measures ANOVA with condition (Visual-only or Combined) and heading direction as factors revealed a significant effect of condition and heading direction and a significant interaction. Thresholds were reduced in the Combined condition relative to the Visual-only; optic flow parsing was facilitated by congruent vestibular stimulation. Thresholds were lowest for lateral heading (laminar flow) and highest for forward movement (radial flow), probably because of the geometry of the optic flow pattern. Finally, vestibular facilitation was greatest for lateral heading but negligible for forward movement.

Acknowledgement: NIH DC007620 and NSBRI PF01103 through NASA 9-58.

55.14, *6:00 pm*

The effect of lunar gravity on perception: ambient visual cues have less effect on orientation judgements than they do under normal gravity

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INTRODUCTION: We previously reported that during the brief periods of near-zero microgravity of parabolic flight there was a significant reduction in the influence of a tilted background visual scene on the perceived orientation of a foreground object (Dyde et al., 2006, http://journalofvision.org/6/6/183/). This was unexpected, as removing the gravity cue should result in a relative increase of the influence of the remaining cues. Is there something special about zero gravity, or would just reducing gravity have a similar effect?

Tuesday Sessions

METHODS: Parabolic flights were used to create periods of lunar (one sixth of earth's) gravity. Six subjects experienced an average of 38 parabolas, i.e. approximately 13 minutes of reduced gravity each. Control data were collected during periods of 1g level flight and during the 2g phases of parabolic flight. Perceived orientation was measured using the OCHART protocol (Dyde et al., 2006, Exp. Brain Res. 173: 612) in which a tilted character is identified as either a 'p' or 'd' to find its orientation of maximum ambiguity from which the perceptual upright (PU) is calculated. The effect of a visual background on the orientation of PU was measured using two backgrounds tilted +/- 112.5º. The difference in the orientation of PU between the two backgrounds is defined as the "visual effect."

RESULTS: The visual effect was significantly smaller during lunar gravity than during level flight. The visual effect was also smaller during the 2g phases of parabolic flight than during level flight.

DISCUSSION: Modelling these data in terms of a vector sum of gravity, visual and body directions, suggests a decrease in the weighting accorded to ambient visual cues when making orientation judgements. Such a reduction is not predicted by cue combination theory.

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55.15, *6:15 pm*

Shape-Color Synesthesia in The First Year of Life: A Normal Stage of Visual Development?

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Background: It has been proposed that synesthesia (a condition where a stimulus evokes an inappropriate, as well as appropriate, sensory response) may be a normal stage of infancy, resulting from more numerous and expansive neural projections in infant cortex. We investigated this hypothesis by asking whether infants experience grapheme-color synesthesia (graphemes evoke inappropriate sensations of color).

Methods: We used FPL to measure infants' looking preferences in response to combinations of colors and shapes (shapes being a precursor to graphemes). Stimuli consisted of a field of black shapes (triangles or circles) on a colored background, the left and right halves being isoluminant red and green, respectively (or vice versa). We predicted that if an infant perceives triangles as one color and circles as another, these "colored" shapes will interact with the background colors, such that preference for the red versus green background differs between the triangle and circle conditions. Blue/yellow backgrounds were also tested. Analysis: Associations made by adult synesthetes are highly individualized, making it essential that our analysis allow for individual differences (i.e. one infant may associate red with circles, another, green). To accomplish this, for each infant, the proportion of trials on which the red background was preferred to green was compared between the triangle and circle conditions. These individual comparisons were then compared as a group to the distribution expected from chance.

Results: We found a significant effect of shape on red/green preference at 2-months, but not 3- or 8-months. An effect of shape on blue/yellow preference was observed later at 3-months, but not 2- or 8-months.

Conclusions: Our data are consistent with infants experiencing synesthetic-like associations between colors and shapes for a brief developmental period. These associations occurred later for the blue/yellow backgrounds, possibly reflecting slower development of the blue/yellow system (koniocellular) than the red/green system (parvocellular).

Acknowledgement: NIH/NEI R01-EY12153-06

55.16, *6:30 pm*

New results in the neuroscience, behavior and genetics of synesthesia

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Synesthesia is a phenomenon in which stimulation of one sense triggers an experience in another sense. For example, a voice may be not only heard, but also seen, tasted, or felt as a touch. Common forms of synesthesia include an experience of color or texture triggered by letters, numbers, weekdays, months and musical pitches. While synesthesia has traditionally been studied with small sample sizes (between 1 – 16 subjects), a large scale understanding of this condition has remained elusive. We here present data from over 6,000 rigorously verified synesthetes, whose perceptions have been tested and quantified using our Synesthesia Battery (www.synesthete.org; Eagleman et al, 2007). In addition, while synesthesia has been explored with behavioral and neuroimaging experiments, its genetic basis remains unknown. We present results from our ongoing family linkage analysis, which aims to pull the gene(s) for colored-sequence synesthesia. Synesthesia lends itself well to genetic analysis for 3 reasons: (1) synesthesia runs in family trees, (2) our battery of tests allows confident phenotyping, and (3) synesthesia seems to result from increased cross-talk between neural areas, which suggests a set of candidate genes. For the first time, a rich understanding of the phenomenon of synesthesia – from the genetics to the neuroimaging to the behavior – appears possible, and this understanding will serve as an inroad to the normal operations of neural cross-talk and perception.

URL: www.eaglemanlab.net

55.17, *6:45 pm*

Visual and somatosensory guidance of reaching movements in the medial parieto-occipital cortex of the macaque

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Primates are skillful in reaching targets in their peripersonal space both when they use visual information and when they rely only on somatosensory information. We studied the role of visual and somatosensory guidance of reaching movements by recording single cells in the medial parieto-occipital area V6A, where neurons are modulated by reaching execution in darkness (Fattori et al, 2005), as well as by visual (Galletti et al., 1999) and proprioceptive stimuli (Breveglieri et al., 2002).

A total of 75 units were recorded from V6A in 2 Macaca Fascicularis executing reaching movements towards targets located in different positions. Reaches were performed with the contralateral arm in two conditions: in darkness (Dark) and full light (Light). In Dark, only the reaching target was visible, whereas in Light the monkey also saw its own arm and the environment. The guidance of the arm was merely proprioceptive in Dark, proprioceptive and visual in Light.

We found that 67 out of 75 cells were modulated by reaching execution in at least one spatial position in either background (comparison with baseline activity, t-test, $p<0.05$). A two-way ANOVA ($p<0.05$) was performed (factors: target position, visual background): task-related neurons were 90% (61/67). In about half of them (32/61) the strength of spatial tuning was similar in Light and Dark. A third of neurons (19/61) showed modulations stronger in Light, while a minority (10/61) unexpectedly showed stronger modulations in Dark. V6A population showed a poor coherence of spatial tuning between Dark and Light and some cells showed opposite spatial preferences in Dark and Light.

These data demonstrate that both visual and proprioceptive signals modulate the neural activity in V6A when the arm reaches targets located in the peripersonal space. However, they argue against a simple additive interaction between these signals.

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Attention: Brain Mechanisms

Tuesday, May 12, 5:15 – 7:00 pm
Talk Session, Royal Palm Ballroom 4-5
Moderator: Christian Olivers

55.21, *5:15 pm*

Attention modulates the neural mechanisms that give rise to center-surround interactions

John Reynolds[1] (reynolds@salk.edu), Jude Mitchell[1], Kristy Sundberg[1]; [1]Systems Neurobiology Lab, The Salk Institute, La Jolla, CA

An emerging view of the attentional system is that feedback signals impinge on sensory processing areas so as to enhance attended stimuli at the expense of unattended stimuli. An important goal is to understand the nature of the circuitry that transforms these feedback signals into improved sensory processing. One model of this circuitry, the normalization model of attention, posits that the brain has co-opted gain-control circuits that may originally have evolved to adapt sensory processing to changes in the strength of sensory input. According to this proposal, attentional feedback signals to the visual system scale the inputs to normalization circuits in primary and extrastriate visual cortices. Recently Heeger and Reynolds proposed an extension to the normalization model of attention that incorporates a narrow excitatory field and a broader inhibitory field. This model makes two predictions about attentional modulation when a stimulus in a neuron's classical receptive field is paired with a second stimulus in the suppressive surround. Directing attention to the stimulus in the center should diminish surround suppression and directing attention to the surround stimulus should increase surround suppression. We tested this in macaque area V4 and find clear support for both predictions. These findings demonstrate that attention modulates the neural mechanisms that give rise to center-surround interactions, and provide support for the normalization model of attention.

Acknowledgement: Funding provided by NEI grant 1R01EY016161

55.22, *5:30 pm*

Attention reduces low frequency correlated noise in macaque V4

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Correlated firing among sensory neurons limits the accuracy with which sensory information can be decoded from neuronal populations (Zohary et. al., 1994). Attention might improve sensory processing by reducing correlations in the responses evoked by an attended stimulus. To examine this we recorded from pairs of neurons in visual area V4 as monkeys performed an attention-demanding object tracking task that placed a preferred stimulus inside the overlapping region of the two neurons' receptive fields. We measured correlations in the neurons' responses when the stimulus was either attended or ignored. After controlling for correlations induced by the stimulus we find that trial-by-trial spike count correlations are reduced when attention is directed to the stimulus. The dominant source of noise contributing to the variability in spiking is best characterized as '1/f' low frequency noise, as seen in the spike power spectrum of single units. We also examined this low frequency noise reduction by computing the coherence of spiking with local field potentials (LFPs). Consistent with our pairwise spike count analysis, we observe a significant attention-dependent reduction in spike-LFP coherence at low frequencies. We also find that attention reduces the variability of individual neuron's responses, as measured by the Fano Factor. An analysis of the spectra of individual neuron's spike trains with and without attention reveals that this reduction in Fano Factor reflects a reduction in rate fluctuations over the same range of low frequencies where we see reductions in correlated activity. Therefore, we conclude that attention improves signal quality by reducing low frequency rate fluctuations, and this reduction contributes to our previously reported attention-dependent reductions in Fano Factor.

Acknowledgement: NEI Grant R01EY13802

55.23, *5:45 pm*

Retinotopic Maps of Covert Attention in Human Superior Colliculus

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Purpose: Neural microstimulation experiments in the superior colliculus (SC) of primates enhanced performance in a spatially selective manner while they maintained fixation, suggesting a role for covert visual attention in SC (e.g., Müller et al, PNAS 102, 524, 2004; Cavenaugh, et al., J Neurosci 26, 11347, 2006). Previous fMRI experiments have shown a rough retinotopic organization in human SC corresponding to direct visual stimulus (Shneider & Kastner, J Neurophysiol 94, 2491, 2005). We performed experiments to determine if retinotopically organized signals corresponding to covert visual attention were present in human SC. Methods: We measured the retinotopic organization of SC to direct visual stimulation using a broad wedge of flickering dots (eccentricity 1−9°, azimuthal width 144°) that slowly rotated (24-s period) around the fixation mark. To measure the retinotopy of covert attention, we used a full-field flickering (4-Hz) grating (1 cpd) stimulus at 90% contrast. Subjects were cued to perform a difficult orientation-discrimination task within a region (eccentricity 1−9°, azimuthal width 90°) that slowly rotated (24-s period) in azimuth around fixation.. High-resolution fMRI (1.3 mm voxels) was acquired (3 s/volume) in 8 slices within SC using a 3 shot spiral sequence and a TE of 45 ms. Results: We obtained detailed retinotopic maps of covert attention in the superficial layers of SC. These maps were in good registration with those corresponding to direct visual stimulation. There was evidence for weaker retinotopic responses to both direct visual stimulation and covert attention in the deep layers, but little (if any) response in the intermediate layers. Conclusions: Signals corresponding to covert visual attention are present in the superficial layers of SC. These signals are retinotopically organized in register with the signals produced by direct visual stimulation. Similarly organized signals may be evident in the deep layers.

55.24, *6:00 pm*

Decoding neural mechanisms of purely voluntary shifts of spatial attention

Michael Esterman[1] (esterman@jhu.edu), Yu-Chin Chiu[1], Leon Gmeindl[1], Susan Courtney[1], Steven Yantis[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

Recent work by Gmeindl et al.1 showed that the medial superior parietal lobule (mSPL) is transiently engaged during both cue-driven and uncued (purely voluntary) shifts of spatial attention. We applied multivoxel pattern classification (MVPC) to their data, training the classifier on the cued shift events and testing the classifier on the uncued shifts, and found that spatiotemporal patterns of BOLD activity in mSPL were consistent for both cued and purely voluntary shifts of attention. To further examine the neural basis of attentional control, we used MVPC within mSPL to compute a decision time series that reflects, on a moment by moment basis, the degree of shift-like activity. We then entered this decision time series as a regressor in a univariate (voxelwise) GLM analysis. This analysis revealed significant covariation in several regions, including bilateral caudate and prefrontal cortex. We compared this procedure to a whole brain correlation analysis using the mean mSPL BOLD timecourse as a seed region. Only a subset of the regions identified in the correlation analysis was identified with the multivariate decision time series analysis. Furthermore, we identified task-related regions that were not revealed in a standard univariate GLM using regressors denoting only the time of task events. This novel multivoxel decision time series analysis thus provides both greater specificity than a conventional correlation, and greater sensitivity than a standard GLM analysis. The results suggest that the control of spatial attention extends beyond the well-known frontoparietal network to include the basal ganglia.

1. Gmeindl, Gao, Yantis, & Courtney (2008, November). Neural mechanisms of purely voluntary covert shifts of attention. Paper presented at the 38th annual meeting of the Society for Neuroscience, Washington, D.C.

Tuesday Sessions

55.25, *6:15 pm*

Convergence of goal-directed and stimulus-driven selection in lateral prefrontal cortex

Christopher Asplund[1, 2, 3] (chris.asplund@vanderbilt.edu), Jay Todd[1, 2], Andy Snyder[1, 2, 3], Christopher Gilbert[1], René Marois[1, 2, 3, 4]; [1]Department of Psychology, Vanderbilt University, [2]Vanderbilt Vision Research Center, [3]Vanderbilt Brain Institute, [4]Vanderbilt University Center for Integrative & Cognitive Neuroscience

Selective attention can be deployed under the observer's control (goal-directed) or be captured by novel or salient events in the environment (stimulus-driven). These two types of selection are generally regarded as dissociable and rely on mostly distinct neural circuits, with a dorsal parieto-frontal network primarily involved in goal-directed selection and a ventral parieto-frontal network processing stimulus-driven information. However, it has also been argued that the two forms of selective attention must ultimately interact, although the neural mechanisms by which they do so are not understood. Using fMRI, here we show that the inferior frontal junction (IFJ), located at the posterior portion of the inferior frontal sulcus and a core brain region of the ventral attention network, may represent a neural site of convergence for goal-directed and stimulus-driven selection. In the goal-directed aspect of the experimental task, subjects searched for and responded to a target letter embedded in a rapid serial visual presentation (RSVP) of distractor letters. Stimulus-driven attention was elicited by presenting an unexpected and task-irrelevant distractor stimulus (face) before the target in a small percentage of the trials. The sudden appearance of the surprise stimulus provoked a strong BOLD response in the ventral network, namely the IFJ and temporo-parietal junction (TPJ). By contrast, activity in IFJ, but not TPJ, was in phase with the dorsal brain regions during the goal-driven behavior of searching for and responding to the target. Correlation analysis further supported the result that IFJ's co-activation switches from dorsal brain regions to ventral brain regions with the presentation of an unexpected stimulus in the midst of goal-directed behavior. These findings suggest that the IFJ acts as a central hub for stimulus-driven and goal-directed selection.

55.26, *6:30 pm*

The divided self: fMRI reveals within-subject fluctuations in the resistance to attention capture over time

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The extent of our ability to ignore distraction from salient objects has long been the subject of considerable controversy. One possible resolution could be that observers vacillate between periods of time when attention capture is relatively strong and periods when capture is negligible. The present fMRI study was designed to investigate this possibility. Observers were scanned while searching static displays for a target circle among nontarget squares; an irrelevant color singleton distractor appeared on 50% of trials. Results typically reveal a "capture effect," in which RTs are slower on distractor-present than distractor-absent trials (Theeuwes, 1992, Percept Psychophys). The current analysis sought to identify neural predictors of variability in this capture effect. To this end, a whole-brain data-driven approach was used to determine whether fMRI activity preceding each trial, or pretrial signal, could predict RT (Leber, Turk-Browne, & Chun, 2008, Proc Nat Acad Sci). Results uncovered several brain regions in frontal and parietal cortices in which pretrial signal predicted attention capture effects. Specifically, on trials when pretrial signal was low, capture was substantial; yet, when pretrial signal was high, capture was negligible. This confirms that, within single sessions, individuals do indeed vacillate between periods of susceptibility and resistance to capture. Moreover, additional analysis established a striking link between the capture-predicting regions and occipital early visual areas: as pretrial activity in the frontoparietal regions increased, the trial-evoked visual response to singleton distractors, when compared to non-singleton items, was almost completely attenuated. This result demonstrates frontoparietal control over attentional prioritization, which varies on a moment-to-moment basis. Taken together, the present findings illuminate a visual processing system that is dynamic, and they offer a parsimonious resolution to the contentious debate over attention capture.

55.27, *6:45 pm*

Sound increases visual saliency: Evidence from EEG

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Recently we have demonstrated that synchronized auditory signals can greatly increase the saliency of visual target events in cluttered, continuously changing displays [Van der Burg, E, Olivers, CNL, Bronkhorst, AW, and Theeuwes, J. (2008). Journal of Experimental Psychology: Human Perception and Performance]. The sound makes the visual target pop out. This "pip and pop" effect occurs even though the sound carries no information on the location or identity of the target, as long as it is synchronized with the visual event. Here we report evidence from EEG data that the pip and pop effect results from an early, pre-attentive integration of auditory and visual signals. This audiovisual integration boosts the visual signal and causes it to capture attention.

Participants performed a visual search task with displays consisting of a multitude of oblique bars that continuously flipped between different orientations. The target was a bar that changed to horizontal or vertical, and the task was to indicate its orientation with an unspeeded response. Behavioral data showed the pip and pop effect: Accuracy was better when the target change was accompanied by a sound, compared to when no sound was present, or when the sound was synchronized with a distractor instead. EEG analysis revealed an early modulation of the event-related potential (ERP) around 50 ms from target onset, when a tone was synchronized with the target, compared to the summed activity of those conditions in which only the auditory or only the visual signal was present. Around 200 ms, a lateralized ERP component (the N2pc) to the target emerged, reflecting the capture of spatial attention to the location of the target. This was followed by an increased P3 component reflecting target identification. Thus early audiovisual integration causes visual events to gain priority over competing visual events.

URL: www.psy.vu.nl/pippop

Face Perception: Inversion and Viewpoint Effects

Tuesday, May 12, 2:45 – 6:45 pm
Poster Session, Royal Palm Ballroom 6-8

56.301

Face perception enhances the detection of spatial frequencies between 2-4 cycles per degree (16-32 cycles per face)

Noah Schwartz[1] (noah@wm.edu); [1]Department of Psychology, The College of William & Mary

It is widely believed that faces are processed differently by the visual system than most non-face stimuli. Despite substantial evidence in support of this belief, many questions remain as to how specialized face processing is achieved, and if it affects the raw visual input as a means of operating upon incoming face stimuli. We have previously shown that face inversion effects depend on stimulus duration, emerging 52-75ms after stimulus onset. This result suggested that specialized face processing is not continuously active but is deployed deliberately when a face-like stimulus is detected (Schwartz, VSS07). In the current study, we leverage this finding in order to measure the effect of specialized face processing on low-level contrast detection. Using a backward masking paradigm, we measured contrast sensitivity in subjects who were asked to detect a Gabor stimulus that was preceded by an upright face, an inverted face, or by random Gaussian noise that was structurally dissimilar but spectrally similar to face images.

Tuesday Sessions

Mask and Gabor stimuli were displayed for 82ms, separated by a 12ms ISI. Gabor stimuli were presented randomly at 8 spatial frequencies ranging from 0.25 to 10cpd, and 3 orientations (horizontal, vertical, oblique). Detection thresholds were measured using the QUEST procedure (Watson and Pelli, 1983) augmented by 0% and 30%-contrast catch trials. Compared to a non-masked control condition, we found that sensitivity decreased by an average of 0.3 log units for all SFs masked by pink noise. In both face conditions, similar decreases were observed for all SFs except 2-4cpd (16-32cpf) which remained equal to control levels despite the mask. These data suggest that specialized face processing involves the selective enhancement of SFs between 2-4cpd. While sensitivity was preserved for both upright and inverted face masks, additional research is necessary to determine how these frequency bands operate in subsequent specialized processes.

56.302

Are the Face Inversion Effect and the Composite Face Effect Mediated by Different Spatial Frequencies?

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Last year at VSS, we showed that the same spatial frequencies (SFs) are used for the identification of upright and inverted inner facial features (Abstract #153). Here, we report three follow-up experiments based on the same SF Bubbles technique to shed light on the relationship between the face inversion effect (Yin, 1969) and the composite face effect (Young, Hellawell, & Hay, 1987). In Experiment 1, we replicated our previous findings on the face inversion effect in a 10-choice identification task with 300 trials per orientation and per observer and with 20 faces from the set of Goffaux and Rossion (2006) revealed through an elliptical aperture hiding contour information—the same SFs were used to identify upright and inverted faces. In Experiment 2, we displayed the faces of Experiment 1 with contour information. For upright face identification, we replicated our previous results; for inverted faces, however, the use of SFs was shifted toward lower SFs. Intriguingly, this shift is in the opposite direction to that predicted by Goffaux and Rossion (2006) who found that holistic processing is largely supported by low SFs. In Experiment 3, we re-examined SF tuning in the composite face paradigm of Goffaux and Rossion (2006) using the SF Bubbles technique. Preliminary results confirm and extend their results. In sum, holistic processing—as indexed by the composite face effect—and face identification appear to be mediated by different SFs.

56.303

Optimal viewing positions for upright and inverted face recognition

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Upright faces are easier to recognise than inverted faces. Eye-tracking studies have shown that the same pattern of ocular fixations across the stimulus are obtained with inverted and upright faces, suggesting that the inversion effect cannot be explained by a difference in the features fixated as a function of orientation (Williams & Henderson, 2007; but see Barton, Radcliffe, Cherkasova, Edelman & Intriligator, 2006). One possibility, however, is that the areas fixated with inverted faces are not optimal for recognition, in contrast to fixations with upright faces. Here, we tested this hypothesis using the optimal viewing position paradigm. Five participants were first familiarized with the stimulus set, made of the faces of five female and five male famous actors. First, the exposure duration needed by each participant to identify upright faces centered at fixation with an accuracy of 90% was determined using QUEST (Watson & Pelli, 1983). Then, upright or inverted faces were displayed for this duration (less than 100 ms for all subjects) at random positions within a distance of 7.8 deg of visual angle horizontally and 11.7 deg of visual angle vertically relative to fixation. A mask made of the average of the ten faces in the stimulus set was displayed immediately after target offset. Participants were asked to identify the target face. Each participant completed 3,000 trials for each orientation. We then determined correct response probabilities as a function of viewing position. The results show, for example, that the optimal viewing area is smaller for inverted than for upright faces. Implications of these results for the face inversion effect will be discussed (e.g., Sekuler, Gaspar, Gold, & Bennett, 2004; Willenbockel et al., 2008).

56.304

Coupling between fMR-adaptation and perceptual discrimination of upright and inverted faces

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Using the method of fMR-adaptation (also termed repetition suppression) we have recently demonstrated that the neuronal tuning to faces is very narrow, and follows the perceptual discrimination of subjects (Gilaie-Dotan and Malach, 2007). However, it is not clear whether this relationship between neuronal selectivity and perception is unique to faces or is a more general property of object representations. In order to examine this issue, we have compared our initial finding with an identical experiment in which the faces were inverted upside-down. This manipulation disrupts familiarity and expertise effects while preserving all low-level feature compositions. In the upright and inverted experiments, subjects were exposed to faces under four conditions: different faces, repeated presentation of an identical face and two levels of morphing which introduced small or large differences between faces. Regions of interest were localized using a separate face localizer experiment containing both upright and inverted faces. Behaviorally, we found that there was a significant broadening of the selectivity for inverted compared to upright faces. Examining the fMRI response amplitudes revealed only slight reduction in activity for inverted faces in the fusiform face area (FFA). Yet importantly, the tuning of fMR-adaptation in the FFA as well as in the object-related Lateral Occipital Complex (LOC) showed significant broadening for inverted faces. This broadening nicely correlated with the perceptual discrimination behavior for upright and inverted faces. Our results support the notion that the ability of human observers to discriminate objects and faces can be attributed to the tuning properties of single neurons underlying these representations rather than being a consequence of some vector representation of broadly tuned neurons. This mode of coding is apparently not unique to faces but appears to be a property of object representations in general, regardless of their familiarity or behavioral relevance.

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56.305

Contrast-based adaptation shows asymmetric transfer of aftereffects between inverted and upright faces

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Some current models of face perception propose that upright and inverted faces use different processes: an expert mechanism for upright faces and a generic object-recognition process for inverted faces. If so, we hypothesized that the transfer of adaptation effects between upright and inverted faces should be limited. We used a novel contrast-based adaptation technique to measure changes in the ability of human observers to recognize inverted or upright faces at test after adapting to a face in either orientation. We used two adapting durations, a short 100ms duration at which adaptors facilitate recognition of the adapted face ('same-face') but inhibit recognition of other faces ('other-face'), and a 1600ms duration at which adaptors suppress all face recognition, but more so when the test and adaptor are from different identities (Oruc I, Barton JJS. Brief adaptation increases sensitivity of face recognition. VSS 2008). Eight subjects participated. We had subjects perform two orientation-congruent conditions, one for upright faces and one for inverted faces, and also two orientation-incongruent conditions, one in which the adaptor was inverted and the test upright (upright-adaptor/inverted-test), and one in which the adaptor was upright and the test inverted (inverted-adaptor/upright-test). We found that both upright and inverted orientation-congruent conditions generated significant aftereffects that differentiated between same-face and other-face trials at both 100 and 1600ms. In the incongruent conditions, more modest adaptation aftereffects were found with the upright-adaptor/inverted-test condition, but no aftereffects with the inverted-adaptor/upright-test condition. This asymmetric partial transfer of adaptation may suggest that upright faces can partially adapt the mechanisms used for inverted faces, consistent with effects on generic recognition systems that are relatively robust to the effects of orientation, but inverted faces cannot adapt the mechanisms primarily used for upright faces, which may represent an orientation-dependent expertise process.

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56.306

Generalized impairment of featural and configural information in the lower region of the face through inversion

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All faces are created equal in the sense that each face shares the same set of features of two eyes, a nose and a mouth that are arranged in a similar configuration. Given their common parts and spatial layout, recognition of a specific face must therefore depend on our ability to discern subtle differences in the featural and configural properties of a face. An enduring question in the face processing literature is whether featural or configural information plays a larger role in the recognition process. To address this question, the Face Dimensions Test was designed where the featural and configural properties in the upper and lower regions of a face were parametrically manipulated. Configural information was modified by varying either the distance between the eyes or the distance between the nose and mouth. Featural information was manipulated by either scaling the size of the eyes or mouth features (Experiment 1) or altering their shapes via a morphing procedure (Experiment 2).

In a same/different task, discriminability was first equated across the four dimensions (eyes-featural, eyes-configural, mouth-featural and mouth-configural) in faces shown in their upright orientations. Next, sensitivity was measured when the faces were presented upside down. Whereas inversion equally impaired the discrimination of featural and configural differences, it selectively disrupted the perception of changes in the lower region of the face. The lower half deficit appears to be face-specific because changes in orientation did not influence perception of information in top or bottom halves of houses (Experiment 3). In summary, these results suggest that inversion does not differentially interfere with the perception of features and their relations, but produces a general impairment of information in the lower region of a face.

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56.307

TMS studies of the face inversion effect

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Inversion disrupts face recognition more than object recognition, and neuropsychological patients have shown behavioral dissociations between upright and inverted faces. These effects suggest that upright and inverted faces engage different mechanisms, but the neural basis for this difference is not clearly understood. Here we used repetitive transcranial magnetic stimulation (rTMS) to examine the role of a core component in the face-processing network, the occipital face area (OFA), in the perception of upright and inverted faces. A previous study demonstrated that rTMS to the right OFA disrupted perception of upright face parts (Pitcher, Walsh, Yovel & Duchaine, 2007). Here we tested inverted face stimuli that varied in either the face parts (eyes and mouth) or the spacing between these parts (Yovel & Kanwisher, 2004). Subjects performed a sequential same / different discrimination task while rTMS (10Hz for 500ms) was targeted at the right OFA, the left OFA, or vertex (a TMS control site). Discrimination of the inverted face part stimuli was impaired when rTMS was targeted at the right OFA only. rTMS had no effect on the inverted face spacing stimuli and had no significant effect on either type of face stimuli at the left OFA. In combination with our earlier-published results for upright face stimuli, these findings indicate that the right OFA represents face components regardless of face orientation. In a second experiment we examined the role of the lateral occipital (LO) object region in the processing of inverted and upright faces. Preliminary results suggest that whereas rTMS to the rOFA impaired perception of both upright and inverted faces, rTMS to rLO impaired discrimination of only inverted faces. Taken together, these results suggest that inverted faces are processed both by the occipital face-specific mechanisms (OFA) and more general object-selective mechanisms (LO), whereas upright faces are primarily processed by face-selective regions.

56.308

Spatio-temporal dissociation between low- and high-level effects of stimulus inversion on early face-sensitive electrophysiological responses

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Event-related potential studies in humans have shown that presenting a face upside-down increases the amplitude and latency of the face-sensitive N170 component recorded over occipito-temporal scalp regions. A similar effect on the preceding P1 component has also been reported. These observations have been taken by some authors as evidence that the effect of face inversion – so detrimental for face perception - takes place in visual cortex as early as 100 ms following stimulus onset. However, previous studies have not investigated a possible bias in the position of fixation between upright and inverted faces that may contribute to this electrophysiological face inversion effect. Here we measured the ERP response to upright and inverted faces while instructing subjects to fixate either the upper or the lower part of the image, independently of orientation. The manipulation of orientation and fixation position affected differently the latency and amplitude of the P1 and N170. While fixation position modulated the latency effect of inversion similarly for the P1 and N170, manipulating fixation position influenced the amplitude effect of inversion differently for the P1 and N170. First, both the P1 and N170 latency delay due to face inversion was larger when subjects fixated the upper part of the stimulus. Second, while the effect of inversion on the P1 amplitude was sensitive to fixation position at all posterior electrodes, the amplitude increase of the N170 due to inversion was insensitive to fixation position at right anterior occipito-temporal electrodes. These observations suggest that while the inversion effect on the N170 amplitude observed on right anterior occipito-temporal electrodes is related to the activation of high-level face representations, the inversion effect on the P1 amplitude is mostly due to low-level differences between upright and inverted face stimulations (e.g. location of high contrast regions, position of the face in the visual field).

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56.309

Viewpoint Aftereffects: Adapting to full faces, head outlines, and features

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Previous research has shown that adapting to a face horizontally rotated about a vertical axis produces a perceptual shift, where the test face appears rotated slightly away from the direction of the adapting face (Fang & He, Neuron, 2005). We have recently confirmed this finding in our lab using synthetic face stimuli. In the current study, we sought to explore how the geometric elements of our stimuli independently contribute to this effect. In a two alternative forced choice task, subjects were presented with an adapting face oriented 20 degrees to the left or right for four seconds, followed by a briefly presented test face, which was randomly chosen in each trial from a set of seven faces spanning +/- 6° around a frontal view. Subjects were instructed to choose whether each test face appeared left or right of center. By assessing the orientation of the test face at which subjects were equally likely to choose left or right (point of subjective equality), we were able to assess the strength of adaptation. We tested subjects in three conditions: Adapting to full faces (Intact), head outlines only (Outline), and features only (Features). In all conditions, the test faces were full faces. We found that Intact adapted more strongly than Features ($p<0.05$), Outline adapted stronger than Features ($p<0.024$), and a trend showing stronger adaptation in Intact vs. Outline ($p<0.123$). These results suggest a non-linear combination of outline and features, with a privileged role for the head outline in encoding the direction of gaze.

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56.310

View-based categorization and face discrimination: Does categorization occur after face detection?

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Research has suggested that object recognition does not follow a linear processing sequence of object detection, object categorization, and within-category identification. Rather, an object's category is retrieved as soon as it is detected (Grill-Spector & Kanwisher, 2005, Psychological Science). Here we examined whether face recognition is processed likewise, when face view is regarded as a category. We measured behavioural performance on three tasks: face detection, face-view categorization, and within-view face identification, by using the method of constant stimuli combined with a two-alternative forced-choice (2AFC) match-to-sample paradigm. The stimuli were synthetic faces (size: $3.25^o \times 4.49^o$) with 5 views for each face identity (front, 20^o left, 20^o right, 20^o up, 20^o down). The observer's task was to identify the previously-flashed stimulus between two alternatives, following brief presentation of a stimulus (duration between 13 and 133 ms) and a mask. The two alternatives were: (1) a face and a non-face (detection task), (2) two different face views of the same individual (categorization task), and (3) a face and its anti-face with the same view (identification task). Detection threshold as a function of presentation time was the point of 75%-correct performance on the psychometric function. The results showed a significantly shorter threshold duration for face detection than for face-view categorization, and only a slightly (non-significantly) shorter threshold duration for face-view categorization than for face identification. Further analysis suggested a significant difference between the psychometric functions for categorization and identification. We demonstrated that the face-view category is retrieved after face detection, and importantly, this view-based categorical analysis takes almost as long as the face identification process. We therefore concluded that the processing sequence of view-based face recognition does not follow Grill-Spector and Kanwisher's proposal on object recognition. Additional processing is essential for face-view categorization as opposed to face detection.

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56.311

Face view adaptation and its effect on face view discrimination

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Adaptation to a visual pattern could alter the sensitivities of neuronal populations encoding the pattern, which usually results in a visual aftereffect. However, the function role of visual adaptation is still equivocal and its relation to visual aftereffect is largely unknown. In this study, we took advantage of face view adaptation to investigate these issues. In the first experiment, we measured the magnitude of the face viewpoint aftereffect (Fang and He, 2005) as a function of the angular difference between adapting and test face views. Test face views were always near the front view. The magnitude of the aftereffect increased as the angular difference increased from 0 deg to 20 deg, then decreased until 90 deg. Unlike the tilt aftereffect, substantial face viewpoint aftereffect could be observed even at 90 deg. In the second experiment, we measured the effect of adaptation to different face views on face view discrimination at the front view. Compared to the pre-adaptation discrimination threshold, adaptation to the front view (0 deg) decreased the threshold, but adaptation to 15, 30, 60 and 90 deg side views increased the threshold, which was highest in the 30 deg side view adaptation condition. These results suggest that the functional role of face view adaptation not only adjusted the boundary of our perceptual categories, but also changed the performance of our face view discrimination. We propose a computational model to account for these two phenomena and their relation in terms of the adjustments of tuning functions of face view selective neurons after adaptation.

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56.312

An investigation of pose-contingent effects in unfamiliar face recognition by combinatoral manipulation of yaw and roll

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In this study, the challenging task of unfamiliar face recognition is investigated, focusing on the effects of viewpoint and orientation (together referred to hereafter as pose, and individually as yaw and roll). Two experiments were conducted using singly, briefly presented stimuli in a sequential matching task. In experiment 1, the face pose presented in the study display was randomized from 84 (the combinatorial product of 7 yaw angles and 12 roll angles). Test pose was always identical to that used in the study display. In signal trials, the face shown in the test display matched that shown in the study display; in noise trials, the face shown in the test display was new. In experiment 2, study and test pose were individually randomized (i.e. typically did not match), requiring observers to recognize faces presented at different poses from study to test. Experiments 1 and 2 were otherwise identical. Four observers completed 16800 trials per experiment. This experimental framework yields performance data without prejudice for specific viewpoint effects, enabling a range of hypotheses to be tested post hoc. In this study, the ¾ view advantage, qualitative aspects of the face inversion effect, and the impact of face size, shape, and the impact of low-level image statistics on face recognition are evaluated and correlated with face pose. Results may be summarized as follows. Continuous pose-contingent performance was observed across both rotational dimensions. Pose at both study and test was seen to be significant (experiment 2). Both absolute pose and pose offset were seen to be significant (experiment 2). Limited evidence for a ¾ view advantage in experiment 2 only was found. Image statistics were seen to be exploited to a greater degree during the recognition of inverted faces, but contributed significantly to recognition in all pose conditions (experiments 1 and 2).

Face Perception: Face Space, Categorization and Representation

Tuesday, May 12, 2:45 – 6:45 pm
Poster Session, Royal Palm Ballroom 6-8

56.313

The Development of Face Prototypes: Evidence for Simple and Opposing Aftereffects in Children

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Norm-based coding underlies adults' expert face processing (Valentine, 1991). Adaptation aftereffects for several facial characteristics (e.g., race, sex) indicate that this prototype is updated as new faces are encountered (Webster et al., 2004). For example, prolonged exposure (adaptation) to one kind of facial distortion (e.g. facial features compressed inward) temporarily shifts preferences, making similarly distorted faces appear more attractive. Adults' face space has been further specified by opposing aftereffects: When adapted to two face categories (e.g. Caucasian and Chinese) distorted in opposite directions (e.g. expanded vs. compressed), adults' attractiveness ratings shift in opposite directions (Jaquet et al., 2007), as long as the two sets of faces belong to different categories (Bestelmeyer et al., 2008). Recent studies have used aftereffects as a tool to investigate the development of expert face processing. Our lab has shown that 8-year-olds exhibit attractiveness aftereffects in the context of a computerized storybook (Anzures, et al., in press). Here we extend our previous work in two ways. First, using a slightly modified method we provide the first demonstration of attractiveness aftereffects in 5-year-old children. After reading a storybook with either compressed or expanded facial features, 5-year-olds were more likely to choose a face distorted in the direction of adaptation than an undistorted face when asked which member of a face pair was more attractive, ps <.01. Second, we provide the first evidence of opposing aftereffects in 8-year-old children. After reading a storybook in which Caucasian and Chinese faces were distorted in opposite directions, 8-year-olds treated Caucasian and Chinese faces as separate categories whose prototypes can be shifted in opposite directions, p = .02. For example, following adaptation to compressed Chinese and expanded Caucasian faces, 8-year-olds' attractiveness ratings selectively increased for compressed Chinese and expanded Caucasian faces. We are currently testing 5-year-old children for opposing after-effects.

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56.314

Face Adaptation With and Without Attention

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After adaptation to faces with contracted (or expanded) internal features, faces previously perceived as normal appear distorted in the opposite direction. These face aftereffects suggest that face-coding mechanisms adapt rapidly to changes in the spatial relations of face features and/or the global structure of the face. What role does selective attention play in the face aftereffect? Past attempts to answer this question have yielded conflicting results (Moradi, Koch & Shimojo, 2005; Murray & Yan, 2006). We report work in which adaptation to ignored faces was tested under conditions of high attentional load and where attention to the non-face task was optimal. Before and after an adaptation phase, participants rated the normality of morphed distorted faces ranging from 50% contracted through normal to 50% expanded. In the adaptation phase, participants were presented with a highly demanding rapid serial visual presentation (RSVP) of red or blue Xs and Ts flanked to the left or right by a face with 50% contracted features. The ten individual letters in the RSVP stream were each presented for 160 ms and separated by a 20 ms inter-letter interval. Forty participants either attended to the adaptation faces (attend condition), or ignored them and counted the number of red Ts in the RSVP stream (ignore condition). A monetary incentive was provided to encourage full attention to the letter-count task in the ignore condition. A reduced but significant face aftereffect was observed when adaptation faces were ignored. These results suggest that face adaptation, as a possible mechanism for rapid updating of what looks normal, occurs automatically even under conditions in which general capacity demands are very high.

56.315

Exploring the nature of the multidimensional face space

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Many researchers agree that faces are perceptually represented in a multidimensional space; however, the nature of the constituent dimensions of this space remains unclear [Wilbraham et al. (2008), JOV 8(15):5]. The research described here further explored the nature of this face space. In Experiment 1, a variety of homeomorphic image transformations, each at several magnitudes, were applied to images of faces. Some of these transformations approximated naturally-occurring craniofacial changes (e.g., growth), while others did not. On each experimental trial, observers indicated which of two transformed images depicted the same individual as an untransformed sample image. The difference in image structure produced by each transformation was indexed with several metrics involving either pixel intensities or wavelet outputs, enabling performance comparisons across transformations. The results suggested that observers' judgments may have been based on configural relations among facial features that remain relatively invariant over some types of transformations, but not others.

In Wilbraham et al. (2008), we observed that randomizing the amplitude spectrum produced reasonably recognizable images, while randomizing the phase information did not. Based on this observation, Experiment 2 was designed to examine face matching performance when only phase information is preserved. Observers matched unaltered sample images to three types of comparison images: unaltered images, images with randomized amplitude spectra, and transformed images from Experiment 1 that produced changes in image structure similar in magnitude to that resulting from amplitude randomization. The amplitude randomization had little effect on performance with respect to baseline performance on unaltered images, unlike the effects of other variations of similar magnitude. From these results we concluded that the information specified in the phase spectrum is sufficient for face recognition, while the amplitude information is relatively unimportant, suggesting that phase information likely plays a significant role in the ability to recognize faces.

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56.316

What "exactly" is a prototype? Not sure, but average objects are not necessarily good candidates for...

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Prototypes play a central role in theories of visual sciences, for instance, for the "recognition by prototypes" framework. Typically, prototypes are defined as results of principal components or averages of given exemplars. Both approaches seem promising as they are based on clear models that allow specific inferences, but data from 2 empirical studies contradict both assumptions. In study 1, we let 41 participants sketch the "prototypical face they have in mind". By comparing the drawings with anthropometric face data, we found systematic deviations from the average face. Participants displaced cardinal features, most pronouncedly the eyes much higher, and drew the size of features very differently. In study 2, 107 participants were exposed to 2 average faces (a female and a male one) which were covered after 30 seconds; then they had to draw both faces from memory. Again systematic distortions from the average faces were found which were compatible with results from study 1. Both studies indicate that prototypical faces and even sketches depicting average faces do not seem to be based on principal components and averages but follow an abstracted configuration of a face.

56.317

Are objects like faces? Norm-based versus exemplar-based coding as revealed by adaptation aftereffects

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High-level perceptual aftereffects have assisted in resolving the long-standing question of whether the dimensions of faces are encoded as deviations from a statistical average (norm-based coding) or as absolute values (exemplar-based coding). However, this technique has not been used in the investigation of the processing strategies underlying non-face object perception.

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The present research investigated norm-based versus exemplar-based coding of horses (which, like faces, have a shared first-order configuration), houses (which can vary dramatically in their first-order configuration), and faces. Horses were distorted by changing their stockiness, houses by changing the window size, and faces by expansion or contraction. Norm-based (broadband-opponent) models predict that the magnitude of aftereffects will increase with distance of the adaptor from the proposed norm, and that adaptation to any stimulus that is not the norm will produce aftereffects that affect perception of the whole range of stimuli. In contrast, exemplar-based (multiple-narrowband) models predict the strongest aftereffects for test stimuli close to the adaptor, with aftereffects rolling off as the distance from adaptor to test stimulus is increased. Horses, like faces, produced aftereffects consistent with a norm-based) processing strategy. Results for houses were inconsistent with norm-based coding, and more consistent with an exemplar-based representation. The results are discussed in terms of the uniqueness of face processing, and the importance of a shared first-order configuration and observer experience as a determinant of the processing strategies used by the visual system.

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56.318

Can holistic processing be improved in the normal population?

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The purpose of this study is to investigate the role of experience in holistic processing of faces. Although faces are processed more holistically than objects, research using non-face objects has shown that holistic processing develops for homogenous classes of objects for which an individual has expertise (Gauthier et al, 2000). Although research has indicated that experience can increase holistic processing of other-race faces (Tanaka et al. 2004; Michel et al., 2006), it is less clear whether face training can increase holistic processing of own-race faces among neurologically intact individuals. Using the traditional paradigm for training expertise in Greebles (a novel homogeneous object set; Gauthier & Tarr, 1997), we trained undergraduates to discriminate five families of highly homogeneous faces (similar to sextuplets). In order to assess changes in holistic processing, the composite task was administered before and after face training. The composite task requires participants to make a same/different judgment to either the top or bottom of face pairs while ignoring the non-cued part. Interference from the non-cued part indicates holistic processing. Preliminary results (n = 4) suggest that such training increases holistic processing, indicating that even among normal participants, experience can enhance mechanisms associated with expert face processing.

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56.319

Brad Pitt & Jude Law: Individual-Contingent Face Aftereffects and Norm- versus Exemplar-Based Models of Face-Space

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Contingent aftereffects have recently been shown for faces differing in orientation (upright/inverted; Rhodes et al., 2004), sex (male/female; Little et al., 2005), race (Caucasian/Chinese or African; Jaquet et al., 2008; Little et al., 2008), age (child/adult; Little at al., 2008) and species (human/monkey; Little et al., 2008). That is, simultaneous adaptation has been shown to opposite distortions (e.g., eyes moved together vs. eyes moved apart) for different face categories. These contingent aftereffects are interpreted as evidence that different cell populations code different face categories, and sometimes as evidence that there are different "norms" for different face categories. Here we show contingent aftereffects for in-out eye-distance in two individuals (Brad Pitt and Jude Law). In the adaptation phase, half the participants rated the attractiveness of pictures of Brad with eyes moved together (eyes in) and Jude with eyes moved out (eyes out), and half rated the reverse (Brad eyes out/Jude eyes in). In the test phase, participants judged which of a pair of pictures looked most normal. In each pair, two versions of the same picture of Brad or Jude were shown, one eyes in and one eyes out. Those who saw Brad eyes out/Jude eyes in at adaptation were more likely to prefer Brad with eyes out at test compared to Jude. Those who saw Brad eyes in/Jude eyes out at adaptation were more likely to prefer Jude with eyes out at test compared to Brad. Based on previous results this might be interpreted as showing separate cell populations and norms for Brad and Jude. However, a norm for each individual seems essentially the same as exemplar-based coding. Thus, these results may suggest that face recognition is more exemplar-based than norm-based. Alternatively, the current distinction between norm- and exemplar-based coding may need to be rethought.

56.320

Integration of attractiveness across object categories and figure/ground

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When a 2AFC preference task is performed within the same object category; face (FC) or natural scene (NS), a distinctive segregation occurs – a familiar FC is chosen more than a novel FC across trials, whereas a novel NS tends to be chosen more than a familiar NS (Shimojo et al., VSS'07, '08). How would the preference choice change if a FC is presented with a surrounding NS (just like a typical commercial advertisement)?

Thus we combined a central FC [old (o) or new (n)] and a surrounding NS (o or n) as an integrated single stimulus, for which subjects were asked to rate attractiveness in a 7-point scale. We selected 21 pictures, excluding too high- and too low-rated, from a pre-rated set in each category and used the 11th as a repeating (o) stimulus. There were two experiments with different instructions: 1) Rate the attractiveness of the entire picture, or 2) Rate the central face only, neglecting the surrounding.

The results of Exp 1 clearly betrayed the prediction by simple summation of attractiveness across objects where the FCo-NSn combination would have the highest slope of accumulated attractiveness. Instead, the results were: FCn-NSo > FCo-NSn > FCo-NSo = FCn-NSn in the order of slope of the rating X trial number plot. The results of Exp 2 were more consistent with the simple summation model: FCo-NSn = FCn-NSn > FCo-NSo > FCn-NSo.

The 1) results suggest that attractiveness is integrated in a non-additive way across object categories and figure/ground. The 2) results can be accounted for by two factors; Familiarity preference in FC at an explicit level, and novelty preference in NS at an implicit level. These results together indicate a high degree of nonlinearity and implicit processing in memory-based attractiveness integration.

56.321

Center-surround interactions in face perception

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For many stimulus dimensions, the appearance of a central stimulus is strongly affected by the presence of contrasting stimuli in the surround. We examined spatial contrast interactions in face perception and found the opposite effects – a centrally fixated face can strongly bias the appearance of surrounding faces, while faces in the periphery conversely have little influence on the central face. The interactions were measured using morphs between a male and female face cropped to remove external features. Images were displayed for 1 sec intervals every 3 sec while the morph level was adjusted with a 2AFC staircase to determine the gender boundary. Judgments were made in the fovea and periphery, either for the test face alone or in the presence of a simultaneously presented male or female face from the extremes of the morph. Settings for most subjects exhibited an asymmetric contrast effect in which the central face biased the peripheral face toward the opposite gender, with similar shifts from 1.5 to 6 deg in eccentricity and for face widths ranging from 1 to 2 deg. However, evidence for assimilation effects – in which peripheral faces appeared more like the central face – was also observed, suggesting that the interactions are labile and at least in some cases in directions opposite to those predicted by adaptation. Similar biases were also observed along other facial dimensions including expressions. Our results are consistent with a foveal specialization in face perception, but could also reflect differences in attention. Faces even in the near periphery are difficult to resolve and perceptually unstable, and thus their perceived attributes may be more susceptible to the more robust representations formed for the centrally attended face.

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56.322

Happy or Sad? The Effects of Age and Face Race on Expression Aftereffects

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Emotional facial expressions provide a useful indicator of others' affective states. Adults perceive blends of facial expressions categorically (i.e., separated by a clear boundary) and dynamically; an ambiguous expression is perceived as sad following adaptation to a happy expression, but as happy following adaptation to sad. These expression aftereffects are strong when the adapting and probe expressions share the same facial identity, but are mitigated when they are posed by different identities, indicating that adults' perception of facial expression is integrated with identity (Fox & Barton, 2007). In Experiment 1, we extended these findings by comparing categorical boundaries and expression aftereffects in adults versus children (n = 20 per group). We created two morphed continua of facial expressions (happy-sad, fear-anger) in which contiguous faces differed by 5%. Participants classified each face in one of the two continua in three blocks of trials: no-adaptation, same-identity adaptation and different-identity adaptation. For the happy-sad continuum, both 5- and 7-year-olds showed adult-like category boundaries. All groups showed significant aftereffects in the same-identity condition, but the effects were larger for 5-year-olds ($p <.01$). Only 5-year-olds showed significant aftereffects in the different identity condition ($p <.01$), indicating that their perception of identity and expression is less well integrated than that of adults. For the fear-anger continuum, 9-year-olds showed adult-like category boundaries and aftereffects; 7-year-olds were unable to categorize the morphed expressions. In Experiment 2 we tested Caucasian adults on a happy-sad continuum comprised of Caucasian or African-American faces. Their categorization of expression was not affected by face race, but they showed larger aftereffects in both identity conditions for other-race faces ($p <.01$). Aftereffects in the different identity condition were only significant for African-American faces ($p <.01$), indicating that expression and identity may be less well integrated for other-race faces than own-race faces.

56.323

Motion-gradient defined facial expressions and the nature of face representation

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Face perception and motion analysis are standard functions of the ventral and dorsal visual pathways, respectively. Although it has long been recognized that the separation of the two pathways is far from absolute, little is known about the relationship between face and motion processing. Based on the well-known phenomenon of motion mislocalization, we show that without varying any form cues, happy and sad facial expressions can be solely defined by local motion gradients in second-order cartoon faces. Moreover, we probe face representations by measuring how these second-order cartoon faces interact with first-order cartoon and real faces in cross-adaptation experiments. We find that the pattern of interactions is better explained by statistical similarities and differences between the backgrounds of the adapting and test stimuli than by the common notion of separate mechanisms for first- and second-order processing. Our work suggests that both form and motion cues, and both local features and background statistics, contribute to face representations.

56.324

Adapting to anti-expressions: a journey through expression space

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To explore the encoding of facial expression a facial expression 'space' was constructed by averaging faces to produce a gender and identity neutral face for each expression, and an overall average face (the norm). We then made anti-expressions by morphing from an average expression through the norm, and investigated the aftereffects produced by these anti-expressions. We adapted participants to an anti-expression then showed them the norm and asked them to indicate which of the 6 expressions (excluding neutral) best described the norm. Participants consistently selected the expression that matched the anti-expression to which they had been adapted (i.e. adapting to anti-sad resulted in the norm appearing sad). These aftereffects may be the result of the way the stimuli were constructed, or may be an indication that facial expression is encoded with reference to a prototype, similar to the way recent evidence suggests we encode facial identity. To explore the latter possibility we adopted a technique previously used to study facial identity and measured the effect of adaptation along two trajectories. One trajectory went from an average expression (happy) to the matching anti-expression (anti-happy), passing through the norm. The other trajectory went from the same expression (happy) to a non-matching anti-expression (anti-fear), and therefore did not pass through the norm. Adaptation is believed to cause a shift in the norm, so a greater effect of adaptation observed for the trajectory passing through the norm would suggest facial expression to be encoded with reference to the norm. Our results showed no differences between the two trajectories. We are currently investigating additional trajectories within expression space.

56.325

Attentional Bias and its effects on Change Blindness to Human Faces in the Flicker Paradigm

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The flicker paradigm was used to investigate the nature of attentional biases and their potential effect on change blindness in a series of face-only arrays. In particular, we examined the effects of "Sex of Face", and of Participant (Male and Female face changes on Male or Female participants, Ex Post Facto) and "Face Type" (cropped, with no hair present and uncropped with hair intact) on the detection of change. Faces were independently rated on a series of characteristics for consistency. Participants completed 60 flicker trials, one quarter of which were no-change controls. In each experimental trial, one of the six faces alternated with another of the same sex until participants detected the change. Analysis showed that participants required fewer flickers to detect changes in full than cropped faces of both sexes ($p <.001$). In addition, Face Type also interacted with face sex ($p = 0.037$), with participants viewing more flickers on female cropped than female full faces ($p = 0.03$). For male faces, Face Type did not affect the number of flickers needed ($p = 0.76$). Change detection was unrelated to participant sex, contrary to the own-sex biases observed in the face recognition literature. Results support claims that hair and facial outlines contribute heavily to face recognition and that their absence impairs change detection.

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56.327

Predicting psychophysical responses from stimulus features: A statistical evaluation of human gender categorization models

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One of the main challenges in visual psychophysics is to identify the stimulus features on which the visual system bases its computations: they are a pre-requisite for computational models of perception. Here, we use logistic regression for extracting critical stimulus features and predicting the responses of observers in psychophysical experiments. Rather than embedding the stimuli in noise, as is done in classification-image analysis, we infer the important features directly from physically heterogeneous stimuli. Using this approach -which we call 'decision-image analysis'- we predict the decisions of observers performing a gender-classification task with human faces as stimuli.

Our decision-image models are able to predict human responses not only in terms of overall percent-correct, but predict, for individual observers, the probabilities with which individual faces are (mis-)classified. Comparing the prediction performance of different models can be used to rigorously rule out some seemingly plausible models of human classification performance: We show that a simple prototype classifier, popular in so-called "norm-based" models of face perception, is inadequate for predicting human responses. In contrast, an optimised generalised linear model can predict responses with remarkable accuracy. While this predictor is based on a single linear filter, this filter is not aligned with the first principal component of the stimulus set, in contrast to what has been proposed by proponents of "eigenface-based" models.

In addition, we show how decision-images can be used to design optimised, maximally discriminative stimuli, which we use to test the predictions of our models. Finally, the performance of our model is correlated with the reaction times (RTs) of observers on individual stimuli: responses with short RTs are more predictable than others, consistent with the notion that short RTs may reflect earlier, more perceptual decisions modelled well by our decision-images, whereas longer RTs may be indicative of a larger cognitive or top-down component.

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Perceptual Organization: 2D Shape

Tuesday, May 12, 2:45 – 6:45 pm
Poster Session, Orchid Ballroom

56.402

Orientation tuned curvature detectors revealed by the shape-amplitude after-effect

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Aim: Contour shape after-effects have been used to reveal the mechanisms that process and represent curvature-defined shape. Here we use the shape-amplitude after-effect, or SAAE, to explore whether curvature detectors are tuned for the overall orientation of a curve. Methods: We measured the perceived amplitude of curved contours in the upper and lower visual fields as a function of the orientation of adapting contours, which were respectively higher and lower in amplitude than the test. Results: SAAEs (i) are greatest when the adaptor and test are the same orientation, (ii) decrease rapidly as the orientation of the adapting contours is rotated away from the test, the data being well fit by a Gaussian function with a standard deviation of 15°, (iii) increase again when the adapting contours are rotated 180° relative to the test contours. The increase at 180° is not consistent with curvature opponency. Control experiments show that the shape of the tuning function cannot be explained by local orientation adaptation. Conclusions: Curvature encoding mechanisms are tuned for orientation. The slight increase in SAAEs when adaptor and test differ by 180° could be explained by the combined operation of polarity-selective and polarity-non-selective curvature mechanisms. The results are discussed in relation to recent psychophysical and physiological models of form processing.

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56.403

Does plaid-selective adaptation arise from the same mechanism as the curvature aftereffect?

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The process through which the outputs of V1 cells are combined at later stages in the form pathway remains largely unknown. As a step toward understanding this aspect of visual processing, we have shown the presence of mechanisms responding selectively to particular conjunctions of Gabor patterns (localised Fourier energy). To study these we used a compound adaptation technique, whereby the effect of adapting to a particular combination of Gabor elements is compared directly with equivalent adaptation to the same elements presented in isolation. When the Gabor elements fully overlap, to form a plaid, there is a greater contrast adaptation to this compound stimulus than predicted by equivalent adaptation to the components (Peirce & Taylor, 2006; Neuroscience 141:15 18). When the components abut but do not overlap, so as to form a concave contour, there is greater adaptation to the curvature of this contour than predicted by local tilt aftereffects (a curvature aftereffect, CAE) (Hancock & Peirce, 2008; Journal of Vision, 8(7):1 11).

Here, we aimed to determine whether the selective plaid adaptation effect results from a similar mechanism to the CAE by measuring the tuning of both effects to the spatial characteristics of the adaptors and probes. Both effects were clearly tuned to spatial frequency (SF) of the probe relative to the adaptor. However, when the SF of the component gratings differed relative to each other, the CAE was maintained, whereas plaid adaptation was markedly reduced for even moderate differences in the SF of the components.

We conclude that the effects are subserved by separate mechanisms, lying beyond the simple oriented filters of V1, yet before the shape-processing mechanisms that give rise to effects such as the shape frequency aftereffect (Gheorghiu and Kingdom, 2007; Vision Research 47:834 844) or radial frequency adaptation (Bell et al, 2008; Vision Research 48:2293 2301).

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56.404

Perception of the Ebbinghaus illusion in 5- to 8- month old infants

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The Ebbinghaus illusion is a geometric illusion based on a size-contrast between a central circle and surrounding circles. A central circle surrounded by small inducing circles is perceived as being larger than a central circle surrounded by large inducing circles. In the present study we investigated 5-8-month-old infants' perception of the Ebbinghaus illusion by using a preferential-looking paradigm.

A total of 26 Japanese infants aged 5-6 and 7-8 months participated in this study. Infants were shown the overestimated figure and the underestimated figure of the Ebbinghaus illusion side by side. If infants perceive the Ebbinghaus illusion, the central circle of the overestimated figure appears larger than that of the underestimated figure. Therefore, we hypothesized that infants would show a preference for the overestimated figure.

We measured infants' preference for the over estimated figure in the following three conditions: normal condition, flash condition, and annulus condition. In the normal condition, the overestimated figure and the underestimated figure were shown in static. In the flash condition, the central circles were flashed, so that they attract infants' attention. In the annulus condition, only the inducing circles were shown. Results showed that 5-6 and 7-8 month-old infants preferred the overestimated figure of the Ebbinghaus illusion only in the flash condition. These results suggest that infants' preference reflects their perception of the size illusion of the central circle, indicating a perception of the Ebbinghaus illusion by 5-8-month-old infants.

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56.405

From illusory contours to faces: A first step in relating foundational characteristics of perceptual organization

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Last year (Bittner et al., VSS 2007), we presented a series of experiments demonstrating that hierarchical forms containing illusory contours could produce dimensional consistency effects. These effects were accompanied by the presence of both perceptual and decisional influences evidenced by violations of perceptual and decisional separability. The current experiments extend this work in two ways. Experiment 1 is an analysis of the previous hierarchial forms with all physical dimensions present. These analyses allow for a comparision with the original results between the physical presence and absence of dimensions. Experiment 2 is a comparison of face-like and object-like hierarchical stimuli. These analyses start a progression of studies to bridge the fields of object and facial perception. Hypotheses in this work are that (a) perceptual organization relies as much or more at the level above physical similarity; (b) perceptual organization reflects both perceptual and decisional factors; and (c) perceptual organization of forms and faces reflect a common strategy.

56.406

EEG correlates of perceptual organization

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We perceive the visual world not as a meaningless jumble of colors and shapes, but rather as organized recognizable structure. The obviousness of the distinction between these two alternatives makes it all the more surprising that we do not yet have any reliable EEG-based markers that can distinguish brain activity across the two conditions. The goal of this project is to identify the hitherto elusive neural correlates of perceptual organization. To this end, we recorded high-density (128-channel) event-related potentials (ERPs) while adult observers viewed sequences of images created using Random Image Structural Evolution (RISE – Sadr & Sinha, 2001). In these presentations, an image progressively "evolves" out of noise. For each sequence there is a point at which the observer experiences perceptual onset – i.e., the image becomes coherent and the object is recognized. Our strategy for uncovering neural markers of perceptual organization involved comparing the EEG signals that occur in response to images before versus after perceptual onset. Traditional ERP waveform analyses revealed that early visual components (occurring within the first 300 ms) over posterior regions of the scalp differentiate between images that occur early in the sequence (before perceptual onset) versus late in the sequence (after perceptual onset). Ongoing efforts are focused on validating this marker, disentangling the contribution of attention from perceptual organization, and identifying any additional markers via signal classification techniques drawn from the domain of machine learning. As we demonstrated at last year's meeting (Moulson et al., VSS 2008), the combination of component-based analysis and single-trial classification is a powerful approach that has the potential to provide significant insights into the time course of perceptual organization in the brain.

56.407

Haptic and visual defragmentation of shapes

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In our work with late-onset vision patients in Project Prakash, our results suggest that, immediately following sight onset, subjects exhibit an overly fragmented interpretation of their visual world. It is tempting to infer that this hyper-fragmentation is at least partially responsible for their deficits in object recognition.

To test the hypothesis that hyper-fragmentation is a debilitating condition for object processing, we presented shapes made up of dots, parametrically varying the resolution of the shape contour and embedded in noise. Normally sighted subjects were excellent at finding the shape when allowed to view the entire figure, as expected, under all parameters tested. However, when viewed through a series of apertures (mimicking a hyper-fragmented view), performance dropped precipitously.

This experiment leaves open at least one confounding interpretation. Normal vision is not usually performed through an aperture, so the aperture may be particularly disruptive in vision. Haptic exploration, on the other hand, is routinely performed through the "aperture" of the finger tips. Normal subjects who performed a haptic version of the same task exhibited poor performance as expected. Since haptic object identification may be unnatural for these subjects, we also tested completely blind subjects, for whom haptic exploration is the norm. Even these subjects exhibited extremely poor performance at low resolutions. Both normal and blind subjects, however, were excellent at identification of high resolution shapes in the haptic condition as well as the visual aperture condition.

We conclude, therefore, that the ability to identify an object depends not so much on the simultaneous perception of all components of the shape, but rather on the presence of cues indicating the interconnectivity of the fragments and on the ability to parse these cues.

56.408

Object Substitution Masking Disrupts Visual Feature Binding

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While much is known about the processing of features in visual cortex, less is known about how separate features are bound together. Many theories of feature binding have proposed a role for feedback processing in visual cortex. One function of reentrant processing may be to confirm the correct binding of features. The initial feedforward representation may be sufficient for feature identification, but correct binding may require feedback. To test this theory, we used a form of masking, Object Substitution Masking, thought to selectively disrupt feedback processing in visual cortex. Subjects (n=10) viewed an array of six elements for 75 milliseconds. Each element was composed of a pair of crossed vertical and horizontal bars. One of the bars was white and the other was red, green, or blue. The orientations of the white and colored bars were chosen randomly for each item. The target item was cued by four small dots surrounding the crossed bars. In the unmasked condition the dots disappeared with the target, but in the masked condition the dots persisted for 300 milliseconds after the target disappeared. Subjects' task was to identify the color and orientation of the colored bar in the target item. In this task, identifying the target bar's orientation requires correct feature binding, but identifying its color does not. The mask had a small but non-significant effect on the color judgment; subjects were 99% correct in the unmasked condition and 94% correct in the masked condition. On the other hand, the mask had a large effect on the orientation judgment; subjects were 89% correct in the unmasked condition and 64% correct in the masked condition ($p<0.001$). These results suggest that feature identification may be possible without reentry, but the binding of visual features relies on feedback processing.

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56.409

Simultaneous shape-contrast and global assimilation effects in the perception of aspect ratio

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During brief stimulus presentation shape perception remains in a "labile" state in which features are susceptible to perceptual distortion (e.g., Suzuki & Cavanagh, 1998). Shape distortion effects are typically examined using adaptation paradigms with sequential stimulus presentations. Here we present two aspect-ratio related distortions that occur when two ellipses are briefly (40 ms) and simultaneously presented. We measured perception of individual ellipses by randomly post-cueing one of them and having observers indicate the perceived aspect ratio of the post-cued ellipse. We call the first effect a "simultaneous shape-contrast effect." That is, the aspect ratios of briefly presented ellipses appear to "repel" each other. For example, if a slightly tall ellipse and a taller ellipse are simultaneously flashed, the less tall one appears flatter and the taller one appears even taller. This effect is quite non-retinotopic in that it occurs across a distance of at least up to 7° and whether the ellipses are presented within a single quadrant, across quadrants, or across visual hemifields. We call the second effect a "global assimilation effect." That is, when the two flashed ellipses are horizontally organized, the individual ellipses appear flatter than they actually are, whereas when the ellipses are vertically organized, the individual ellipses appear taller than they actually are. Interestingly, flat ellipses tend to be resistant to this global assimilation effect. In summary, in brief viewing two simultaneously presented aspect ratios appear to repel each other and global organization is incorporated into perception of individual shapes. These results are consistent with the idea that shape perception emerges from rapid neural processes involving both lateral and hierarchical interactions.

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56.410

Learning to Recognize 2D Contour Shapes

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To recognize a shape, the representation of a currently available shape must be matched to the representation of a previously presented shape. Many studies have investigated characteristics of the stored representation, but relatively few have looked at what types of shape are more or less difficult to represent. In a series of experiments, we measured how quickly subjects could learn to recognize various types of shape (closed contours, open contours, and segmented contours) and tried to infer the shape characteristics that predict better learning. Over 9 alternating training and test sessions, subjects attempted to learn to recognize 16 novel shapes. During each training session, subjects viewed each of the 16 shapes twice while making same/different shape judgments. During each testing session, subjects viewed the 16 shapes from the learning set and 16 new shapes, all presented in a random sequence. Subjects were asked to label each shape as either a member of the learning set or a new, never before seen shape. We found that open 2D contours were just as quickly learned as closed 2D contours, suggesting that shape learning is insensitive to the global and structural differences between these shape types. In contrast, we found that separating the contours into two parts significantly impaired learning, suggesting that shape learning is sensitive to contour connectedness.

56.411

Investigating shape representation using sensitivity to axis and part-based transformations

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Part-based approaches organize global shape in terms of segmented parts and their spatial relationships. By separating the representation of parts from that of their spatial relationships, they provide a shape representation that is robust under transformations such as articulating limbs that are common in biological objects. Skeleton or axis-based approaches can provide a compact representation of both parts and their spatial relationships (Feldman & Singh, 2006; Singh & Feldman, VSS07). The current study measured visual sensitivity to different kinds of shape transformations based on axes and parts. In Expt 1, stimuli were simple elongated shapes, and four types of axis-based transformations were applied: length change, width change, curvature change, and orientation change. In Expt 2, the simple shapes used in Expt 1 were added to a base shape; hence each now constituted a part on a larger shape. The same four shape transformations were applied, plus a lateral shift in the location where the part protruded from the base. Observers saw a test shape (masked) followed by two successive alternatives (also masked). One of the two alternatives matched the test shape, the other was modified along one of the transformation dimensions, allowing us to measure thresholds for detecting the various types of shape transformations. In order to compare thresholds across transformations, they were converted into a common measure based on the normalized area of the symmetric difference. In both experiments, the highest sensitivity was found for changes in width and length of the part, followed by curvature, and then orientation. The sensitivity to lateral shifts of the part (in Expt 2) was the poorest. The results indicate that observers are most sensitive to changes involving the intrinsic parameters of a single axial branch, and less so to changes involving the spatial relationship between two axial branches.

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56.412

How is the inner contour of objects encoded in visual working memory? Evidence from holes

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We used holes defined by binocular disparity to study how the inner contour of an object (i.e., the boundary of a hole) is encoded in visual working memory (VWM). Many studies in VWM have shown that an object's contour properties can be integrated with its surface properties via their shared spatial location, yielding an object-based encoding benefit. However, encoding of the hole contours has rarely been tested. We presented circles containing a bar under a change detection paradigm. To compare VWM capacity for objects having a hole to those with the corresponding solid complement, we manipulated binocular disparity of bars, creating two types of displays, a hole display and a conjunction display. Relevant features to be remembered were the color of circles and the orientation of bars (or holes). If the contour defining a hole is perceptually owned by the surrounding object (an outer circle) rather than by the hole itself, the object-based encoding hypothesis (Luck & Vogel, 1997) predicts that the orientation can be integrated with the color of an outer circle via their shared spatial location. Thus, in the hole display, change detection performance should be better than in the conjunction display where orientation and color were assigned to different parts of an object, and comparable to performance in a single bar display where both orientation and color were assigned to a single bar. However the results revealed that performance in the hole display did not differ from that in the conjunction display, suggesting that the shape of a hole is encoded with the same load as that of its complement. We conclude that the boundary defining a hole is not automatically encoded together with the surface properties of the outer object via object-based feature binding, but rather is encoded independently from the surrounding object.

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3D Perception: Disparity and Other Depth Cues

Tuesday, May 12, 2:45 – 6:45 pm
Poster Session, Orchid Ballroom

56.413

The Venetian-blind Effect: A Prior for Zero Slant or Zero Disparity?

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When sensory information is uncertain, prior expectations affect the percept. For example, perceived surface slant tends toward zero when the input signals are unreliable. This is Gogel's equidistance tendency, or a prior for zero slant. When the images presented to the two eyes differ greatly, the ability to estimate disparity worsens. This is a consequence of using inter-ocular correlation to estimate disparity and can be thought of as a preference for zero disparity. We investigated whether a zero-slant prior or zero-disparity preference dictates the perceived slant of ambiguous stereo-defined surfaces. We presented vertical sinewave gratings of different spatial frequencies to the two eyes. As the frequency ratio differed increasingly from 1, the surface no longer appeared like a slanted plane, but rather looked like a series of small slanted patches: this is the well-known Venetian-blind effect. The zero-slant prior predicts that phantom blinds will appear when the specified slant differs too much from zero. The zero-disparity preference predicts that they will appear when the frequency ratio differs too much from 1. Both hypotheses predict the effect, including the number of blinds. To distinguish the hypotheses, we presented the stimuli in eccentric gaze where a frequency ratio of 1 does not correspond to zero slant. The data clearly showed that frequency ratio, not slant, determines the occurrence of the blinds. However, the perceived slant of the envelope of the blinds fell in-between the values predicted by the two hypotheses. Thus, the Venetian-blind effect is caused by a preference for zero disparity, but the perceived slant of the stimulus is affected by a prior for zero slant.

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56.414

Binocular vision with null disparity disrupts the effects of extra-retinal signals

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We studied a novel phenomenon indicating that the integration of extra-retinal information and the optic flow is a necessary but not sufficient condition for slant constancy during active head motion; congruency between monocular and binocular cues to depth is also required.

In two experiments, we measured observers' performance in a rotation-detection task during active vision. Two viewing conditions were compared: binocular vision with null disparity (same image projected to the two eyes) and monocular vision. Static or rotating slanted planar surfaces were simulated with 90/270-deg tilt (Experiment 1) and 0/180-deg tilt (Experiment 2). Observers produced oscillatory lateral head movements which were recorded by an Optotrack Certus system. The position of random dots on a CRT monitor were updated in real time, simulating the correct projection of a random-dot planar surface on the image screen by taking into account the head position of the observer and the rotation of the surface.

Full perceptual constancy was found for simulated stationary surfaces under monocular vision, but not under binocular vision with null disparity. A stationary surface appeared to be stationary when it was viewed monocularly; however, it appeared to be rotating when it was viewed binoculary with null disparity. Moreover, in both experiments, rotation sensitivity was larger for monocular than for binocular vision. Response bias was shifted in opposite directions, with an overall tendency to judge surfaces as being stationary in monocular vs. rotating in binocular vision.

Monocular vision supports full slant constancy. Binocular vision with null disparity (1) disrupts the effect of extra-retinal signals produced by head movement, and (2) induces the perception of an apparent rotation counter to the heading direction.

56.415

Integration of stereo-motion information for guiding calibrated reach-to-grasp movements

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One frequently reported result is that, for perceptual tasks, the amount of perceived depth is larger when motion and disparity cues are presented together than when only one of these depth cues is shown at a time. It is not known whether this increase of perceived depth in the combined condition is also found when depth estimation is aided by action. The action of reaching-to-grasp might provide additional information about the depth of target objects, thus further disambiguating the estimation of 3D depth from projected images.

We tested this through an experiment investigating the problem of integration of motion and stereoscopic depth information for two manual depth estimation tasks: one based in perception [depth estimated through fingers adjustments], and one in action [depth estimated through reach-to-grasp]. In both tasks, observers viewed a display composed of three vertical lines embedded in a cloud of random dots; two flanking lines were positioned at fixation distance with the third line midway between the two located in depth (in front of the flankers). Observers estimated five different levels of depth separation between the flankers and the central line. 3D information was provided either by binocular disparities (stereo only), image velocities (motion only) or both (stereo-motion). Haptic feedback was provided in one fourth of the trials to calibrate depth estimates and ensure that normal visual-open-loop prehension occurred even in trials lacking haptic feedback (Bingham, Coats, Mon-Williams 2007).

The results show that in the combined condition, observers perceived a larger amount of estimated depth with both the perception and action tasks.

56.416

Percept of shape distortion induced by binocular disparity and motion parallax

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A flat surface lying in a frontal plane appears slanted in depth about a vertical axis when the image in one eye is horizontally magnified relative to the image in the other eye. The surface appears to slant away from the eye seeing the smaller image. Horizontal magnification disparity also produces shape distortion. Since the vertical angular size of the surface remains the same both with and without horizontal magnification of the image, the side that appears farther away appears larger. A rectangular figure with horizontal magnification disparity is therefore perceived as a horizontally tapered isosceles trapezoid slanted about a vertical axis. It seems that the apparent shape distortion induced by disparity has not been measured systematically although it is well established that the apparent slant approximates to the geometrical prediction. The aim here is to examine the apparent shape distortion induced by disparity. The test stimulus was a random-dot stereogram presented in a mirror stereoscope in a darkroom. The dots were depicted in a rectangular area. The stereoscopic image was a 100-mm-square at 500 mm ahead of the subject. Ten magnitudes of slant were tested: ±50, 40, 30, 20, and 10°. Subjects indicated the perceived slant of the test stimulus with an unseen paddle and then adjusted the taper of a trapezoid on a computer monitor to coincide with the apparent shape with buttons. The apparent slant and shape distortion from motion parallax were also investigated. Subjects monoularly viewed a single random-dot pattern displayed on a computer monitor while making side-to-side head movements. Stimulus translation and head movement were synchronized. For both disparity and motion parallax the perceived taper angle was smaller than prediction even though the perceived slant was almost veridical. While the predicted taper increases as slant increases, the perceived taper was immutably about 1°.

56.417

Stereoscopic shape discrimination is invariant across random changes in size

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A single experiment evaluated human observers' ability to discriminate the shape of 3-dimensional solid objects that varied in size and orientation in depth. The object shapes were defined by binocular disparity, Lambertian shading, and texture. The object surfaces were smoothly curved and had naturalistic shapes, resembling those of water-smoothed rocks. On any given trial, two objects were presented that were either the same or completely different in terms of shape. When the "same" objects were presented, they differed in their orientation in depth by either 25, 45, or 65 degrees. The observers were required to judge whether any given pair of objects were the "same" or "different" in terms of shape. The size of the objects was also varied by amounts up to +/- 40 percent relative to the standard size. The observers' shape discrimination performance was strongly affected by the magnitude of the orientation changes in depth -- thus, their performance was viewpoint dependent. In contrast, the observers' discrimination abilities were not affected by changes in the overall size of the objects. It appears that human observers can perceive the 3-D shape of objects in a manner that is independent of size.

56.418

Quantifying with precision a stereokinetic percept

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When a drawing of two circles is rotated in the image plane, a cylinder is vividly perceived (Musatti 1924). We hypothesize that this percept is a compromise between two preferences of the visual system: minimal deformation and slow motion. We quantified this percept and asked: Is the perceived shape identical across observers? Observers, viewing monocularly, adjusted one circle's size relative to the other such that the perceived cylinder is uniformly thick, and indicated which circle was in front. The resultant circular size ratios differed reliably between observers. To determine whether this difference was due to perceived viewing distance or shape or both, the cylinder was replaced by an imperfect cube. The same observers psychometrically determined whether the front square was larger than the back square, and the perceived distance was calculated from the square size ratio at PSE. The distances differed reliably between observers. The perceived viewing distance was alternatively measured whereby observers touched a stimulus with an LED attached to a finger. The stimulus was the same two circles, except only one of which was visible. (A control with binocular viewing was also conducted.) All stimuli in our studies were presented using a two-way mirror at 45°. The LED's location was tracked by four cameras. The average viewing distance from multiple sessions was remarkably consistent with that from the cube psychometric measurement, within-subjects. Combining the viewing distances and circular size ratios, we found that the perceived cylindrical shapes differed reliably between observers, indicating their differently weighted preferences. We deliberately used an impoverished stimulus to study the way in which prior preferences compromise to reach a (bi-stable) percept, and how this compromise differed between observers. The principle of this compromise is hypothesized to be stimulus-independent, and this study is one step toward testing it.

56.419

A "hole" new look at grapheme-color synesthesia

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Grapheme-color synesthesia is a phenomenon whereby letters or numbers (graphemes) evoke the visual perception of color. In this experiment, seven synesthetes were primed for synesthetic color and spatial plane with letter-shaped holes cut from circular discs. Primes and probes appeared sequentially (8ms SOA) in either the same or different plane of 3D space (induced with stereoscopic glasses). Probes were congruent or incongruent to the color synesthetically induced by the letter-shaped primes. All synesthetes showed positive color priming effects, replicating previous studies and showing for the first time that synesthetic color can be induced by letter-shaped holes. Synesthetes also showed effects of plane; they were faster to name colors that appeared in the opposite plane of depth relative to the letter prime, a result likely due to the residual representation of the prime that lasts beyond the 8ms inter-stimulus interval and competes for representation with the probe when it appears in the same 3D location of space. This result was also seen in a separate experiment for non-synesthetes who viewed colored letter primes followed by colored probes, and contrasts with previous synesthetic research showing that the relationship of spatial plane to prime-probe pairs correlates with the vividness of visual imagery of synesthetes. Specifically, synesthesia was suggested to be supported by visual imagery and, when vivid, would suppress visual perception and perceptual binding, reducing prime-probe competition. In the current study, vividness of visual imagery did not correlate with RTs for any condition when synesthetic color was induced from letter-shaped holes; an important clue that actually furthers the idea that synesthesia is supported by visual imagery. Together, these findings suggest that grapheme-color synesthesia is induced from the shape of a letter, even when the shape itself has no surface properties, and acts similarly to non-synesthetic color priming.

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56.420

Perception of shape-from-texture in the periphery using a simulated central scotoma

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Purpose. Studies of eccentricity dependent sensitivity loss typically require participants to maintain fixation while making judgments about stimuli presented at various eccentricities in the peripheral visual field. However, training participants to fixate can prove difficult. Therefore, we have developed a novel alternative in which eccentricity of stimulus presentation is controlled using a simulated central scotoma of variable size.

Method. Participants were asked to identify 3D surfaces comprising hills, valleys and plains in three possible locations. Therefore there were 27 different surfaces, yielding a 27 alternative forced choice task. Surface shape was conveyed by texture. Participants performed the task for simulated scotomas of 0, 1, 2, 4, 8 and 16° diameter over an eight-fold range of stimulus sizes. Position of scotoma was based on current fixation location captured with an eye tracker (SR Research Eyelink 1000, binocular tracking).

Results. The psychometric functions for each simulated scotoma were left shifted versions of each other on a log size axis. Therefore, when we divided stimulus size at each eccentricity (E) by an appropriate $F = 1 + E/E2$ (where E2 is the eccentricity at which stimulus size must double to achieve equivalent-to-foveal performance) all thresholds collapsed onto a single psychometric function. Therefore, stimulus magnification was sufficient to equate sensitivity to shape-from-texture for all scotoma sizes. The average E2 value required to achieve this was 1.67° (N = 4, SEM = 0.304, 95% CI - 0.62° to 2.73°).

Conclusions. In all cases, scaling with $F = 1 + E/E2$ eliminated most scotoma-dependent variation from the data. The data show clear evidence that size scaling is sufficient to equate the perception of shape-from-texture across in the presence of scotomas.

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56.421

Two representations of object size in early human visual cortex

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Three-dimensional context has a dramatic effect on how we perceive object size – the exact same size projected on the retina can appear small if the object is perceived to be close and large if the object is perceived to be far away. These size illusions raise the question of how 3D context influences neural representations of object size. Here we show, using averaged scalp-recorded electrical potentials (ERPs), that there are two successive representations of object size in early visual cortex: an early representation that reflects the size projected on the retina and a later representation that incorporates 3D context and reflects perceived size. In an initial experiment, we presented circular 2D checkerboards that varied in size on a uniform gray background. We found two latency-defined ERP components centered approximately at the occipital pole that were modulated by stimulus size. In a second experiment, we presented sphere-shaped checkerboards that varied in size at near and far apparent distances in a 3D rendered scene, making the perceived size of the stimulus dependent on its location. The magnitudes of the early and late components were again modulated by absolute stimulus size, replicating the finding from experiment 1. However, the components differed in how they interacted with the location of the stimulus. The early component was not affected by perceived size – the magnitude was the same for stimuli at near and far distances. In contrast, the magnitude of the late component was modulated by perceived size. The stimulus in the far location produced a systematically higher-magnitude response than the near location, reflecting behaviorally quantified perceived size differences between the two locations. These results suggest that the close relationship between the perception of object size and neural activity in early visual cortex results from feedback of 3D contextual information from higher visual areas.

56.422

Shape-dependence of a size illusion explained by spatial mapping in V1

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Perceived size of an object depends not only on its retinal image size but also on its perceived distance to the observer. This principle leads to well known visual effects such as the Ponzo illusion and the hallway illusion: holding retinal image constant, the angular size of an object is perceived larger for far as compared to near objects. Here we investigate the extent to which the size effect is modulated by the shape of the object.

In a behavioral experiment we measured the magnitude of the effect in a computer rendered hallway scene using three different shapes: a spherical object (ball), a narrow horizontal rod and a narrow vertical rod. Each shape was presented in five different absolute image sizes. We quantified the effect as the ratio of the image size (radius for the ball, length for the rods) of the front object to that of the back object at the point of subjective equal image size.

For the ball, we found that the magnitude of the effect depends on absolute image size: the perceived angular size difference between the near and far ball decreases as the radius of the ball increases. In contrast, there was no dependence on absolute size for either of the rod shaped objects. Furthermore, for horizontal rods we consistently observed a larger size effect than for balls.

We explain the pattern of results using a model based on a functional form of the mapping from visual space to cortical space (Schwartz, 1980) in primary visual cortex (V1). The model assumes that observers' image size estimation is based on the amount of V1 area recruited. This suggests that the pattern of cortical activity in V1 may constitute a basis for perceptual coding of angular image size.

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56.423

Decoding disparity and motion-parallax defined depth in human visual cortex

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Using high-resolution imaging and multivariate pattern analysis (MVPA), we recently showed that dorsal visual areas contain information highly diagnostic of disparity-defined depth position. Like binocular disparity, motion-parallax can provide reliable information about depth structure. Moreover, cross-adaptation effects between the depth cues suggest common neural circuitry. Here, we investigate similarities in the decoding of depth position defined by disparity or motion-parallax. We used an fMRI block design and presented observers with random dot patterns that depicted a central plane in front of or behind a background plane. Depth position was defined by (i) disparity or (ii) motion-parallax. In particular, binocular disparity (+/- 9 arcmin with respect to the background) specified a near or far position for the central plane. In motion-parallax conditions, the central plane moved horizontally with a sinusoidal motion to depict either near (larger movement amplitude) or far (smaller amplitude) positions. In all conditions the background plane moved horizontally with the same sinusoidal velocity profile. Using a linear support vector machine, we assessed the information content of each visual area relating to near vs. far depths defined by either disparity or motion-parallax cues. In line with our previous work, we found the highest discrimination accuracies for disparity-defined depth were observed by decoding the pattern of voxel responses from dorsal retinotopic cortex. Accuracies for motion-parallax conditions were highest in early visual regions, likely reflecting responses to motion transients. However, in contrast with early areas, accuracy in dorsal areas was very similar for motion-parallax and disparity conditions. These results suggest differences between the representation of disparity and motion information in early areas, whilst information about depth from two different depth cues may converge in dorsal visual cortex.

56.424

3D cue combination in spontaneous eye movements

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We make eye movements continuously to obtain an understanding of the 3D world around us, but how does the visual system plan these scanning movements of the environment? Here we study what 3D visual information is used to plan saccades. Cue conflict studies have shown that the visual system combines cues in a statistically optimal way for perception. Recently, it has been shown that 3D surface orientation influences spontaneous saccade directions when viewing a surface (Wexler & Ouarti, 2008). Here we use cue conflict stimuli to study whether cues are combined in an optimal way for eye movements. We investigated the perceived tilt and the direction of saccades made in reaction to a tilted cue conflict stimulus.

Stimuli consisted of slanted planes with monocular (perspective) and binocular (disparity) cues each specifying a different tilt angle. We used both small (0o-45o) and large (180o) tilt differences. The reliability of the disparity signal was varied so as to observe a change in weighting of the two cues for perception and saccade direction.

Observers were asked to view the plane and told that they were free to make eye movements across the plane for 3 s, after which they reported perceived surface tilt using a visual probe controlled by a joystick.

Perceptual and saccade data show similar results. For small cue conflict, a combined estimate of surface depth gradient is used to judge tilt and to plan saccade direction. For large conflicts both oculomotor and perception systems abandon cue integration and base their output on only one of the cues at any one time.

Wexler, M., & Ouarti, N. (2008). Depth affects where we look. Curr. Biol., in press.

56.425

Cue probability learning by the human perceptual system

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The visual system should rely heavily on a cue that has high ecological validity, and less on a cue that has low validity. We used the cue recruitment paradigm of Haijiang et al. (2006) to measure the ability of a new cue to control perceptual appearance after training in which the new cue was paired with a long-trusted cue with different levels of contingency. We predicted that the new cue would have greater subjective reliability when paired consistently with long-trusted cues. Stimuli were rear-projected movies of a rotating wire frame Necker cube. The new cue was stimulus position (above or below fixation) and the long-trusted cue was binocular disparity coupled with occlusion (which effectively disambiguated apparent rotation direction). Each experimental session consisted of 240 training trials (containing both new and trusted cues) and 240 test trials (new cue only) in a counterbalanced pseudorandom sequence. Thirty two trainees participated in four groups of eight. The probabilistic relationship between the new and trusted cues on training trials was 0.5, 0.7, 0.85, or 1.0, for the different groups, respectively. Each trainee ran three sessions on consecutive days. On Days 1 and 2 cue probability was fixed at one of the four levels. On Day 3 the probability on training trials was 1.0 for all groups but contingency was reversed. Subjective reliability of the new cue increased with cue probability, as indicated by inter-group differences in the effect of the new cue on apparent rotation direction on Day 3: those trainees exposed to high contingency on Days 1 and 2 responded according to that training even after contingency was reversed on Day 3. Analysis of data from the zero-contingency group (probability 0.5) revealed that the first few trials of the experiment had a surprisingly large effect on the subjective reliability of the new cue.

56.426

Recruitment of an invisible depth cue

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Cue recruitment occurs when a sensory signal is put into correlation with trusted cues and subsequently influences perceptual interpretation as the trusted cues do. In all cue recruitment experiments to date, the signal has been well above detection threshold and was easily visible. For example, it has been shown that object position and motion can be recruited as a cue to influence the interpretation of the ambiguous Necker Cube (Haijiang et al., 2006). Here we asked whether a signal that is not visible on its own could be recruited as a cue. Vertical size ratio (VSR, the ratio of vertical angles subtended by an object at the two eyes) is normally used to correct for relative position of the head when interpreting horizontal disparity (Gillam & Lawergren, 1983; Backus et al 1999) but it is not visible in displays consisting of horizontal lines only because there are no horizontal discontinuities. We manipulated VSR of displays simulating a cylinder composed of horizontal lines that rotated about a horizontal axis. On training trials, the rotation direction of the cylinder was unambiguously specified by horizontal disparity and occlusion cues and these trusted cues were correlated with the VSR cue to be recruited. On test trials, the display did not contain horizontal disparity or occlusion, so that the rotation direction specified by the trusted cues was ambiguous. If participants however made use of the VSR cue in the test display rotation direction could become unambiguous after training. For 8 out of 9 participants, apparent rotation on test trials became contingent on the value of VSR. We conclude that a signal need not have perceptual consequences by itself for the system to assign it a new use during the construction of appearances.

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56.427

Short-term dynamics of perceptual bias for bistable stimuli

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The perception of a bistable stimulus is influenced by prior presentations of that stimulus. This influence has been characterized as priming, and more recently as a memory process that biases perception on independent multiple timescales on the order of seconds to minutes (e.g. Brascamp et al., 2008; Pastukhov & Braun, 2008). Cue recruitment studies show that learned bias can last for days, and that reversing it requires extensive retraining (Haijiang et al., 2006). These very-long-term biases are measured using trial sequences of disambiguated and ambiguous stimuli, so it is important to understand how recent stimulus presentations interact with such biases on a given trial.

We investigated short-term temporal influence using rotating Necker cubes. Observers viewed a randomly permuted sequence of 480 trials, each consisting of a 2-sec movie depicting a rotating cube just above fixation. The sequence included 320 “Training” trials (rotation direction disambiguated by stereo and occlusion cues) randomly interleaved with 160 “Test” trials (no disambiguating cues). Observers reported whether a dot moving right-to-left or left-to-right through fixation on each trial moved in the same direction as the front or the back of the cube.

Reported rotation on Test trials correlated positively with reported rotation for both recent Test trials and recent Training trials. Correlations were highest with the immediately preceding trial, diminishing for earlier trials. This temporal pattern of correlations indicates an active influence from recent trials. The short-term influence of the Test trials was at least as great as that of the Training trials. It therefore seems likely that a perceptual decision itself can affect perceptual decisions on subsequent trials. Some observers developed a bias to perceive all Test trials in one direction, suggesting an interaction of recent history with an internal state variable that governs a long-term perceptual bias.

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Scene Perception: Spatiotemporal Factors

Tuesday, May 12, 2:45 – 6:45 pm
Poster Session, Orchid Ballroom

56.428

Empirical data on the configural architecture of human scene perception using natural images

Lauren Barghout[1] (lauren.barghout@gmail.com); [1]self-funded

Purpose: Both local and configural processes play a role in the figure-ground organization of scenes. Local factors include bottom-up processes that fuse smaller regions into a larger figure. Configural theories propose top-down processes able to utilize more global scene information, prior experience, and meaningfulness. The Berkeley Segmentation DataSet (Martin, Fowlkes, Tal, & Malik (2001)) provides a corpus of images whose contours were hand segmented by humans and annotated for figure-ground status. Though useful for studying local mechanisms, an additional dataset designed to capture configural information is also needed.

Methods: Paper surveys consisted of a photograph and the instructions: “Please put an “x” at the ‘center of the subject of the photograph and write a few words to describe it”. Photographs, downloaded the internet via Google, search were chosen for object type and configuration to match an N by M factorial design, where N represents object type (such as a bird)

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and M the number of objects of the same type appearing in the image. Configurations of single, double, triple and large numbers were used. For each photograph, at least 50 surveys were collected.

This method assumes that asking someone to mark the 'center of the subject of the photograph' serves as a proxy of the figural status of the region centered at the point marked. Since the method does not distinguish between a foreground, a single object or an object within an object, I use the term 'spatial taxon' to refer to a region centered around the position indicated by survey participants. This operational definition is analogous to but also much broader than the term 'figure' as defined in the literature.

Conclusion: A dataset of natural scenes annotated with empirically derived spatial taxons and their relative frequency provides insight as to the configural architecture of natural scenes.

URL: www.laurenbarghout.com

56.429

Dealing with natural scenes: electrocorticographic correlates of object and context processing in Rhesus Monkey

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In the real world, objects never appear isolated but embedded in a meaningful context. We recently showed, at behavioral level, that context can influence rapid object categorisation in both Human [Joubert & al. 2008] and Macaque [Fize, Cauchoix, Fabre-Thorpe, Submitted]. Whereas neural correlates of object recognition have been largely studied in monkey, we know very little about neural coding of scene's context, its interaction with object processing and its possible precedence.

Here we investigate context and object coding at the neural population level on two head-free monkeys engaged in a rapid go/no go visual categorisation task while their electrocorticogram were simultaneously recorded. Stimuli were manipulated photographs composed by objects embedded in natural environments or man-made contexts. The animal/non-animal categorisation task thus used both categorically congruent objects and contexts (animal and natural context, manmade object and context) and incongruent ones (animal in a manmade context, manmade object in a natural context).

From averaged evoked potentials, we first confirmed the existence in V4 of a differential activity between animals and manmade objects picking at 96ms [Fize & al, Submitted]. Moreover we found that scene's contexts, which were irrelevant for the task, induced a strong differential activity in a neighbouring electrode 20ms earlier. Finally, using single trial time-frequency analyses, we evidenced stronger low frequencies (3-5Hz) phase synchronisation when objects were presented in a congruent context than in an incongruent one, around 80ms after stimulus onset.

During the rapid visual processing of natural scenes, neural signatures of context and object processing and their interaction occur in the neighborhood of V4 area in less than 100ms after stimuli onset.

Acknowledgement: funded by CNRS, FRM and DGA

56.430

Finding "good" features for natural scene classification

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Humans are adept at determining the base-level category of natural scenes (Tversky & Hemenway, 1983). What visual features of an image does an observer use in such categorization tasks? Previous computational studies have established that classification of scenes is possible using power spectral information (i.e., magnitude of spatial frequencies; Oliva & Torralba, 2001) and local texture descriptors (Fei-Fei & Perona, 2005). Here we take a new approach toward identifying possible features that distinguish between categories by comparing good and bad examples of a category. If a particular feature is relevant to human categorization, it should also provide better classification for good than bad examples of that category. Using linear pattern recognition algorithms, we performed multi-way classification on six categories (beaches, city streets, forests, highways, mountains and offices), each comprised of 50 images that were rated by naïve participants as "good" examples of their category, and an additional 50 that were rated as "bad" examples of their category (Torralbo, et al., VSS 2009). We found that several feature sets, including the power spectrum, color histogram, and local surface geometry and texture information (Hoiem, et al, 2005) resulted in average classification rates significantly above chance-level.More importantly, when these classification results were separated into "good" and "bad" examples, all three feature sets showed greater classification accuracies for "good" than "bad" category exemplars. These results suggest that all three feature sets are viable candidate features that humans could use to distinguish among our natural scenes categories.

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56.431

What is the function of the parahippocampal place area? Testing the context hypothesis

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The parahippocampal place area (PPA) is a region in the human collateral sulcus that responds more strongly to visual scenes (e.g. images of landscapes or cityscapes) than to other visual stimuli. Several competing hypotheses have been offered to explain the response properties of this region. Epstein and Kanwisher (1998) proposed that the PPA encodes spatial layout information, which is obtainable from visual scenes but not from nonscene objects. In contrast, Bar and colleagues propose that the PPA encodes "context" which they define as information about which objects "typically cooccur in the environment around us" (Bar et al., 2008). Evidence for the context hypothesis comes from reports that the PPA responds more strongly to "strong-context" than to "weak-context" objects (Bar & Aminoff, 2003; Bar et al., 2008) and more strongly to famous faces (for which contextual associations are available) than to nonfamous faces (Bar et al., 2008). We re-examined these claims by scanning subjects with fMRI while they viewed scenes, strong and weak context objects, scrambled versions of these objects, and famous/nonfamous faces. Contrary to previous reports, we found that the strong>weak context effect was only reliable at slow presentation rates that facilitated mental imagery, while the famous>nonfamous face effect did not replicate. Based on these results, we hypothesize that previously reported context effects in the PPA might be explained in part by scene imagery. Rather than being "unequivocal" (Bar et al., 2008), we suggest that the evidence in favor of the context hypothesis is in fact less than compelling, and that the spatial layout account of PPA function is still quite viable.

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56.432

The costs of multiple concurrent tasks in scene perception

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Motivation. Everyday scene perception often involves attending to a variety of component processes and relations that change over seconds. Most research in scene perception fails to capture this richness because researchers have focused on single tasks with brief time courses. We designed experiments to address the complexity of natural scenes, involving multiple tasks that evolve and overlap across time. This research presents a novel paradigm for assessing the perceptual demands of simultaneously monitoring multiple scene dimensions and allows us to examine an important theoretical contrast: The attentional set hypothesis is that task set is an important determinant of perception, and that the need to repeatedly change task set will interfere with performance. In contrast, if scene perception is efficient and primarily bottom-up, then changes in task set should cause minimal interference.

Methods. We created 4 animated processes (tasks) involving targets and distractors defined by dynamic changes in one property: motion, location, color, or shape. The display screen was divided into 4 quadrants. In the single task conditions, one task filled each quadrant; in the multitask condition, there was a different task filling each quadrant. Each trial consisted of 30 seconds of animations involving a total of 136 distractors and 8 targets. 36 observers were required to monitor all four quadrants for targets.

Results and discussion. Performance is reasonably summarized by overall accuracy in each condition. Accuracy averaged 79.4% across the four single task conditions. In the multitask condition, overall accuracy was 5.3% lower. The reduction in performance was statistically reliable ($p < .01$); however, the ability to achieve multitask levels near single task levels is impressive given the requirement to simultaneously perform four distinct tasks. Impressive scene perception abilities found in previous research with single task paradigms appear to extend multitask scene perception with only small decrements.

56.433

Scene perception in low vision: a study on people with macular degeneration

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Research on scene recognition in normally-sighted people have shown the extent to which human observers use diagnostic image information such as colour, orientations or texture to quickly categorize natural images (Oliva 2005 Gist of the scene. In the Encyclopedia of Neurobiology of Attention. L. Itti, G. Rees, and J.K. Tsotsos (Eds.), Elsevier, San Diego, CA (pages 251-256). for a review). Even under degraded visual conditions such as low contrast, blurring or large visual eccentricity normally-sighted observers are able to categorize scenes quikly on the basis of their spatial properties.

In contrast to word and face perception, few investigations have been devoted to the understanding of how people with low vision perceive scenes (see Boucart et al. 2009 Visual neuroscience)

People with age related macular degeneration (acuity equal or lower than 1/20) were presented with coloured photographs of scenes. As we were interested in testing whether people with low vision can quickly grasp the gist of a scene, images were flashed for 300 ms either centrally or randomly in the 4 corners of a 21′ computer screen. In separate blocks of trials people were asked to categorize scenes on the basis of naturalness (natural/urban), temperature (hot/cold landscape) and indoor/outdoor.

Performance was above chance (65 to 78% hits) for temperature and naturalness respectively but at chance when the task was to decide if the scene was indoor or outdoor. Accuracy showed a ceiling effect for normally sighted controls. These results indicate that people with low vision can use image properties to recognize scenes and fail when categorization requires object identification (indoor/outdoor).

56.434

Title: Inter-stimulus Screen Contrast affects Scene Masking in Early Processing

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Abstract: Scene perception research often uses visual masks to vary processing time. However, little is known about the effects of spatial and temporal masking parameters when masking real world scenes. Studies using visual masking typically include a blank screen inter-stimulus-interval (ISI) between target and mask, which is frequently black. However, some researchers use a neutral gray ISI screen adjusted to the mean luminance of the target and mask. Doing so is presumably based on the plausible assumption that sudden changes in contrast between target, ISI, and mask, may affect masking by causing pulses of neural activity in transient response cells. The sustained-transient theory of visual masking (Breitmeyer & Ogmen, 2006) argues that activity in transient channels can interfere with processing in sustained channels. If so, we would expect that such effects should be much greater with a black ISI than an equiluminant gray ISI.

Method: Subjects performed a scene gist recognition task with either black (high contrast) or equiluminant gray (low contrast) ISI screens. Masking strength was also manipulated by using either fully phase-randomized scenes-as-masks (weak mask) or normal scenes-as-masks (strong mask), and a no-mask control condition. Target and mask duration were both 12 ms, and ISI varied from 0-84 ms (SOA 12-96 ms).

Results: Consistent with the sustained-transient theory, the high-contrast black ISI condition produced significantly stronger masking than the equiluminant gray ISI condition, but only at ISIs of 0-12 ms (SOAs 12-24 ms), and only in the weaker phase-randomized scene-as-mask condition. ISI (or blank screen) contrast with the target had no effect in the no-mask condition.

Conclusions: Contrast between ISI screen versus the target and mask affects scene masking, but only at short ISIs with moderate strength masking. If masking is very strong, or conversely very weak (long ISIs, or no-mask), there is no effect of ISI contrast.

56.435

Where in the World? Human and Computer Geolocation of Images

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In this work we measure how accurately humans can localize arbitrary photographs on the Earth and contrast this against a baseline computational method.

Previous work has studied the placement of scenes into semantic categories (e.g. kitchen, bedroom, forest, etc...) both by humans and computers. With moderate numbers of categories, simple texture-based methods can group scenes almost as well as humans (Renninger 2004, Oliva 2005). The success of computational methods is not a result of any high-level understanding of scenes, but rather the ease of which these hand-defined categories can be separated by low-level features.

In this study we examine human performance at organizing scenes according to geographic location on the Earth rather than hand-defined semantic category. Participants are shown novel images and asked to pick the location on a globe where the photograph was taken. This task is difficult – many scenes are geographically ambiguous while others require high-level scene understanding and knowledge of cultural or architectural trends across the Earth. On the other hand, photographs of landmarks are easy to geolocate for both humans and computers.

We compare and contrast human performance with a data-driven computational method using 6.5 million geolocated photographs. For a novel photograph, the algorithm finds the most similar scenes according to the scene gist descriptor, texton histogram, and other features. A voting scheme produces a geolocation estimate from the locations of matching scenes.

Image geolocation is one of few high-level visual tasks where computational methods are competitive with humans. While humans are superior at using high-level scene information (e.g. traffic direction, text language, tropical flora, etc...) our computational method has a geolocated visual memory larger than almost any human. We break down the performance of humans and computers according to scene type and analyze the situations in which humans and computers are disparate in performance.

56.436

Variation in scene gist recognition over time in central versus peripheral vision

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Scene gist is recognized within a single fixation. However, it is unknown whether gist recognition varies over space, specifically central versus peripheral vision, and over time, within a fixation. A related issue is whether attentional focus affects scene gist recognition (Evans & Triesman, 2005; Li, et al., 2001).

Tuesday Sessions

Previous research (Larson & Loschky, 2008) showed that both central and peripheral information can produce equal scene gist recognition, provided there is roughly twice as much area in the periphery. However, those studies did not vary processing time (through masking) or manipulate attention.

Methods: Scenes contained information only in a central circular region (the "window"), or blocked that central region (the "scotoma") and only contained information in the periphery. These conditions were perfectly divided by a critical radius, such that both window and scotoma images produced equal gist accuracy when unmasked (i.e., unlimited processing time). Images and masks were presented for 24 ms each, with two SOAs (24 or 84 ms), and a no-mask condition. Central fixation was ensured by using an eyetracker and an algorithm requiring fixation. We manipulated the focus of attention by randomly interleaving trials of an alternate task, in which subjects had to discriminate a small briefly flashed "E" or "3" at fixation for 20% of trials (20% E/3 task, 80% gist recognition task).

Results: There was an interaction between central versus peripheral information and SOA. At the shortest SOA, central information produced better gist recognition than peripheral information. Unlimited processing time produced equal performance for central and peripheral information, as predicted based on use of the critical radius.

Conclusion: When attention is focused at the center of vision, centrally presented information is preferred early in processing, though with unlimited processing time, gist is equally processed in central or peripheral vision. Thus, gist recognition was influenced by attention.

56.437

Invariance to Mirror Image Reversals in the Lateral Occipital Complex (LOC) and Parahippocampal Place Area (PPA)

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Electrophysiological and behavioral studies in many species (e.g., octopus, pigeon, monkey, and human) have demonstrated mirror-image confusion for objects, perhaps because left/right information is rarely important in object recognition (e.g., a cup is the same cup when seen in left or right profile). However, unlike object recognition, scene recognition and navigation crucially require left/right information; the identity and navigability of a scene are completely different when it is mirror reversed. Thus, we predicted that object representations in object-selective cortex would be invariant to left/right reversals, but scene representations in the scene-selective cortex would not be. To test for such left/right information encoding, we ran an event-related fMRI adaptation experiment. In each trial, we successively presented images of either two objects or two scenes; each pair of images was: 1) the same image (presented twice); 2) two completely different images; or 3) a scene or an object, followed by the mirror-reversed version of the same stimulus. Consistent with our prediction, preliminary results showed partial invariance to the mirror reversals in the object-selective lateral occipital cortex (LOC), to a greater extent in its anterior subregion (posterior fusiform gyrus, pFs) than its posterior subregion (LO). However, contrary to our prediction, we also found invariance to left/right orientation for scenes in the parahippocampal place area (PPA). These findings pose a challenge to hypotheses of the PPA's role in scene recognition, navigation, and reorientation.

Acknowledgement: Supported in part by: NIH grants 13455 (NK), and a Kirschstein-NRSA EY017507 (DDD)

Color and Light: Chromatic Mechanisms

Tuesday, May 12, 2:45 – 6:45 pm
Poster Session, Orchid Ballroom

56.438

Cortical Recovery Following Gene Therapy in a Canine Model of Achromatopsia

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Purpose: To measure the cortical response to visual stimulation in dogs with hereditary loss of retinal cone function using rod- and cone-directed stimuli.

Methods: Two normal dogs (CNGB3 null mutant carriers), 5 achromatopsia-affected dogs (CNGB3 mutants with S- and L/M-cone dysfunctions), and 2 CNGB3 mutants treated at 1.5 and 3 months of age (recovered L/M-cone function demonstrated by ERG) were studied using BOLD fMRI. Prior to the imaging studies, the treated animals received unilateral recombinant adeno-associated virus (rAVV) subretinal injections containing human CNGB3 cDNA. During scanning, the animals were sedated with Ketamine/Valium and mechanically ventilated following neuromuscular blockade. Rod- and cone-directed stimuli were developed using the silent-substitution method, determined with respect to published spectral sensitivity properties of the canine L/M-cone and rod opsins. Visual stimulation was a 4-quadrant checkerboard, 5 Hz flicker presented for 30 seconds, alternating with a static gray screen. Scanning was conducted with low (0.41 cd/m2) and high (1194 cd/m2) average luminance stimuli, corresponding to the canine scotopic and photopic range.

Results: Following transformations of functional data to a standardized canine digital atlas, activation was observed in the lateral gyrus (striate/parastriate cortex). Within this region, the response to high luminance, cone-directed stimuli in the normal and treated animals was more than double that of the affected CNGB3 mutants (140 mm3 vs. 310 mm3, p=0.068). No population differences were observed for the rod-directed responses or at low luminance.

Conclusions: These results suggest that rod- and cone-directed cortical responses can be identified and studied in a canine model of achromatopsia. More importantly, the visual recovery that can be measured in affected animals following gene therapy suggests restoration of L/M-cone cortical responses.

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56.439

Clustering of macaque V1 neurons by luminosity function

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Neurons in primary visual cortex (V1) respond to both luminance and color and are integral to the transformation of color representation from retinal cone axes to perceptual hues. To isolate the coding and circuitry underlying this transformation, we employed the silent substitution method to minimize luminance-related responses. The silent substitution method depends on the choice of luminosity function, typically defined as sensitivity to a ratio of L and M cone subtypes. As the field has not agreed upon a unique luminosity function to study color representation in macaque V1, we began by testing whether the choice of luminosity function, human (1.5L + M) or macaque (1L + 1M, Dobkins et al. 2000), affects the quality of isolation of the color circuitry.

We used intrinsic signal optical imaging to identify blob and interblob structures and measured single-unit responses via targeted multi-electrode arrays in anaesthetized macaque V1. Stimuli consisted of 4 Hz chromatically-modulated drifting gratings presented monocularly.

Our initial results indicate that a heterogeny of luminosity functions are represented by V1 neurons, with a tendency for neurons with similar luminosity functions to cluster together in cortex. This finding is consistent with reports of local clustering of L and M cone subtypes in the human and macaque retina, suggesting that this spatial non-uniformity of spectral sensitivity persists in the color representation through to V1.

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56.440

Slowing Vision: Pattern Pulse MultiFocal Visual Evoked Potential (PPmfVEP) timing dilation under Isoluminant and Luminance Contrast Conditions

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Purpose:The magnocellular (M) pathway's contributions to PPmfVEPs was examined by comparing VEP characteristics with isoluminant (ISO) colour and diffuse red background dartboards against Luminance Contrast (LC) dartboards.

Methods: Participants (n=5) observed stimuli through a stereoscopic display (two screens viewed via mirrors at 45°; lenses gave an effective infinity viewing distance). Stimulus was an 84 region cortically scaled dartboard, eccentricity 23° 4x4 checkerboards briefly pulsed pseudo-randomly (mean frequency 2/second/region). Ten conditions were tested with 30 or 60 cd/m2 mean luminance and grey or chromatic (red-green) checks yielding six LC and four ISO conditions. RGB values were selected with a photometer. Participants viewed a 30Hz reversing dartboard of all regions; for ISO they made it not flicker; for LC they verified it flickered, they then viewed PP dartboards (four 1 minute segments per condition). 64 channels were recorded at 256Hz.

Results: ISO produced a response delayed in initial rise and in peak relative to LC reflecting the absence of faster M pathway transmission for ISO. 90% of the channels were significant ($p<0.03$), with over 50 times power to signal to noise ratio (SNR) for occipital channels. Interestingly, the response to isoluminant stimulus is also larger in amplitude, despite the M component's absence.

Conclusions: PP presentation has better SNR than traditional contrast reversing stimuli, allowing for more conditions in a reasonable length session. This research is the first usage of PPmfVEPs to identify M pathway effects. Potential applications include Dyslexia and Schizophrenia, which have a correspondence with dysfunctional M pathways.

Acknowledgement: ARC Centre of Excellence in Vision Science

URL: http://www.saminverso.com/vss2009

56.441

Hidden Digit Plates of Ishihara Pseudoisochromatic Plates Can Be Read by S-Cones

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Background. Ishihara Pseudoisochromatic Plates are one of the most commonly used screening tools for red-green color vision deficiencies. Even though hidden digit plates are supposed to be read only by those who are color vision defective, multiple studies report that at least some of normal trichromats can indeed read these plates. The purpose of this study was to measure chromaticity coordinates of the dots used in Ishihara Pseudoisochromatic Plates and clarify the mechanism that enables color vision defectives and some normal trichromats to read these hidden digit plates. Methods. Spectrophotometric measurements were made for the 17 numeric plates in the 24-plate version of Ishihara Pseudoisochromatic Plates (2001) using a GretagMabeth Spectrolino Spectrophotometer. The raw measurement values were used to calculate the chromaticity coordinates in the MacLeod-Boynton diagram. Results. As theoretically expected, reading of Ishihara plates by normal trichromats is mediated by the dot chromaticity differences on the L/(L+M) axis, which is the initial stage for the red-green color vision. On the other hand, reading by red-green color vision defective observers is made possible by the dot chromaticity differences on the S/(L+M) axis and luminance differences. Because hidden digit plates can be correctly read by the dot chromaticity differences on the S/(L+M) axis, normal trichromats who can extract S-cone signals effectively can read these plates that are supposed to be read only by color vision defective observers. Conclusion. Normal trichromats read Ishihara plates using their L- and M-cones. Red-green color vision defective observers rely on S-cone and luminance signals in reading the plates. Some normal trichromats can read the hidden digit plates because they can extract S-cone signal difference efficiently despite the distraction from L- and M-cones.

56.442

Blindsight is color-blind to S-cone isolating stimuli: an fMRI study

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Purpose: To investigate and compare the role of achromatic contrast and S-cone contrast in blindsight in hemispherectomized subjects. Methods: We designed an fMRI paradigm using sinewave checkerboard stimuli (0.5cpd, spatial envelope s=1.5cycle, temporal envelope s=250ms) that isolated either the achromatic pathway or the S-cone (blue/yellow) pathway. Stimuli were presented binocularly at 5.4° in the right, left, or in both visual fields. We tested three subjects, one subject with blindsight, one subject without blindsight, and one control subject. We investigated hemispherectomized subjects to exclude the possibility that blindsight is mediated by spared islands of visual cortex. Results: Achromatic and S-cone isolating stimulus presentation in the normal visual field of both hemispherectomized subjects and to both visual fields in the healthy subject activated contralateral visual areas (V1 & V2). The hemispherectomized subject with blindsight, however, showed cortical activation to achromatic stimuli presented to his blind visual field (FEF & V5) but had no significant cortical activation to S-cone isolating stimuli. The hemispherectomized subject without blindsight showed no cortical activation to any stimulus presented in his blind visual field. In the control subject, presentation of an additional stimulus increased the cortical activation relative to that associated to a single stimulus for both stimulus types. The hemispherectomized subject with blindsight demonstrated this enhancement with achromatic stimuli only, consistent with our hypothesis that S-cone isolating stimuli are not processed in the blind field. The hemispherectomized subject without blindsight did not show any enhancement to bilateral stimulus presentations. Conclusions: These results demonstrate that hemispherectomized subjects are unable to process S-cone isolating stimuli in their blind field. This is consistent with the mediation of blindsight by the superior colliculus, which has been shown to lack S-cone inputs in primates as well as in our present subjects, and supports our previous behavioural results [Leh et al., 2007].

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56.443

Contrast adaptation reveals higher-order color processing in the visual evoked potential

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We examined color contrast adaptation to see if the chromatic pattern-onset VEP reflects either narrowly tuned, color processing or lower level, broad-band color tuning. Chromatic contrast adaptation was assessed by measuring changes in the VEP response following patterned adaptation along cardinal and intermediate axes in MBDKL color space. Isoluminant settings were found for each participant through a minimum motion paradigm. Individual contrast thresholds were measured psychophysically along cardinal axes and all VEP stimulus contrasts were equated to be equal multiples of threshold for each subject. Results were consistent with psychophysical data and showed evidence for selective adaptation to both cardinal and orthogonal chromatic axes. There were individual differences in the degree to selectivity. Results suggest that the chromatic VEP reflects more narrowly tuned, higher-order color processing, beyond that of the opponent mechanisms.

56.444

Retaining the McCollough effect: Is sleep = lack of visual exposure?

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Earlier (VSS, 2007), we demonstrated that a retention period consisting mainly, but not entirely, of sleep (8 hours sleep+4 hours wake) following sustained exposure to colored oriented stimuli helped retain the resulting aftereffect (McCollough effect) to a greater extent than when they remained awake over the intervening period. The findings raised key questions, which we address here.

i) Does sleep help retain a greater portion of the plasticity via some mechanism unique to sleep? We adapted and tested observers following an ~8 hour long intervening period that consisted almost entirely of sleep (monitored with sleep logs and actigraphy). As a control, the same observers were run on a separate session in which they remained awake throughout a retention period of identical duration as in sleep, but the adapted eye was deprived of visual stimulation. In the sleep condition, observers (n=4 thus far) retained 76% of the original ME, whereas in the wake (visually deprived) condition, the same observers retained 82% of the original ME. Thus, sleep did not impart greater retention of the aftereffect compared with visual deprivation.

ii) Does sleep help retain the ME via some sleep-dependent mechanism that is independent of sheltering the AE from visual exposure? We provided stimulation throughout the night through the closed eyelid of the adapted eye. Stimulation consisted of a continuous, cyclic pattern of flickering LEDs, which gave rise to the percept of a red ganzfeld. A parsimonious account of the role of sleep in AE retention would be one based on (the lack of) visual exposure in sleep: exposure to light in sleep ought to destroy the AE. Three observers thus far have participated. Additional observers will be required to test the prediction. Our results thus far indicate that there is no mechanism unique to sleep that helps retain the visual aftereffect.

56.445

The locus of neural responses that determine color shifts induced by temporally-varying light

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Introduction: Color appearance of objects is influenced by their surroundings. In chromatic induction, for example, the color appearance of a test field depends upon the chromaticity in the surround. If the surround slowly modulates between two chromaticities in time (say at 2 Hz), then a physically steady central test also is perceived to vary over time. With surround modulation above 3 Hz, however, the test field appears steady even though the surround modulation is salient. Surprisingly, a 6 Hz temporally-varying surround still influences the color appearance of the steady test field. The steady induced color shift in the test is very different than predicted from the time-average surround chromaticity, indicating the influence of a nonlinear neural mechanism. Purpose: This study addresses whether the neural response underlying the induced color shift is a steady (not time-varying) signal before binocular combination occurs. Method: The central test field was a physically steady annulus within a surround temporally modulating between two chromaticities at 6 Hz. Surrounds were modulated along one of four different chromatic lines in Macleod-Boynton color space, all with the same temporal average of equal-energy-spectrum "white". On any given trial the modulation was along the same line in both eyes but haploscopic presentation allowed the surround modulations in the left and right eyes to be either in or out of phase. Rationale: If the monocular neural response underlying the induced color shift is a steady signal then an interocular phase difference should not change the monocular response from each eye and therefore not change the steady color shift. Results and Conclusion: Altering interocular phase caused large changes in the steady induced color shift. The phase dependency implies that induced steady color shifts from temporally-varying surrounds are due to a neural process that combines time-varying responses from each of the two eyes.

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56.446

Multiple chromatic channels revealed by using dichoptic chromatic-masking

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Recent psychophysical and physiological studies indicated that multiple chromatic channels existed in the higher level of the visual system. Their precise features, however, i.e., the number of channels, their chromatic directions and bandwidths, are not yet clearly shown. A purpose of this study is to reveal these features of the multiple chromatic channels by using dichoptic chromatic-masking. A target and a masking stimulus were dichoptically presented to each eye. The stimuli were isoluminant. The target was a Gabor stimulus of 5deg and of 1c/deg. The masking stimulus was of random dots with a localized spatial frequency of 1c/deg. It was a 5deg square with Gaussian contrast profile. The chromatic modulation of the target was made along the r/g (L-M) axis in the DKL cone opponent space. The chromatic modulation of the masking stimulus was made along various directions in 15deg steps from 0deg to 180deg on the isoluminant plane. Its chromatic contrast was fixed at a supra threshold level. The chromatic contrast threshold for detecting the target was measured in each masking condition. The results showed that the threshold varied as a function of the modulation direction of the masking stimulus with the highest value in the 0deg (r/g) direction and the lowest value in the 90deg (y/b (L+M-S)) direction, which indicates that the two r/g and y/b cardinal channels are independent in a higher level as well. The threshold function obtained for an observer mimicked the cosine curve except that the thresholds in 45, 60 and 75 deg (red-yellow) directions were the lowest which was the same as that in 90deg (y/b) direction. This would indicate that the r/g chromatic channel became independent of a chromatic channel that existed in 45deg direction, being suggested as one of the multiple chromatic channels in the higher level.

56.447

Isotropic orientation tuning for masking in human color vision

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Purpose: Cross-orientation masking (XOM) is defined psychophysically as the phenomenon whereby detection of a test grating is masked by a superimposed stimulus at an orthogonal orientation and is thought to be part of a system of gain control that modulates detection and visibility of the test stimulus. Here we investigate the chromatic gain control mechanisms, particularly their orientation tuning.

Methods: Horizontal Gabor stimuli (spatial envelope, σ=2 degrees) were presented in nine combinations of three spatial (0.375, 0.75, 1.5cpd) and three temporal frequencies (2, 4, 8Hz). The mask had the same spatio-temporal frequency and chromaticity as the test but was superimposed with a range of orientations (15-90degs) relative to the test. Binocular contrast detection thresholds were determined using a temporal 2AFC staircase method over a wide range of mask contrasts, scaled in multiples of detection threshold. We used isoluminant red-green or achromatic stimuli.

Results: We find that chromatic XOM (mask at 90 degs) is significantly greater than luminance XOM at equivalent mask contrasts. Chromatic XOM is invariant across all spatiotemporal conditions, unlike luminance XOM that is greatest in the high temporal, low spatial frequency range. We also find that chromatic masking is invariant across orientation difference between test and mask, and remains isotropic for both high and low mask contrasts. This differs from luminance masking, which shows orientation tuning, as previously reported.

Conclusions: The results indicate distinct physiological origins for chromatic and luminance cross-channel masking. We argue for a predominantly cortical site for chromatic XOM masking, whereas previous studies have proposed subcortical M-cell influences for luminance XOM.

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56.448

Assessing functional consequences of adaptation by adapting images rather than observers

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Adaptation is thought to be important for optimizing visual coding, yet performance improvements with adaptation have been difficult to demonstrate for stimulus dimensions beyond mean luminance and color. We explored the functional consequences of contrast adaptation in a new way - by adapting images rather than observers to simulate theoretically complete adaptation to an environment. This allowed us to probe effects of long-term adaptation over time scales that are difficult to test by adapting an observer. The adaptation was modeled as gain changes in the cones and in multiple post-receptoral channels tuned to different color-luminance directions. Image sets were sampled from different environments and the individual images rendered after adjusting the gains so that the average response within each channel was equal across the two environments. This centers contrast responses on the average of the color distribution for a given environment and scales contrast sensitivity inversely with the gamut of the distribution along different color-luminance axes. Visual performance with the resulting adapted images was assessed with a search task for colored targets among neutral distracters, both shown as Gaussian blobs superimposed at random locations across the images. Search times were compared for pairs of original and adapted images and for corresponding targets such that the two stimuli were equivalent except for the simulated changes with adaptation. For natural environments that vary widely in their distributions, pronounced improvements in contrast discrimination and search times are readily demonstrated and thus lend support to functional accounts of contrast adaptation. Assessing performance across the range of environments routinely encountered allows us to assess the extent to which adaptation might significantly impact contrast coding or when performance could be enhanced by pre-adapting images for observers.

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56.449

What kinds of contours limit filling-in of color?

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Filling-in occurs when a visual feature is perceived in a particular region of visual space though that feature actually is absent from the region and present instead in a nearby area. In the particular case of color, a classical example of filling-in is the Boynton Illusion, in which the area contiguous with a black squiggly contour is filled-in by the color from a yellow nearby region. In this case, the squiggly line serves as a luminance contour that bounds the area filled-in by color.

PURPOSE: The present study investigated whether color filling-in is contained also by illusory contours.

METHODS: This study evaluated different kinds of contours: real (luminance-contrast edge) and illusory (Kanizsa square from solid pacmen, Kanizsa square from "bull's eye" pacmen, and horizontally phase-shifted vertical lines). For all stimuli, a yellow square on an achromatic background was presented within one type of contour. In one condition (a control), the yellow square physically abutted the contour. In two other conditions, the square was not touching the contour: in one condition it was approximately 90% of the original square size and in another condition about 80%. These two sizes addressed whether filling-in occurred. Stimuli were presented at five different durations: 1, 2, 3, 4.5, or 8 sec. The subject indicated whether the yellow square appeared to be touching the contour (filled-in color) via a button press. The proportion of times that filling-in occurred at each duration and the response time of filling-in was measured.

RESULTS & CONCLUSIONS: Filling-in occurred for both the real contour and the three types of illusory contours. Thus contours defined by both local luminance contrast and object-based boundaries are capable of constraining filled-in color.

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56.450

Explaining the new with the old: Spreading colors, afterimages, and boundaries

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Anstis et al. (VSS 2008) demonstrated that weak color signals from afterimages and blurry patterns spread across regions defined by strong luminance borders. While those demonstrations are new, they all depend on principles of visual perception that have previously been identified through work on a two-stimulus afterimage (e.g., Francis & Rothmayer, 2003; Francis & Schoonveld, 2005; VanHorn & Francis, 2007). Almost all of the effects described by Anstis et al. will be explained with computer simulations of a neural model that has already described similar phenomena. The analysis of the new cases did, however, reveal a new prediction of the model. The model predicts that it is possible for a color afterimage to appear for unseen visual colors. As Anstis et al. noted, a color plaid sinusoidal grating made of blue/yellow horizontal components and red/green vertical components appears to look like a blue/yellow horizontal grating when black horizontal lines are superimposed on the plaid. At offset of the image, the model predicts that the black horizontal lines produce vertical orientation after-responses that provide boundaries that constrain color after-responses to flow vertically. The unseen red/green colors produce visible afterimages because they are separated by the vertical boundaries, but the after-responses generated by the previously seen blue/yellow colors spread across each other and cancel out. An empirical study validates the model's prediction.

56.451

Individual differences in the Abney Effect

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The hues of most wavelengths change when a desaturating light is added, a perceptual nonlinearity known as the Abney Effect. Mizokami et al (JOV 2006) proposed that these hue shifts reflect compensation for filtering effects imposed by the eye's spectral sensitivity so that constant hues are tied to constant inferred properties of the stimulus (e.g., the mean of inferred Gaussian spectra). We evaluate this hypothesis by testing whether individual differences in the size and form of the Abney Effect can be accounted for by individual differences in spectral sensitivity. Stimuli were uniform 2-deg fields presented in an integrating sphere and generated with an OL 490 Agile Light Source (Optronic Laboratories), which allows the spectrum of the light to be shaped in arbitrary ways. Conventional Abney Effects were assessed by varying the proportion of a flat spectrum added to fixed narrowband spectra, with peak wavelength adjusted in a 2AFC staircase to match hues across different purities. These settings are compared to results for Gaussian spectra that are matched in chromaticity to the Abney spectra. The observer's spectral sensitivity was measured in the same device with flicker photometry. Individual differences in spectral sensitivity (e.g., because of greater lens or macular pigment density) predict measurably different hue shifts to compensate color appearance in different observers. We model these predicted hue shifts for normal variations in observers and compare them to empirically determined constant-hue loci. Changes in the Abney Effect are also predicted between the fovea and periphery (e.g., because of changes in macular pigment density) and thus we also compare the hue shifts at different eccentricities. These analyses help to reveal the stimulus correlates of hue percepts and the extent to which these percepts can be corrected for the spectral filtering effects specific to an individual's eye.

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56.452

Feature Misbinding of Colour and Motion: The Role of Object Shape

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PURPOSE: Peripheral visual objects may be mistakenly perceived to have a feature of similar central-field objects. Consider red dots moving downward and green dots moving upward in the periphery, and red dots moving upward and green dots moving downward in the central visual field. The percept is often all red dots (in both center and periphery) moving upward and all green dots downward (Wu, Kanai & Shimojo, 2004). Here, the role of shape in the misbinding of colour and motion was tested. The working hypothesis was that the likelihood of misbinding a central-field feature to a peripheral object increases with the number of shared visual features among central and peripheral objects. Therefore, with central and peripheral objects that always share a common collection of features for motion and colour, as in Wu et al. (2004), misbinding should increase in frequency with the degree of shared shapes in central and peripheral fields. METHODS: In the periphery, the stimuli were always downward moving red squares and upward moving green diamonds. Objects presented in the central visual field had (1) no shapes in common with peripheral objects (e.g., upward moving red circles and downward moving green circles); (2) one shape in common with peripheral objects (e.g., upward red squares and downward green circles, so squares were in common); or (3) two shapes in common (e.g., upward red squares and downward green diamonds, so both squares and diamonds were in common). Observers reported on each trial the perceived direction of motion of the majority of peripheral red objects and green objects. RESULTS & CONCLUSION: Misbinding was reported in all conditions, with increasing frequency of misbinding from condition (1) to condition (2) to condition (3). Therefore, the probability of misbinding colour and motion increased with the total number of shared features among central and peripheral objects.

Special Populations: Lifespan Development

Tuesday, May 12, 2:45 – 6:45 pm
Poster Session, Vista Ballroom

56.501

Choosing between detection and identification tasks in developmental studies: is a shift in paradigm necessary?

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In developmental studies, either identification or detection paradigms can be used to assess various types of visual functioning. We suggest that detection paradigms may be more suited for assessing the perceptual abilities of the very young (i.e., three-year-olds) and atypical development children, given their less-developed communicative and cognitive capabilities. The objective of the present study was to systematically assess and contrast identification and detection paradigms in order to determine whether paradigm-contingent differences exist at the perceptual level as a function of development. Typically-developing participants were placed in one of 5 age groups (5-6, 7-8, 9-10, 11-12 and 18+ years). For each participant, sensitivity to static and dynamic gratings defined by either luminance-contrast (with and without noise) or texture-contrast (noise) was measured using both identification (i.e, vertical/horizontal or left/right) and detection paradigm. For the latter, participants were asked to indicate which of two spatial locations contained the grating (versus noise or uniform background), regardless of its orientation or direction. An adaptive staircase procedure was used to obtain thresholds. In addition, the developmental level of each participant, as defined by verbal mental ability, was assessed using the Peabody Picture Vocabulary Test (PPVT) for all participants. For all three experimental conditions, no significant differences in sensitivity were found between the detection and identification paradigms as a function of age. These results suggest that at least within the context of the tasks assessed, a paradigm-contingent difference in sensitivity does not exist at a perceptual level from the ages of 5 years through adulthood. We therefore argue that when working with either very young or atypically developing participants presenting with impairments in attention, working memory and/or developmental delay, using a spatial 2AFC detection paradigm may be a more appropriate paradigm for assessing visual function.

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56.502

Discriminability of "top-heavy" versus "bottom-heavy" geometric patterns in 2-, 3-, 4-, and 5-month old infants

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Purpose. It is well documented that infants exhibit visual preferences for real faces and facelike patterns. Recent studies (Simion et al, 2002; Turati, 2004) showed that newborns preferred a non-facelike stimulus with more elements in the upper part of a configuration, and demonstrated that up-down asymmetry is crucial in determining their face preference. However, a reliable discriminability between the up-down asymmetry patterns has not been be demonstrated as the prerequisite for a significant spontaneous preference towards one type of configuration. Thus, the purpose of the present study was to use multiple discrete-trial technique (Chien, Palmer, & Teller, 2003; Civan, Teller, & Palmer, 2005) to further examine the basic discriminability for "top-heavy" v.s. "bottom-heavy" geometric patterns across different ages.

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Methods. The forced-choice novelty preference method (Chien, Palmer & Teller, 2003) was used to test 2-, 3-, 4-, 5-month old infants. The stimuli were the same three pairs of "top-heavy" and "bottom-heavy" geometric patterns in Simon et al (2002). In the familiarization phase of each trial, the infant was presented with two identical geometric stimuli (either "top-heavy" or "bottom-heavy"). In the test phase, the infant was presented with two stimuli where one was the same as in the familiarization and the other was a novel one that was rotated 180°. We expected to see a reliable novelty preference towards the new stimulus if infants could remember the familiarized stimulus and discriminate it from the new one.

Results. Preliminary data analysis showed a fairly balanced and significant novelty preference across ages, regardless of whether the familiarized pattern was the "top-heavy" or the "bottom-heavy" one. In addition, individual infant's novelty responses for the three kinds of stimuli showed no positive correlations at al. This finding does not support the notion that there is an intrinsic preference for "top-heavy" pattern.

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56.503

Temporal Limit of Phase Discrimination in Infants

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Given the dynamic nature of our external world, the ability to accurately judge rapidly appearing and disappearing objects is critical. Previous research has shown that adults are able to individuate two alternating states at a temporal rate of up to 7-10 Hz (Verstraten et al., 2000; Battelli et al., 2003; Aghdaee and Cavanagh, 2007), termed the Gestalt flicker fusion rate (van de Grind et al., 1973). This limit has been linked to the temporal resolution of attention where individuation of the states is mediated by visual attention. The aim of this study was to determine the temporal limit of attention in 6- to 15-month-old infants by psychophysically measuring phase discrimination.

Stimuli were four squares, flickering between black and white states at one of four temporal frequencies (0.1, 2, 5, or 8 Hz), for 5 seconds. The target square, randomly determined, flickered 180° out-of-phase from the other three squares. Only if infants can individuate the states of the squares will they be able to detect and prefer the target. Eye tracking data was used to calculate a target-preference score for each trial (duration of looking to target divided by total duration of on-screen looking). The criterion for reliable target discrimination was an average target-preference score greater than chance (0.25). Results revealed that infants across all ages discriminated the target only at a temporal frequency of 0.1 Hz ($t(34) = 5.334$, $p = 0.0001$), suggesting that the resolution of temporal attention in infants is much coarser than adults. Based on evidence that patients who are affected by right parietal lesions present with dramatically lower temporal frequency limits, this finding may shed light on development of the function of right parietal areas. Future experiments will seek to pinpoint infants' thresholds by examining performance at temporal frequencies between 0.1 and 2 Hz.

56.504

The representation of action in memory: A developmental study

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Processing visuospatial information is critical for interacting with the world. Though visually-guided actions seem effortless, evidence suggests that they require computations that are complex and distinct from representations underlying perceptual judgments that do not require object-directed action (e.g., Bridgeman, Kirch, & Sperling, 1981; Milner & Goodale, 1995). One such distinction lies in the role of memory: when a visual stimulus is removed and then a movement is initiated, the way in which the action is carried out changes relative to when the stimulus remains visible. It has been proposed these differences exist because action representations are used only for online purposes and disappear or degrade under delay. In the current study we explored how visual-manual action representations develop, and in particular how they interact with memory. Four and six year-old children and adults were presented with wooden blocks of various heights (3-6 cm). Participants were asked to reach and grasp the wooden blocks when they were visible or after the blocks were covered for up to 3 seconds. When the target remained visible during reach/grasp, the children's performance was qualitatively similar to that of adult participants: children scaled their grasp to the size of the target. When the target had to be remembered, the four year olds no longer scaled their grasp to the size of the block, unlike the adult participants. However, in a comparable perceptual judgment task where the participant did not act on the object, children were able to scale their response to the size of the target, even under delay, suggesting children's difficulty in the reaching task was not a general limitation of memory or attention. The unique difficulty for children in representing size-for-action suggests that representations of action are distinct from representations for perceptual judgment tasks and that these representations undergo different developmental timelines.

56.505

Mental Rotation in Preterm Children

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Mental rotation refers to the process of rotating the image of an object to determine if it is identical to another object presented at a different orientation (Shepard & Metzler, 1971). This ability is thought to involve regions of the cortical visual system involved in processing real motion (e.g. Zacks, 2008). Because children born preterm often show damage to these regions (e.g. Back et al., 2001) and compromised motion processing (MacKay et al., 2005; Taylor et al., submitted), we predicted that they would experience more difficulty than full-term controls with mental rotation. We assessed mental rotation ability (using identical and mirror-image objects) in 15, 5-9 year-old children born at <32 weeks gestation, and in 16 full-term controls. The two groups were matched in age and SES and had a similar gender distribution. We observed a classic mental rotation function; thus, matching accuracy decreased as the angular disparity between stimuli increased ($F = 13.3$, $p < .001$). Both groups showed a similar function, suggesting that preterm children can mentally rotate unfamiliar figures in the picture plane (although, as response time data were not collected, it is not clear if they are as efficient as controls in this regard). Despite showing a typical mental rotation function, preterm children performed more poorly than their full-term counterparts overall ($F = 10.6$, $p < .001$), even on trials involving the 0^{o} disparity, mirror-normal discrimination ($t = 2.1$, $p < 0.05$). This suggests that preterm children may have a relative deficit in their ability to mentally transform objects out of the picture plane, a skill thought to be required to make accurate mirror-normal discriminations (cf. Hamm et al., 2004). This finding is consistent with other evidence suggesting the dissociability of (planar) mental rotation and mirror-normal discrimination ability (e.g. Davidoff & Warrington, 2001; Lawson et al., 2000).

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56.506

The development of luminance- and texture-defined form perception during the school-age years

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The objective of the present study was to assess the development of luminance- and texture-defined static form perception in school-aged children. This was done using an adapted Landolt C technique (Bertone & Faubert, submitted) where C-optotypes are defined by either luminance- or texture-contrast, the latter necessitating non-linear processing beyond standard striate-mediated analysis to be resolved. Typically-developing children

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were placed in one of 4 school-age groups ranging from 5 to 12 years of age; an adult group (18 years+) was also assessed. Gap-opening-identification thresholds for C-optotypes defined by either luminance-contrast (with and without noise) or texture-contrast (noise) were measured. All participants were presented with C-optotypes with gap-openings presented in either of 4 orientations (up, down, left or right). An adaptive staircase procedure was used to measure gap-opening-identification thresholds (minimum luminance- or texture-contrast modulation) for all three conditions and age groups. In addition, the developmental level of each participant, as defined by verbal mental ability, was assessed using the Peabody Picture Vocabulary Test (PPVT). As expected, gap-opening identification sensitivity (1/threshold) increased with age for all conditions. For both luminance-defined (with and without noise) conditions, adult-like performance was attained between the ages of 9 and 12 years. By comparison, the sensitivity to texture-defined C-optotypes was significantly lower than that of adults at 12 years of age, having increased steadily from the age of 5 years. These results suggest that mechanisms underlying static form perception develop at different rates, depending on the physical attribute defining the form. Luminance-defined form perception appears to reach adult-like levels (or plateau) earlier than for texture-defined information, suggesting that the development of mechanisms mediating higher-order form perception persist into adolescence.

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56.507

Development of Direction-of-Motion Discrimination to Detection Threshold Ratios (MOT/DET) for Luminance (Light/Dark) and Chromatic (Red/Green) Stimuli: Infants, Adolescents and Adults

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Background: The use of luminance versus chromatic information for motion processing has been quantified by comparing the contrast threshold for discriminating direction of a moving grating (MOT), to the contrast threshold for detecting that same moving grating (DET), producing a MOT/DET ratio. Adults exhibit MOT/DET ratios near 1.0 for luminance gratings, but closer to 2.0–4.0 for chromatic gratings, suggesting that luminance information provides stronger input to motion mechanisms than chromatic information. By contrast, infants exhibit MOT/DET ratios that are comparable for luminance and chromatic gratings, suggesting that in early development luminance and chromatic information provide equal input to motion. The current study tested adolescents and adults to more finely track developmental changes in MOT/DET ratios from infancy to adulthood. Method: Data were collected from 12-15 year-olds, 15-17 years-olds and adults, and were compared to data previously obtained from 3 month-olds (Dobkins & Teller, 1996). The stimuli were moving luminance (light/dark) and chromatic (red/green) horizontal gratings (1.0cpd, 5.5Hz, subtending 2.0x2.0°). In the MOT task, a single interval was presented and participants indicated whether the grating moved up or down. In the DET task, participants indicated in which of two intervals the moving grating was presented. The relative contribution of luminance versus chromatic information for motion processing is measured by the difference in log MOT/DET ratios for luminance and chromatic gratings (Diff-Ratio), with values > 0 indicating stronger luminance versus chromatic input to motion processing. Results: Mean Diff-Ratios increased significantly with age ($F(3,88)=7.23$, $p<0.01$). Post-hoc tests revealed no differences between infants and 12-15 year-olds. And, adults exhibited larger Diff-Ratios than both infants and 12-15 year-olds. Conclusion: The relative input of luminance versus chromatic information to motion processing changes over the course of development, with a relative decline in chromatic input. This pattern of asymmetry becomes adult-like by 15 years of age.

56.508

Age-related changes in contrast gain related to the M and P pathways

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The mechanisms responsible for the age-related reduction in contrast sensitivity are not fully understood, with evidence for the importance of both optical and neural origins. Whether there are differential age-related changes in the magnocellular (M) and parvocellular (P) pathways across the lifespan has not been studied extensively, but differences may reveal a neural locus of contrast sensitivity loss. The pedestal-delta-pedestal and pulsed-pedestal paradigms were used to evaluate psychophysically the contrast gain signature of the M and P pathways, respectively, for younger (mean age of 22) and older (mean age of 81) observers. A four-square array was presented as an increment or decrement to the background for 35 msec, with one test square presented at a slightly higher or lower retinal illumination compared to the other three. Using a four-alternative forced choice procedure, the observer's task was to choose the unique square. The two paradigms differ only in the pre-trial adaptation and inter-stimulus array, with adaptation to a uniform field or adaptation to a pedestal four-square array, respectively. Stimuli were presented in Maxwellian view, and heterochromatic flicker photometry was used to equate the illuminance for each observer. The contrast gain slopes obtained with young observers are consistent with previous reports. An overall increase in threshold discrimination was found with increased age using the pulsed-pedestal paradigm, but the contrast gain signature was similar to that of the young observers. The pedestal-delta-pedestal paradigm revealed a moderately reduced contrast gain slope in older observers. Both pathways appear to undergo age-related sensitivity losses, but the contrast gain signature is altered only in an M pathway.

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56.509

Test of senescent change in photopic spatial summation

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Previous research has demonstrated age-related increases in scotopic spatial summation area, correlated with age-related losses in rods and ganglion cells. Grating spatial summation is typically measured in terms of contrast threshold vs. area. As area increases, there is a decrease in contrast threshold up to a critical size, after which there is no further change in contrast threshold. We measured contrast detection thresholds for foveally presented stimuli over a range of sizes in groups of younger (age range 19-20 years) and older (age range 67-83 years) observers. To control for age-related changes in pupil area, the stimuli were presented in a Maxwellian-view optical system. A bite-bar and auxiliary optical system were used to maintain alignment of the pupil with respect to the optic axis of a 2x astronomical telescope. The stimulus was a 76 Troland, vertical, 5 cpd Gabor patch that was increased in area from 0.13 to 12.56 deg2. Threshold for each stimulus area was measured using a two-alternative forced-choice method combined with QUEST adaptive staircase procedure. The data demonstrated a reduction in threshold up to a critical area, and could be fitted with a bilinear function (having slopes of 0.5 and 0 on log-log coordinates) using a least-squares criterion to define spatial summation area (the inflection point of the two functions). Consistent with previous work, we find an age-related increase in contrast detection threshold. In contrast to scotopic conditions, we found that foveal, photopic summation area remains relatively intact with increases in age.

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56.510

Age-Related Changes in the Inhibitory: Excitatory Balance in Macaque Monkey Primary Visual Cortex

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Our visual perception changes across the lifespan, reflecting developmental and aging changes in the neural mechanisms that mediate vision. Studies of age-related changes in human visual perception and in macaque monkey physiology have suggested that the main neural mechanism is a loss of inhibition as a result of less GABA. In contrast, a number of recent studies looking at developmental plasticity in V1 have shown that the balance between inhibitory and excitatory mechanisms is a key factor in early maturation. Here, our goal is to characterize age-related changes in excitatory and inhibitory synapses in V1 to determine if changes in aging are specific to GABAergic mechanisms or reflect a change in the inhibitory:excitatory balance. We used Western blot analysis to quantify the expression of 14 synaptic proteins in V1 of macaque monkeys ranging in age from 4-33 years old. We examined the changes in expression of both inhibitory and excitatory synaptic proteins. For inhibition, we measured GABA synthesizing enzymes (GAD65/67), the GABA vesicular transporter (VGAT), the inhibitory modulating cannabinoid receptor (CB1), GABAA receptor subunits (GABAAα1, α2, α3), and the GABA receptor anchoring protein (Gephyrin). For excitation, we measured AMPA receptors (GluR2), NMDA receptor subunits (NR1, NR2A, NR2B), the vesicular glutamate transporter (VGlut), and the excitatory receptor anchoring protein (PSD-95). On the inhibitory side, there was loss of VGAT, Gephyrin, and GABAAα1 with aging. On the excitatory side, there was a loss of PSD-95, NR1, NR2A, and NR2B. To compare the balance, we calculated an index of Gephyrin to PSD-95 expression and found a shift toward more Gephyrin with aging. These results show age-related losses in both inhibitory and excitatory components of synaptic function suggesting that it is a shift in the balance of these mechanisms that underlies visual changes in aging.

56.511

The effects of aging on contrast discrimination

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It is well established that contrast sensitivity for sine wave gratings is reduced in older observers, but comparatively little is known about how aging affects the perception of supra-threshold contrast. The current experiments therefore examined contrast discrimination in groups of younger (n=11; mean age = 23 years) and older (n=12; mean age = 69 years) observers. In experiment one, the target -- a horizontal 1.5 c/deg Gabor pattern -- was added to a mask grating of the same spatial frequency, orientation, and spatial phase. Threshold-vs-contrast (TvC) curves were obtained by measuring detection thresholds for the target as a function of mask contrast, which ranged from zero to 0.32. As was reported by Beard et al. (1994), TvC curves had similar dipper shapes in both age groups. Contrast discrimination thresholds were higher in older observers, but the age differences were reduced greatly after discrimination thresholds were normalized by dividing them by detection thresholds (i.e., thresholds measured with a zero contrast mask). In a second experiment, TvC curves were measured using a vertically-oriented mask. As expected, using a mask that was orthogonal to the target significantly altered the shapes of the TvC curves, which were nearly flat and increased slightly only at the highest mask contrast. Contrast discrimination thresholds were higher in older observers, but, as was found in the first experiment, age differences were eliminated by normalizing discriminating thresholds by detection thresholds. Hence the results from both experiments suggest age differences in supra-threshold contrast discrimination can be explained by age differences in contrast sensitivity.

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56.512

Evidence for no increased surround modulation in the aging visual system

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Age-related changes in perceptual performance are thought to be due, in part, to a degradation in intracortical inhibition for older observers (Leventhal et al., 2003). Although decreased inhibition can sometimes lead to improved performance (e.g., Betts et al., 2005), inhibitory mechanisms are necessary for focusing on central targets in the receptive field while ignoring surrounding patterns. Saarela and Herzog (2008) investigated the effect of surround masking on visual suppression in young observers, and found that the presence of a surround annulus does not modulate central target detection. If inhibitory mechanisms are impaired in older observers, we would expect a larger effect of surround masking as a function of age. Six younger (mean age 27 years) and six older (mean age 73 years) observers detected a target within the centre of an iso-oriented centre-surround pattern in a 2-IFC task. Stimuli consisted of Gabor gratings at six different base contrast levels (0, 0.0025, 0.005, 0.01, 0.02, 0.08). The diameter of the centre of the stimuli (3.6 deg) was half the size as the surrounding mask (7.2 deg). Two interleaved staircases varied the contrast of the central target to obtain target discrimination thresholds. Consistent with previous findings, surround masking did not produce an effect for young observers. Although higher thresholds for target detection were observed for older adults, there was no significant effect of the surrounding mask across age ($F(1,10) = 0.0919$, $p = 0.77$). In addition, the extent of the modulation did not vary as a function of mask contrast ($F(4,40) = 0.2603$, $p = 0.75$). These results are not consistent with the hypothesis that intracortical inhibitory mechanisms are less effective in elderly observers. Future research will extend this result by investigating the effects of time-course, orientation, and surround mask configuration as a function of age-related changes in inhibitory mechanisms.

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56.513

The effect of aging on the spatial pooling of local orientation signals

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Pooling orientation information allows observers to perceive form and texture that extend beyond spatially-limited receptive fields. Additionally, pooling the activity of low-level units may help the visual system to overcome the effects of noise in individual mechanisms, and may be important for the integration of local orientation elements into contours (e.g., Wang & Hess, 2005), an ability that appears to be impaired among older observers (Roudaia et al., 2008). The current study used methods describe by Dakin (2001) to investigate whether the ability to pool orientation information across space declines with normal healthy aging. Nineteen younger (mean age=23) and 17 older (mean age=71) observers discriminated textures composed of 128 3-cpd Gabors (radius = 1 deg) that were positioned randomly within an annular field (inner and outer radii = 0.5 & 3.4 deg). The orientation of each Gabor was selected randomly from one of two Normal distributions with means of ±M and a variance of s2. The task was to discriminate the mean orientation, and threshold (defined as 2M) was measured as a function of s2. Performance on this task depends on i) the accuracy with which the orientations of the texture elements are encoded, and ii)

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the efficiency with which information is pooled across elements. Hence, an effect of aging on local orientation coding or spatial pooling should alter the threshold-vs.-variance (TvV) curves. However, the TvV curves did not vary as a function of age ($F(1,5)=1.49$, $p=0.22$). This result extends previous studies showing that aging does not alter the perception of orientation for local contours (Betts et al., 2007; Delahunt et al., 2008; Govenlock et al., in press), and suggests that the spatial pooling of orientation is preserved in old age.

56.514

Age-Related Differences in the Use of Optical Flow and Landmark Information in Steering Control

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Research on optical flow has demonstrated its usefulness for the perception of heading (Warren, Morris, & Kalish, 1988; Warren, Mestre, Blackwell & Morris, 1991). In addition, studies have shown that landmarks are used in controlling steering (Andersen & Enriquez, 2006). The present study investigated age-related differences in the use of optical flow information and landmarks in steering control. Older and younger observers were presented with computer generated displays simulating vehicle motion through a random dot ground plane scene. The horizontal position of the observer was perturbed according a sum of three sinusoidal functions and observers were asked to steer the vehicle to null out the perturbation (compensatory tracking task). When the dots moved out of the observer's view they were recycled at the horizon while remaining their previous positions. In Experiment 1, the independent variables were dots density and the presence of landmark information which was depicted by color coding one of the dots on the ground plane. In Experiment 2, the number of landmarks was manipulated to assess the number of landmarks used to control steering. In Experiment 3, the reappearing positions of the landmarks were shifted horizontally by a certain amount when they were recycled. This was done to further test the use of landmark information in steering control. The results showed that younger observers had reduced steering error compared to older observers. Older observers were more dependent on optical flow information for steering control when there was less landmark information. With increased landmark information, both younger and older observers improved their driving performance. However, older observers had a high degree of error when there were 7 or 10 landmarks presented in the scene.

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56.515

The effects of fog and aging on the ability to detect collisions

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Previous research has shown age-related decrements in the detection of collision events with moving objects (Andersen & Enriquez, 2006). The current study examined whether there are age-related differences in collision detection with fog. On each trial, younger and older adults observed a scene for 3, 5, or 7 seconds. The scene consisted of a simulated ground surface and a ball moving on a straight trajectory towards the observer through four levels of fog. The scene disappeared before the ball reached the observer plane. The contrast was 0.12 for the no fog and 0.03 for the fog conditions at the beginning of the ball's motion. At the end, the contrast was 0.23, 0.37 and 0.51, respectively, during the 3, 5, and 7 second display durations for the no fog condition and 0.04 during all display durations for the fog conditions. The subject's task was to indicate whether or not the object was on a collision path with the observer. On half the trials the display simulated a stationary observer while on the remaining trials the display simulated forward motion of the observer. Results showed that main effects were found for both fog density and age, as well as for duration and presence/absence of egomotion. The ability to detect collisions for younger adults, although significantly reduced when fog was present, was greater than older adults under the highest fog density conditions. High fog density also resulted in decreased performance for short display durations. Both age groups performed equally well during the 7 second scene duration, while older adults were significantly worse than younger adults at detecting collisions during the 3 and 5 second scene durations. These results suggest that when driving under fog conditions, older adults may have an increased risk of crash and require more time to detect an impending collision.

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56.516

Effects of Normal Aging on Face View Adaptation

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A recent study about normal aging from our laboratory reported degraded face recognition across views but not with same views (Habak, Wilkinson, & Wilson, 2007, Vision Research). Therefore, we hypothesized that normal aging would affect face view adaptation. Younger (26 ± 5.1 years) and older (67 ± 5.2 years) subjects of 15 each with normal vision were recruited. They were required to make a two-alternative-forced choice of which direction a test face (200 ms) was facing after being adapted to an adapting face (5 s). Four adapting faces orientated at a side view (20°), an up view (20°), and their corresponding frontal views (for baseline measurement). Seven testing faces were orientated from left 6° to right 6° for side view and up 9° to down 9° for up or down view. The proportions of judging "right" or "down" view of 10 repetitions were calculated for each testing face at each condition. Point-of-subjective-equivalent (PSE) and sigma values were calculated from a psychophysical function. The older and younger groups showed similar baselines suggesting that thresholds of non-frontal view perceiving neurons are intact across aging. The older group showed a larger shift in PSEs and shallower slopes for the two adapting conditions suggesting that normal aging causes an increase in bandwidth of view-tuned neurons. These findings help to explain the degraded face perception in older population.

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56.517

The Effect of Simulated Cataracts on Speech Intelligibility

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The classic study of Sumby and Pollack (1954) demonstrated that visual information aided speech intelligibility under noisy auditory conditions. Their work showed that visual information is especially useful under low signal-to-noise ratios where the auditory signal leaves more margins for improvement. We investigated whether simulated cataracts interfered with the ability of participants to use visual cues to help disambiguate the auditory signal in the presence of auditory noise. Speech intelligibility was tested under an auditory only condition and two visual conditions: normal vision and simulated cataracts. The light scattering effects of cataracts were imitated using cataract-simulating filters. Participants wore blacked-out glasses in the auditory only condition and lens-free frames in the normal auditory-visual condition. Individual sentences were spoken by a live speaker in the presence of prerecorded four-person background babble set to a speech-to-noise ratio of -16 dB. The speaker was trained to match the rate, intensity and inflections of a prerecorded audio track of everyday speech sentences. The speaker was blind to the visual conditions of the participant to control for bias. Participants' speech intelligibility was measured by the accuracy of the written account of what they believed the speaker to have said. Relative to the normal condition, speech intelligibility was poorer when participants wore simulated cataracts suggesting that cataracts may interfere with both visual and auditory perception.

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Motion: Mechanisms

Tuesday, May 12, 2:45 – 6:45 pm
Poster Session, Vista Ballroom

56.518

Psychophysics and neurophysiology of the rapidly generated MAE

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Previously, we reported that 67ms of motion adaptation is sufficient to generate perceivable static MAEs, even when subjects are unable to discriminate the adapting motion direction (Tadin & Glasser, VSS2008). This finding indicates that the MAE is not merely an illusion that follows prolonged motion exposure, but rather a process that can occur every time we see motion. Here, our aims are to (1) test whether the rapid MAE exhibits the same stimulus tuning as the conventional MAE and (2) investigate whether MT neurons exhibit adaptation on the same brief timescale as the rapid MAE.

(1) Psychophysics: To obtain stimulus tuning of the rapid MAE (200ms adaptation), subjects rated perceived MAE strength for various combinations of adapting and stationary test stimuli. Notably, we found that for high-contrast adapting stimuli, MAE strength decreased with test contrast, increased with adaptation speed and exhibited partially low-pass tuning to the adaptor spatial frequency. Size tuning was relatively flat except for the smallest sizes.

In parallel experiments, we measured perceived MAE duration using conventional adapting stimuli (30s adaptation, 10s top-ups). Except for the adapting duration, all stimulus parameters were identical to the rapid MAE measurements. Results revealed that, despite a 100-fold difference in adaptation duration, tuning of the rapid MAE mirrored that of the conventional MAE. This finding suggests that conventional and rapid MAEs likely share underlying neural correlates.

(2) Neurophysiology: Motion adaptation was measured for a population of MT neurons in alert macaques. Adapting stimulus was a high-contrast Gabor patch presented for 67ms, with speed, spatial frequency and size set to each neuron's preferred values. Adaptation was followed by a 400ms stationary test stimulus (3% contrast). We found that neural responses following null-direction adaptation were significantly stronger than following preferred-direction adaptation; a result suggesting a possible neural correlate for rapidly generated static MAEs.

56.519

Neuronal and psychophysical responses to brief motion stimuli

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Recent psychophysical work has shown that performance in a direction discrimination task decreases with increasing stimulus size for brief, high-contrast stimuli (Tadin et al., 2003). This psychophysical surround suppression has been linked to the inhibitory spatial surrounds that have been observed in motion-sensitive visual area MT. However, many cells in MT lack surround suppression, and so it is not clear why the surround-suppressed cells would be the sole determinant of visual perception.

We have recorded from 88 neurons in area MT of the alert macaque, using brief (<40 ms) motion stimuli for which psychophysical surround suppression was shown to be strong. Remarkably, we find that MT neurons that lack surround suppression fail to respond to such stimuli, while the responses of surround-suppressed neurons are robust and direction-selective. Thus psychophysical surround suppression for brief stimuli can be attributed to a link between the spatial and temporal properties of MT neurons.

We extended this finding by introducing a delay between the appearance of the stimulus and its subsequent motion. When the stimulus was presented foveally, this motion onset delay improved discrimination performance for large stimuli, thus eliminating psychophysical surround suppression. However, poor performance for large stimuli returned as the stimulus was moved farther into the visual periphery. Recordings in MT confirmed that, for eccentric receptive fields, direction selectivity decreased with increasing onset delays. Thus these results reveal a complex interaction between stimulus size, duration, and eccentricity that may be linked to mechanisms of short-term adaptation in the visual system.

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56.520

Inactivation of area MT has separate influences on the spiking of single neurons and neuron populations in primate V1

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For decades it has been debated whether visual information is carried by the spike rate of independently-responding neurons or by patterns in the spike trains of neuron populations. Several studies have suggested that both modes of neural coding may be complementary in processing visual information. The relative roles of feed-forward, horizontal and feedback pathways in the generation of these potential neural codes, however, remain unclear. In this study, we examined the influence of feedback on the spiking properties of single neurons and pairs of neurons in V1 of the anesthetized, paralyzed bush baby by inactivating the middle temporal (MT) motion-sensitive area with Muscimol. MT sends feedback projections to V1 that have been proposed to modulate V1 function. Area MT initially was identified by optical imaging. Subsequently a 100-electrode array was inserted into V1 and the orientation, temporal and spatial frequency and direction selectivity of all well-isolated neurons were examined. Next MT was blocked and responses re-examined. No statistically significant differences in any of these single neuron tuning properties were found following MT inactivation. Spike-time and spike-count correlations between pairs of neurons were also examined before and after MT inactivation. After inactivation the probability of detecting significant spike-time correlation peaks (21.8% vs. 39.7%; N = 2278 pairs) and their amplitudes (0.0169±0.0015 vs. 0.0122±0.0018; ±SEM; $p<0.05$) was reduced although spike count correlations were not significantly reduced (0.149±0.012 vs. 0.173±0.012; ±SEM; $p<0.10$). These data suggest that inactivation of higher area feedback has a greater influence on spike timing between neurons than on the tuning properties of individual neurons.

56.521

Modelling the substructure of direction selective receptive fields in macaque V1

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The 'subunits' that provide input to direction selective (DS) complexcells in macaque V1 have not been identified. Variousexperimental protocols have been used to characterise these subunits,and one enduring method has been that of examining theresponses to pairs of stimuli that are offset in space and time. Theresulting spatial interaction maps are often interpreted in thecontext of models based on linear-filters, although recent resultshave shown that the interaction maps can take asymmetric forms thatare inconsistent with most common filter-based models(Livingstone and Conway, 2003, J Neurophysiol). Thus, connecting thephysiological characteristics of these subunits with the sets of spikinginputs and circuitry present in V1 remains an unsolved problem. Tobridge this gap, we have developed and compared two filter-basedmodels of DS complex cells - a Reichardt detector and motion energymodel - with several configurations of a physiologically-realistic network model that incorporates populations of spiking unitsrepresenting inhibitory and excitatory V1 simple cells and ON and OFFLGN

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inputs.One set of simulations we have performed to compare these models generatesmaps of 2D directional interactions. The interaction maps for themotion energy model had symmetrical elongated facilitory andsuppressive subregions. In contrast, the Reichardt detector modelgenerated round, symmetric suppressive and facilitory mapsubregions. Neither model generated curved, asymmetrical interactionsthat have been observed experimentally. However, the network model wasable to generate DS units with both elongated and round maps as well as maps withcurvature in which the suppressive subregion was reduced. All ofthese map shapes can be obtained in the model by simply varying theorientation distribution of inputs to the DS units. In continuing workon these models, we are using other protocols to further explore how DScomplex cell receptive fields may be built.

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56.522

A unilateral PFC lesion affects neuronal activity in area MT during motion discrimination tasks

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Neurons in the prearcuate region of prefrontal cortex (PFC) receive inputs from the motion-processing area MT and during motion discrimination exhibit direction selective (DS) responses suggestive of their MT origins (Zaksas & Pasternak, 2006). This region also sends direct top-down projections to MT and the nature of activity in both areas recorded during the same motion task indicates strong functional links between them. We examined the contribution of top-down PFC influences to MT responses and to motion perception while a monkey with a unilateral ibotenic PFC lesion discriminated directions of two sequential stimuli, sample and test, separated by a delay.

Recordings from the ipsilateral MT revealed abnormalities during all phases of the task. During the sample, a significant decrease in responses and a drop in DS, was accompanied by a transient increase in response variability. During the delay, suppression in activity and a subsequent anticipatory increase in firing rates, common in normal MT, were absent. This was accompanied by abnormally low variability of delay activity, suggesting that the top-down PFC signals may be among contributors to the variability in delay activity in normal MT. During the test, on trials when its direction matched the direction of sample, the normally transient response suppression was more sustained, suggesting PFC involvement in the sensory comparison phase of the task.

Behavioral testing revealed deficits in direction thresholds at longer delays, indicating a disruption in the maintenance and/or attentional components of the task. These deficits were most dramatic when the task required rapid reallocation of spatial attention. The lesion effects were confined to the contralesional visual field, suggesting a link to retinotopic areas involved in motion processing (eg. MT). Our results demonstrate the importance of PFC influences for normal MT activ

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56.523

Temporal modulations of motion properties produce distinct motion-contrast and form-related VEP responses in adults and infants

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Motion information contributes to the separation of figure from background, and yet relatively little is known about the neural circuitry or developmental time course of this aspect visual processing. We measured steady-state visual evoked potential (SSVEP) responses to moving dot displays in which four “figure” regions emerged from and disappeared into the background at a specific frequency (1.2 Hz: 1F1), based on differences in dot direction, speed, motion coherence, density, and lifetime. We previously reported that in adults, responses at the fundamental frequency (1F1) increased monotonically with direction, coherence, and speed, while responses at twice the fundamental (2F1) increased at low levels before saturating. Here, we report that adults’ 2F1 responses increase then saturate at relatively short dot lifetimes (111 ms), and that responses are strong, but consistent across a wide range (2-24%) of global dot densities. Further, in infants unlike adults, 1F1 responses to direction differences show an inverted-U shaped pattern, with peaks at intermediate direction differences (45-90 deg), and weak responses to 180 deg. We conclude that mechanisms underlying the detection of motion contrast and 2D form-from-motion in adults operate relatively quickly and are robust under sparse signal conditions. Infants show larger individual differences than adults, and in some cases, non-monotonic responses to motion contrast. This suggests that some aspects of motion contrast and 2D form-from-motion processing mature early, while others do not. High-density SSVEP data from both infants are adults are beginning to identify the cortical substrates for these perceptual processes.

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56.524

Bistability of flicker vs. rotational apparent motion: psychophysics and steady-state visual evoked potentials (SSVEP)

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A counter-phase flickering 8-arm radial pattern induces bi-stable alternations between perception of flicker (F) and rotational apparent motion (R). We studied the effect of stimulus parameters on the relative time spent seeing the rotational apparent motion, R/[R+F]. Results were then used to investigate how the averaged power spectra of steady-state visual evoked potentials (SSVEPs) in the stimulus-driven frequency bands varied as a function of the changing percept. Observers maintained the central fixation for the duration of each 1-min trial and continually indicated the periods of flicker perception and the periods of rotation perception by pressing buttons throughout a trial. In the behavioral experiment, two different contrasts, 80% and 100%, and four different flicker frequencies ranging from 2.5 Hz to 10 Hz were randomly intermixed in a factorial design. R/[R+F] increased as flicker frequency decreased, and as stimulus contrast decreased. Selecting (for each observer separately) parameters that induced approximately 50% rotational apparent motion, we recorded EEG and calculated SSVEP as a function of percept. The preliminary results suggest that SSVEP power at the 2nd harmonic of flicker frequency in posterior (occipital) electrodes changes according to perceptual state, yielding higher power during perception of flicker than during perception of rotational apparent motion. This is consistent with the phenomenological experience reported by observers, that the sense of flicker is reduced during periods of rotational apparent motion. Neurally, this could reflect greater phase locking in one perceptual state (F) than the other (R).

56.525

New image velocity code explains contrast and center-surround effects in MT neurons

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It is still an open question as to how the image velocity of a moving edge can be derived from the outputs of a small population of speed-tuned Middle Temporal (MT/V5) neurons. If the MT neurons span a range of spatial frequencies (sfs), then low sf units will dominate the output simply because of their larger receptive fields. The output distribution across the population of MT neurons becomes skewed at locations away from the edge and coding schemes such as winner-takes-all or the weighted vector average will produce an incorrect velocity estimate. We have overcome this problem in a model that uses inhibition between MT neurons of different spatial scales. Let MT1, MT2, MT4 and MT8 represent the outputs of model MT neurons tuned to speeds 1, 2, 4 and 8 deg/s (with peak tf = 4 Hz). We construct a basic ‘2nd derivative’ velocity estimator (e.g., dMT2) tuned to 2 deg/s by combining the outputs as follows: dMT2 = MT2 - .5 MT1 - .5 MT4.

Our new code also uses another set of model neurons (rMT1, rMT2 etc.,), identical to the first, but which have their peak tf 'retuned' to 8Hz (Perrone, JOV, 2005). We have discovered that by modulating the MT input neurons to dMT2 with the outputs of the rMT neurons we are able to eliminate the spatial scale problem described above. Furthermore, the rMT neurons in our model have the same speed-contrast dependence shown in actual MT neurons (Krekelberg, et al., J. Neurosci., 2006) and the dMT neurons display similar center-surround contrast effects seen in the MT data of Pack, et al. (J. Neurophys., 2005). The new velocity code is also able to replicate the positive and negative shifts in grating speed estimates caused by changes in contrast (Thompson et al., Vis. Res., 2006).

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56.526

Abnormal cortical activation in response to motion in people who have lost one eye early in life

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Early monocular visual deprivation such as amblyopia is associated with deficits in the perception of motion as well as spatial vision and a decrease in cortical activation in response to motion (Bonhomme et al., 2006). Early unilateral enucleation (removal of an eye), however, results in deficits in the perception of motion but not spatial vision. This latter patient group provides a valuable model to examine the effects of a loss of binocularity on visual motion processing without the potential confound of poor spatial visual ability. We compared cortical activation for motion in early enucleated patients compared to controls using fMRI. Participants: To date, we have tested two adult patients with unilateral eye enucleation before the age of two years and three binocularly intact controls viewing monocularly and binocularly. Methods: Stimuli consisted of white random dot patterns on a black background within a circular aperture. Using a block design motion localizer, stimuli alternated in time between 16 seconds of motion (linear motion in eight different directions, changing direction every second) and 16 seconds of stationary dots. Results: Talairach coordinates for area MT in the one eyed patients are consistent with those of the controls. Preliminary results indicate a greater extent of activation in response to motion in the patients compared to controls in area MT ipsilateral to the remaining eye. The patient with the earliest age at enucleation also shows morphological differences such that early visual areas in the hemisphere ipsilateral to the remaining eye are larger compared to the opposite hemisphere. Conclusions: Unlike deprivation from amblyopia and despite previous behavioural findings for deficits in motion perception with early enucleation, our patients show more activation in response to motion. These findings suggest that early unilateral enucleation results in unique cortical reorganization at both an anatomical and functional level.

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56.527

Visual motion retraining of a cortically-blind field increases BOLD responses in peri-lesional cortex and MT+ - a case study

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Although the effectiveness of visual rehabilitation following post-chiasmal brain lesions is controversial, several visual training paradigms, including one developed in our laboratory, have recently shown promise in restoring both simple and more complex visual functions. A possible mechanism of such recovery is that spared striate cortex is re-activated by training. Alternatively, sub-cortical pathways that bypass striate cortex could transmit visual information into extra-striate visual areas. For example, direct projections from the dorsal lateral geniculate nucleus (dLGN) to V2, V4 and MT, as well as from the superior colliculus/pulvinar to MT have been postulated to mediate different aspects of blindsight. We postulate that V1-bypassing projections and the areas in which they terminate mediate training-induced recovery of visual motion discrimination following V1 damage. To test this hypothesis, we performed event-related functional magnetic resonance imaging (fMRI) in an adult subject with long-standing homonymous hemianopia following a unilateral stroke. fMRI was carried out before and after global direction discrimination training. Prior to training, performance at the chosen blind field location was at chance and fMRI showed an almost complete lack of responsiveness in the damaged hemisphere. Training consisted of performing daily sessions of a left-right direction discrimination task using random dot stimuli in the blind field. After training, direction range thresholds became normal at the retrained location and fMRI showed a robust response both in peri-lesional tissue (putative V2) and the ipsilateral MT+ complex. No "intact" islands of V1 were observed within the lesion. Thus, global motion discrimination training in the blind field of an adult human with long-standing, unilateral V1 damage induced significant functional plasticity in both lower- and higher-level visual areas ipsilateral to the lesion. Future studies will assess whether this effect is robust among different subjects and whether it is specific to global motion retraining in the blind field.

56.528

Dotted Ellipses: Local and emergent motion signals differentially modulate BOLD activity in visual cortex

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An ellipse rotating at a fixed angular velocity appears to rotate faster as its aspect ratio increases. We have hypothesized that this speed illusion arises because regions of high curvature act as form-based, trackable features (TFs). When trackable feature are weak, the corresponding motion signals are weak, generating the illusion. Interestingly, this speed illusion is observed for rotating ellipses whose contours are defined by equally spaced dots even though the local motion of each dot along the contour is unambiguous. In the current work, we used such dotted ellipses as stimuli in a series of block-design fMRI experiments designed to dissociate the processing of local (motion) and global (form) sources of information in the perception of rotational motion. Methods: Participants viewed blocks of high medium or low aspect ellipses continuously rotating at the same angular velocity defined by either 32 dots, which produce the speed illusion (Experiment 1) or 12 dots, which do not (Experiment 2). In the third experiment the actual angular velocities of the 32 dot ellipses were adjusted so that the ellipses of each aspect ratio appeared to rotate at the same speed. Results: Modulations of BOLD activity in early visual areas V1, V2V, V2D and V3D reflected the processing of local dot motion. In contrast, BOLD activity in later visual areas, V3A, V3B, LOC, MT and MST reflected the combined processing of both local dot motion and properties of the emergent form of the stimuli (contour curvature). Conclusion: motion perception in general is mediated in part by the integration of local motion and global form information that likely occurs in V3A, V3B, LOC, MT and MST.

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56.529

The Component Level Feature Model of motion: completed

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A sequence of images is convolved with a bank of filters tuned for orientation and spatial frequency. A two-max rule (i.e. determine the two largest responses) is applied to the response outputs at fixed time intervals. The outputs from the rule are required to be from two different oriented Gabor filters and have a similar spatial frequency. Zero-crossings are then extracted from these outputs. The zero-crossings from each of the two filters correspond to the velocity constraint lines used to compute the "intersection of constraints". Tracking any intersecting zero-crossing over time corresponds to the velocity as predicted by the IOC. Over time these intersecting zero-crossings create motion streaks the length of which corresponds

to the IOC speed and the orientation corresponds to the IOC direction. The Hough transform is used to identify these streaks because they appear as peaks in the Hough transform owing to the fact that they fall along similar oriented lines. Temporal frequency tuned surround suppression (end-stopped) filters encode these oriented streaks because they are tuned for line length and orientation. The temporal frequency tuning is matched to the line length providing a speed tuned response. The model can explain why stationary or non-coherent motion affects perceived motion; why most plaids are perceived to move in the IOC direction; why sometimes they are perceived to move in the vector average; why (under specific conditions) if the IOC or vector average is adapted out motion is perceived in the vector average direction, and vice versa; why motion is affected by non-linearities e.g. squaring; and the phenomena of "motion steaks". The model is invariant with respect to both contrast and phase and appears to be consistent with the physiological observations of both V1 and MT neurons.

56.530

Category effects in BOLD response when viewing dynamic natural scenes

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To efficiently select important features in the environment, processes that categorize input are necessary. Using a visual search paradigm (Vuong & Thornton, 2006; Mayer & Vuong, 2008), we found that observers performed better when searching for biological targets compared to mechanical targets in search arrays of natural videos. This category effect was indicated by faster search times. Furthermore, observers fixated on biological targets earlier in the search process and the durations of fixation on biological targets were shorter than on mechanical targets. As search times and eye movements are indirect indicators of neural processes, we used an fMRI study to investigate whether dynamic natural scenes with biological motion activate different cortical areas compared to dynamic natural scenes with mechanical motion. Fourteen participants were scanned in a 3T scanner while they passively viewed natural scenes belonging to three categories: humans, animals, or machines. They were encouraged to freely move their eyes while viewing the scenes. Videos of each category were presented in separate blocks. We found greater BOLD responses to humans compared to machines in the superior temporal sulcus (STS) and the inferior frontal gyrus (IFG). Similarly, animals compared to machines lead to greater responses in STS and middle frontal gyrus (MFG). No regions were found that were more strongly activated by animals compared to humans, or by machines compared to either biological category. This study shows that the category effect found for search times and eye movements is also reflected in the BOLD response. Importantly, the results point to possible top-down influences from frontal regions, which have been found to represent object categories, on STS, which is involved in processing biological motion. Together with our behavioural studies, these results suggest that both visual and higher cortical areas appear to be tuned to process biological motion.

56.531

Decoding human visual cortical activity evoked by continuous time-varying movies

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In a recent study from our laboratory (Kay et al., Nature 2008, v.452, 352-355) we showed that brain activity measurements could be used to identify which specific static natural image was seen by an observer, even if the image was selected at random from a database consisting of thousands of such images. Here we demonstrate identification of continuous time-varying natural movies from brain activity measurements. We used fMRI to measure brain activity of human observers while they watched continuous, time-varying natural movies. We describe how stimuli are mapped onto measured brain activity in early visual areas by means of an explicit, spatio-temporal encoding model that is fit individually to the data from each voxel. The fitted models for voxels in early visual areas are typically spatio-temporally localized and frequency bandpass. When these models are used to perform movie identification (on a separate set of movies that were not used in fitting), we can identify which specific 20-second movie was seen by an observer with almost perfect accuracy. Furthermore, we can identify one-second movie clips to within +/- one second of their position in the original movie. Our results demonstrate that appropriate voxel-based encoding models can recover relatively fine spatio-temporal information about continuous visual experiences from brain activity measurements. We speculate that it might soon be possible to use similar techniques to reconstruct continuous visual experiences directly.

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56.532

New Objective Psychophysical Methodology for Independently Assessing Dorsal and Ventral Processing Systems in Human Vision

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Anatomical specialization suggests that useful behavioral neural pathway models should have distinct, measurable psychophysical correlates. In this work, we developed objective psychophysical measures that target information-processing associated with dorsal and ventral neural system areas. We predicted that an objective psychophysical measure of the temporal onset of apparent motion would be a good general measure of magnocellular or dorsal system functioning; one that is correlated with critical flicker fusion (CFF), but with less variance. We also predicted that an objective psychophysical measure of the temporal onset of ability to recognize direction of shape-change would target the parvocellular or ventral system. In the apparent motion test, we successively displayed one of four dots in either a clockwise or counterclockwise direction in a square configuration. This provided an objective measure of the threshold of apparent motion, since participants could only correctly discern direction of travel when the display rate was slow enough to experience apparent motion. In the shape-changing test, we successively added or subtracted to the number of sides of equilateral polygon stimuli, and participants indicated the direction of shape-change. This provided an objective measure of the threshold of shape-processing, and was designed to limit magnocellular influence by minimizing shape-contrast and number of stimulus object edges. Our findings revealed a strong correlation between CFF thresholds and threshold scores on the apparent motion test. Moreover, thresholds for the shape-changing task were markedly slower and inversely correlated with thresholds for apparent motion and CFF. We suggest that the apparent motion test shows promise as a reliable measure of dorsal stream processing, and the shape-changing test shows promise as a reliable measure of ventral stream processing. The opposing or inverse relationship between the two measures supports the validity that they tap into two distinct processing systems, consistent with independent dorsal and ventral system functioning.

Attention: Interaction with Memory

Tuesday, May 12, 2:45 – 6:45 pm
Poster Session, Vista Ballroom

56.533

Distinct roles for frontal and parietal cortex in visual working memory and attention

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Objective: How do higher visual areas contribute to the cognitive control of visual processing in the human brain?

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Methods: Subjects were scanned (3T fMRI, BOLD) while performing two tasks designed to probe visual working memory and visual attention. (1) Delayed comparison: A high-contrast grating (randomized orientation and spatial frequency) was briefly (200 ms) presented within an annulus (1-3°) around fixation. After a variable delay (1-16s), a second high-contrast grating was briefly presented with near-threshold changes in orientation and spatial frequency. Subjects were cued to discriminate either the change in orientation or in spatial frequency. (2) Detection: Stimuli were identical to delayed comparison, except that the contrast of the final target grating was at detection threshold, and the gratings' orientations were chosen independently. Subjects detected the presence or absence of the target grating.

Results: Our earlier study (Offen, Schluppeck & Heeger, Vision Research, 2008) reported a dissociation in visual cortex, with sustained delay-period activity only during detection. In the present study, frontal and parietal cortex exhibited patterns of activity that were different from one another, but similar for the two tasks. Consistent with previous reports, the superior precentral sulcus (sPCS, putative human FEF) showed sustained delay-period activity for both tasks; no other frontal or parietal areas showed evidence of sustained activity for either task. In particular, the intraparietal sulcus (IPS) did not show evidence of sustained delay-period activity, as might have been expected.

Conclusion: It is widely believed that sustained delay-period activity in visual cortex is controlled by top-down influences. If so, our results suggest that sPCS is driving delay-period activity in visual cortex, but only during detection, not delayed comparison. Because delay-period activity is evident in sPCS for both tasks, there must be either a gating mechanism or distinct subpopulations of neurons that determine when sPCS sustains activity in sensory cortex.

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56.534

Working memory and the attentional blink: fMRI investigations of the neural correlates of the working memory bottleneck

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The attentional blink (AB) is a well-studied effect that highlights the limitation of temporal attention. The AB is characterised as the impaired detection of the second of two masked targets when the second target falls within ~500ms of the first. Different theories have been proposed to explain the AB but all point to a bottleneck at the level of working memory (WM). And although there are now several published imaging studies of the AB, none have investigated the effect of a concurrent WM manipulation on the neural correlates. Here we present fMRI data of a WM-AB study, where successful completion of the AB task was dependent on successful WM performance. Participants viewed an array of geometric shapes (1 shape – 'low load' or 3 shapes – 'high load') prior to the start of the AB task that contained a further geometric shape in a stream of letters. The participants first target task was to determine whether the geometric shape in the RSVP matched one of those presented in the WM array; additionally, as a second target task, participants had to detect the presence of an 'X' that occurred either in the AB sensitive period ('short lag' - 200 ms) or outside it ('long lag' - 700 ms). The behavioural results show that during the AB period a high WM load impairs performance more than a low WM load; but outside the AB period, high and low WM load was comparable. The imaging results show several areas that have been previously implicated in WM tasks reveal a larger BOLD signal during AB trials (short lag) for high vs. low WM load. These results are explained in terms of shared capacity-limited resources between structures supporting attentional selection in the AB task and WM.

56.535

Working Memory Consolidation Delays Top-down Attentional Processing in Visual Cortex: A Time-Resolved fMRI Study

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The consolidation of information into working memory (WM) can delay central processing of subsequent events. WM, however, is also believed to control the deployment of top-down attention (DeFockert et al., 2001). We therefore used time-resolved fMRI to investigate whether WM consolidation also delays perceptual processing of subsequently presented targets.

In each trial, a masked target (T1; 400 ms display, 100 ms mask) preceded a second unmasked target (T2) by either a short (550ms) or long (1450ms) SOA. To perform the T1 task, participants encoded the identity and location of four distinct keyboard symbols and made an un-speeded response to a probe stimulus at trial's end. To perform the T2 task, participants made a speeded identity response to four identical, adjacent letters ('H' or 'S'). In separate fMRI runs, participants performed either the T1 task alone, or both tasks. In the dual-task condition, T2 response time (RT) was greater at the short than at the long SOA, suggesting that T2 processing was delayed by T1 performance in the former condition. To determine whether T1 processing also delayed top-down attentional enhancement of T2, we examined T2 BOLD response in visual cortex (left middle occipital gyrus; Sergent et al., 2005) by subtracting the single-task waveforms from the dual-task waveforms for each SOA. The resulting timecourses revealed that T2 BOLD response was delayed at the short SOA relative to the long SOA. Furthermore, the magnitudes of participants' T2 BOLD delays correlated with their T2 RT delays. A follow-up experiment, in which substituting a simple detection task for the T1-encoding task eliminated the T2 BOLD response delay, confirmed that our previous results were caused by WM. We conclude that consolidation of a stimulus into WM delays the deployment of attention to subsequent target representations in visual cortex.

56.537

Does Attentional Capture Guide the Contents of Visual Short-term Memory?

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Visual short-term memory allows information within a visual scene to be encoded as an internal representation and actively maintained over time. Because this memory system is capacity limited, however, only a subset of the objects within a visual scene can be encoded in this way. In the present research, we investigated whether the objects that are selected for memory are determined solely volitionally, or whether stimulus-driven attentional capture can bias this selection. Subjects were presented an array of visual objects and asked to remember a subset of them (i.e., their volitional goal). In addition, an irrelevant distractor was used to randomly cue locations within this array (i.e., a stimulus-driven signal). Memory performance was biased by the task-irrelevant distractor, suggesting that attentional capture does guide the contents of visual short-term memory. This finding is discussed within the context of the contingency of attentional capture on top-down control settings, and in terms of the time course of the interaction between top-down volitional attention and bottom-up attentional capture.

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56.538

Working Memory Guidance of Attention Depends on Memory's Relevance for Search

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Do items in working memory guide attention to memory-matching items in the visual field? According to the Biased Competition Model, visual search is completed by items in working memory biasing attention toward similar items in the visual field (Desimone & Duncan, 1995). This leads to the prediction that items in working memory guide search, even if there is no explicit search goal for the item. Involuntary working memory guidance of attention has received empirical support (for a review, see Soto et al., 2008), but contradictory evidence has emerged suggesting that guidance is not involuntary (Woodman & Luck, 2007). In this work, we attempted to determine if guidance is dependent on the memory matching item's relevance for the search task. If working memory guides attention toward similar objects involuntarily, changes in task demands- such as increasing probability of memory match as target- should not influence attention being directed to the memory match. We manipulated the frequency of the memory matching information being the search target in two conditions; 25% memory color as target, and 50% memory color as target. To measure attention being directed to the memory matching distractor, we compared reaction times (RTs) when the memory match is the target to reaction times when it is not. We found a RT benefit when the memory color was the target for both 25% match and 50% match conditions and a larger benefit for the 50% than 25% condition. These effects show that RT guidance effects can be altered by the likelihood of a memory match being important for search. This finding suggests that guidance effects are not completely involuntary -- guidance can be influenced by task demands.

56.539

Eye movements during visual search under memory load

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Visual working memory has been implicated in several models of visual search performance, and of visual attention in general. Recent studies have investigated the involvement of working memory in search by introducing spatial and non-spatial working memory loads during visual search (Woodman, Vogel, & Luck, 2001; Oh & Kim, 2004; Woodman & Luck, 2004), demonstrating that although both types of working memory load increase overall reaction times (RTs), only a spatial working memory load interferes with search efficiency. In the present work, we set out to replicate these studies using eye-tracking to further resolve where and how spatial and non-spatial working memory loads impact search performance. For both spatial and non-spatial working memory loads, we find an increase in the first saccade latency, likely to accommodate encoding, as well as an increase in the time between fixating the target and making a response (target identification time), which may reflect either a disruption in the identification process itself or interference from a preparation for the memory test. Excluding first saccade latency and target identification time, the remaining time in search RTs is not impacted by spatial load, but incurs an additional cost under non-spatial load that is constant across set size. This result, in addition to an increase in both memory errors and overall RT intercepts under non-spatial load as compared to spatial load suggests that joint interference between search and memory tasks may in fact be greater for non-spatial than for spatial loads.

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56.540

The Effects of Learning on Visual Search and Change Detection

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Despite the fact that humans can readily recognize visual objects from one moment to the next, recent work has shown that we have detailed information about only a handful of objects at any one time. One interesting phenomena that highlights this limitation is 'change blindness'. This is the striking phenomenon whereby individuals have difficulty detecting changes to visual stimuli. In a series of experiments, a visual search task was imbedded within a flicker or change detection paradigm. The target was defined by a change across two visual displays separated by a blank temporal gap. Each display contained identical items at each location, except for at the target location, which contained different items. The sequence of visual displays and gaps were cycled until observers detected the changing target item. This paradigm is particularly useful because the type of change, at the target location, can be manipulated. In the current series of experiments the type of change was varied in terms of features (i.e., the number of features changing at the target location) and familiarity of the change (e.g., a changing familiar object vs. unfamiliar object). In addition, we investigated the extent to which change detection performance varied as a function of processing time (i.e., display duration) and practice (i.e., training sessions). The results provide strong support for the idea that visual changes can be detected using both featural-level information (number of features) and object-level information (familiar vs. unfamiliar object). The results are also discussed in terms of the shift from feature-based to object-based processing, and the degree to which change detection performance improved as a function of learning.

56.541

The Mechanisms Underlying Priming of Pop-out

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Recent research has demonstrated that what we attend to at a given time affects how our attention is deployed in the few moments that follow. For instance, Maljkovic and Nakayama (1994) showed that when searching for a discrepant target among homogenous distractors, performance is better when the target and distractors features remain the same than when they switch, an effect known as Priming of Popout (PoP). Two contradicting accounts of PoP have been suggested. The "selection account" proposes that feature repetition facilitates the process of selecting the item that was previously attended. The "post-selection account", proposes that it affects the speed of response decision. In the present study, we demonstrate that PoP is an attentional phenomenon that reflects target activation and distractor inhibition processes set in motion during target selection, with a dissociable part of the effect resulting from response-based factors. By using accuracy measures with briefly presented displays, we show that PoP affects perceptual stages of processing. We accommodate the apparent discrepancy between this finding and previous reports by showing that perceptual effects of PoP occur only when the task requires attentional focusing. In addition, in a RSVP search task we show PoP occurs when temporal rather than spatial selection is required, that is, when only engagement of attention but no spatial orientation of attention is involved. We further demonstrate that common mechanisms underlie PoP in spatial and temporal visual search tasks.

56.542

Retrieval deficits in short term memory (STM) for temporally adjacent items: An Un-Attentional (Mnemonic) Blink?

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When searching for two targets in a stream of rapidly presented items, detection of the second target (T2) suffers if presented within 400-600ms of the first (T1). Prevalent models of this "attentional blink" (Raymond et al, 1992) explain the deficit in terms of both attentional and memory-based capacity limitations (e.g. Chun & Potter, 1997; Shapiro et al, 1997). Recent evidence suggests that the AB occurs independently of manipulations of short term memory (STM) load, casting doubt on the role of memory operations in the AB (Akyurek & Hommel, 2005). Using a variant of the AB paradigm, we directly explored mechanisms of target retrieval from STM. Participants observed an eight item rapid serial visual presentation (RSVP) stream of letters and then judged whether two subsequently presented letters were present or absent in the stream. Importantly, participants were not instructed to search for pre-specified targets. This implies that attentional resources are allocated evenly throughout the stream (and not preferentially directed to T1) and that participants must rely on retrieving the targets from the STM store. Probed letters could occur at varying temporal proximities from each other (analogous to 'lag' differences between T1 and T2 in typical AB tasks). Preliminary results indicate a typical 'attentional blink' pattern: Poor T2 recall when presented in close temporal proximity to T1. Further, this 'un-attentional (mnemonic) blink' only occurred when target letters were probed in the same serial order as presented in the stream (and not when probed in reverse order). These findings suggest that retrieval of an item in STM may have inhibitory effects for other items stored in close temporal proximity and challenge key assumptions made in accounts of the AB.

56.543

The Attentional Boost Effect

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Several theories of perception suggest that changes in task context (e.g., a stoplight changes from green to yellow) produce a brief increase in perceptual processing of the surrounding environment. In line with this proposal, we recently reported a phenomenon in which the infrequent appearance of white target squares in a stream of black distractor squares facilitated encoding of concurrently presented background scenes and faces. This "Attentional Boost Effect" (ABE) occurs in spite of the potential for target detection to interfere with encoding background information. Instead, these data suggest that increased attention to one task facilitates encoding in a second task. However, direct evidence for enhanced perceptual processing is still lacking because subsequent memory, rather than perceptual processing was measured. Two experiments were conducted to determine whether the ABE reflects enhanced perceptual processing. If the ABE is due to enhanced perceptual processing then it should be easier to perceive stimuli that are briefly presented when targets appear. In Experiment 1, participants were asked to report the gender of a single upright face presented briefly (100ms) in a stream of inverted faces. They were also asked to monitor a colored border around the faces and press the spacebar whenever the border was blue (20% of the borders were blue). If target detection enhances perceptual processing of other, concurrently presented items, then gender discrimination should be better for faces with blue borders than for other faces. The data confirmed this hypothesis. Experiment 2 confirmed that memory for faces presented with targets is enhanced even when the faces were paired with targets only once. Therefore, memory enhancements associated with the ABE were not due to multiple exposures of the background item with the targets. We conclude that the ABE reflects enhanced perceptual processing of background information in response to the appearance of infrequent targets.

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56.544

Learning to reject: over repeated trials, feature-specific inhibitory biases are strengthened, whereas inter-trial feature contingencies are not learned

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In this study, we examined the extent of inter-trial learning in the context of the distractor previewing effect. The distractor previewing effect is an inter-trial effect observed during odd-ball target-discrimination searches, and refers to the finding that target discrimination performance is slower if, on an immediately preceding trial, no target was present and all items shared a defining feature with the current target, relative to when all distractors shared a defining feature with the current distractors. Participants were presented with runs of four consecutive trial pairs in which target and distractor features were fixed. Runs consisted of four consecutive target-color previewed (TP) or distractor-color previewed (DP) trial pairs. Runs could contain a repetition of the color segmentation from a preceding run (e.g. two consecutive runs in which target-present displays consisted of green targets among red distractors) or a switch of color segmentation. Our goal was to evaluate learning observed within TP or DP runs, as well as the extent to which learning generalized across runs (e.g. two consecutive DP runs vs. one DP run followed by a TP run). As participants viewed a run of trials, RTs decreased both for DP and TP runs, and in both cases RTs reached an asymptote after three trial pairs. On the subsequent run, RTs increased dramatically if the target-distractor color segmentation was switched, but this decrement in performance was not modulated by the repetition of the preview condition. In sum, our results suggest that inhibitory biases against specific features are strengthened over time after repeated experience with the same feature assignments (green as distractor color). In contrast, participants seemed unable to learn repeated feature-based inter-trial contingencies (e.g. within the current run of trials, if green is a distractor on the current trial, red will be the target color on the following trial).

56.545

Working Memory Influence on Perceptual Processing

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This study examined the influence of working memory on perceptual processing. Each trial began with the presentation of a coloured square. Participants held the colour of the square in memory for a later memory task, and performed a visual search task during the retention interval. Perceptual difficulty on the search task was manipulated via a set size manipulation (2, 4, or 6 letters). Each letter on the search task was a different colour. The colour of the memory square was the same as the target letter, the same as one of the distractor letters, or different from all of the search letters. There was a benefit on the search task when the target letter was the same colour with this benefit increasing with set size. There, also was a cost on the search task when one of the distractor letters was the same colour with this cost remaining constant across set size. We conclude that perception can be biased towards objects that possess a perceptual feature that is consistent with the contents of working memory.

56.546

Cross-Hemifield Attention Benefits for Visual Short-Term Memory

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Visual short-term memory (VSTM) is severely limited in its capacity. Some researchers argue that VSTM capacity limits reflect a central "fixed slot" buffer that holds 4+/-1 objects (e.g., Luck and Vogel, 1997). Others suggest that capacity is variable and depends on the division of attentional resources across items. Recent evidence indicates that attention is mediated by independent resources in the left and right visual hemifields (Alvarez and Cavanaugh, 2005). In VSTM, hemifield independence might occur in terms of (additive) fixed slot capacity or (multiplicative) attentional resources effects on performance. Here, we investigated the "fixed slot," "independent capacity," and "independent resource" models by investigating how VSTM capacity varied between full-field and hemifield stimulus configurations.

Subjects performed a change detection task using oriented bars (50% chance of one bar changing orientation). Stimuli were either restricted to a single (random) hemifield or appeared across the whole visual field. The set size was varied across blocks. By using distractors, the number of presented stimuli remained constant across set size. A second study was performed without distractors to control for attentional demands of distractor suppression.

VSTM capacity was higher when stimuli were presented across the whole screen than when restricted to a hemifield, contrary to the central fixed slots model prediction. However, full field capacity was less than would be predicted from hemifield data by the "independent capacities" model. Instead, full field data were best predicted from hemifield data by a multiplicative "independent resource" model.

Our results demonstrate that VSTM capacity is optimal when objects are presented in both visual hemifields. They do not support either the fixed-slot or independent capacity forms of the capacity model. Rather, the results support the view that VSTM capacity is limited by attentional resources which in turn exhibit a high degree of hemispheric independence.

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56.547

Categorical Effects of Working Memory Load on the Selection of Pop-Out Categorical Oddballs

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Recently, we have shown that the speed at which observers select and respond to a categorical oddball (house amongst faces or vice-versa) is strongly modulated by recent experience with members of that category (Lleras et al., VSS 2008). For instance, observers' RT to a face target is delayed by as much as 100ms if on the preceding trial, there was no target oddball (i.e., the search process "failed" to find a target) and all stimuli were faces, even though the oddball pops-out of the display. Here, we investigate the extent to which working memory load interacts with this categorical selection bias by asking participants to perform a working memory task concurrently with the categorical search task. In Experiment 1, participants alternatively viewed displays containing either one face at fixation (the target for the memory task, a modified one-back task) or three stimuli around fixation (the stimuli for the face/house oddball search task). In Experiment 2, the same design was used, but participants were asked to remember individual houses rather than faces. Importantly, the stimulus in the memory task was never used in the search task. Our results showed a category-dependent effect of working memory load on pop-out selection. When the target in the oddball search did not belong to the memory-task category, performance on the oddball search task was heavily modulated by previous experience with the category, replicating our previous findings. However, when the target in the oddball search task belonged to the memory-task category, the history effect was eliminated. Interestingly, overall RTs were slowed down, suggesting there was a categorical effect of working memory load on oddball selection that amounted to a bias against selecting any stimulus that belonged to the memory-task category. Experiments 3 and 4 further explored the flexibility of this WM-bias on the selection of pop-out targets.

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56.548

Individual visual short-term memory capacity predicts the number of conjunction errors in Treisman's illusory conjunction task

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Treisman & Schmidt (1982) used a divided attention to ask to investigate whether attention is required to bind the features of visual objects (letter identity and letter color). The term "illusory conjunctions" refers to observers' responses where two features belonging to different objects in the scene are reported as belonging to the same object. Several experiments in the literature have studied whether the phenomenon of illusory conjunctions in Treisman & Schmidt's task is purely a visual phenomenon or whether it is influenced by the memory demands of the task. Here, we use a different approach to understand illusory conjunctions. We measured each observer's visual short term memory (VSTM) capacity (K) using a simply color change detection task, and we then look for correlations between K and the different types of errors participants produced in the illusory conjunction task. The illusory conjunction task replicated Treisman & Schmidt's original pattern of results, with higher illusory conjunction errors than feature intrusion errors (e.g., reporting correctly a letter identity conjoined with a color that was not presented in the display). We expected to find a negative correlation between K and intrusion errors (with lower capacity leading to more frequent guessing), yet, somewhat counter-intuitively, there was no correlation between these measures. However, K did significantly positively correlate with illusory conjunctions, $r = 0.6$, suggesting that VSTM had access to features present in the display, yet not to the precise form/color conjunctions they were originally presented in. Our results support the view that VSTM can, under conditions of divided attention, act as a non-differentiated feature storage (remembering visual features without knowing what objects they belonged to) and that illusory conjunctions, at least in the Treisman & Schmidt methodology, are strongly dependent on this form of VSTM storage.

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56.549

Impact of Global vs. Local Attentional Processing on Visual Working Memory Organization

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The concept of global dominance in visual attention argues that when processing visual information, visual attention proceeds in a global to local fashion such that more global aspects of a scene or stimulus are processed prior to more local aspects (Navon, 1977). Similarly, Jiang, Olson, & Chun (2000) provided evidence that information within visual working memory (VWM) is organized in a hierarchical spatial configuration that also proceeds in a global to local fashion. The current experiment examined whether the bias in VWM to organize information in a global spatial configuration is linked to visual attention processes. To examine this, the experiment investigated the impact of performing a global/local attentional task (using Navon figures, e.g., the letter A made out of smaller T's) prior to a VWM task. On an attentional trial, participants were told to either respond to the larger letter (global emphasis) or the smaller letter (local emphasis). Participants completed one attentional trial prior to each VWM trial. In the VWM task, participants made same/different judgments on an array of five colored squares that were presented simultaneously at study. At test, the array varied in four different spatial configuration conditions: one featuring no changes from study (control), one in which a pair of items switched (local change), one in which the same array repeated but in a different location (global change), and one in which a completely novel test stimulus appeared (global and local change). Results indicate a slight disadvantage for completing a local attentional trial prior to the VWM task. The results provide additional support for a global spatial configuration organization in VWM, and suggest that this cannot be modulated by a prior local attentional set.

Wednesday Sessions

Vision and Action: Reaching and Grasping

Wednesday, May 13, 8:30 – 10:00 am
Talk Session, Royal Palm Ballroom 1-3
Moderator: Monika Harvey

61.11, *8:30 am*

Change Blindness is Reduced with Responses that Afford Action

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Change blindness has been used to demonstrate the impoverished nature of visual representations. The verbal report measure in this paradigm underestimates information stored but not immediately available to consciousness because observers must be absolutely aware of changes and put them into words. Detection without awareness perhaps better assesses the true nature of visual representations. We tested whether the qualitative difference between cognitive and sensorimotor visual systems is reflected in implicit detection. Since the sensorimotor visual system is more implicit and does not rely on words, can it better access visual information when verbal report is not required?

Observers were randomly assigned to "cognitive" or "sensorimotor" groups. Both groups viewed 30 photos of natural scenes. On each trial a scene was displayed at a distance of 60cm, followed by a changed scene, without repetition. Observers reported the change on a 2x3 grid when they saw one (<1%), or guessed the change location by trusting their "gut feelings" when a conscious detection was absent (99%).

In Exp 1, the cognitive group chose one of the grid blocks on the response screen. The sensorimotor group touched the monitor with a finger. Hit rates were reliably better in the sensorimotor condition. That is, in the absence of verbal change detection, observers could guess the location of change better when responding with a jab. The cognitive group, however, still performed significantly above chance level.

Exp 2 tested whether action affordance was critical to this sensorimotor advantage. The distance to the stimuli was extended to 3m, well beyond arm's reach, with angular size of the images kept constant. Participants pointed with a laser pointer; thus a jabbing motion could no longer afford any actions. The sensorimotor advantage disappeared in this distance condition. We conclude that visual representations are more effective for stimuli that afford action.

61.12, *8:45 am*

Implicit processing of obstacles for immediate but not delayed reaching in a case of hemianopic blindsight

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When we reach towards an object we are easily able to avoid potential obstacles located within our reach path. Previous research suggests that obstacle avoidance can operate even in the absence of visual awareness. Specifically, patients with right parietal damage who demonstrate a profound lack of awareness for the left side of space are nevertheless able to avoid obstacles they are unaware of. This suggests that obstacle avoidance is governed by the dorsal stream which regulates visuomotor control independently from the ventral stream which enables conscious visual perception. One important question that remains unanswered concerns the visual inputs necessary for obstacle avoidance to occur. Specifically, the dorsal stream receives input from primary visual cortex (i.e. V1) as well as subcortical visual pathways that bypass V1 (e.g. the retinotectopulvinar and retinopulvinar pathways). In the current study we examined obstacle avoidance in CB, a patient who suffered a right occipital stroke resulting in a dense left visual field hemianopia. In the first experiment CB was required to reach to a target region while avoiding obstacles that were located in his right (sighted) or left (blind) visual field, or both fields. The results indicated that the endpoints of CB's reaches were significantly modulated by the position of obstacles placed in his blind field. Specifically, obstacles in the blind field that were placed closer to fixation 'pushed' his reach endpoints further rightward compared to obstacles in his blind field that were placed further away from fixation. In a second experiment, CB's sensitivity to the same obstacles in his blind field was completely abolished when a short 2-second delay was introduced prior to reach onset (compared to healthy sighted individuals who continued to avoid the obstacles). These data provide compelling evidence that the dorsal stream controls obstacle avoidance in real-time, independent of inputs from V1.

Acknowledgement: This work was funded through a Heart and Stroke Foundation of Canada (HSF) postdoctoral fellowship awarded to C.S., a Natural Sciences and Engineering Research Council of Canada (NSERC) PhD award to C.C., and a Canadian Institutes of Health Research (CIHR) operating grant awarded to M.G. The authors would like to thank Dr. David Nicolle for performing the visual field testing with patient CB.

61.13, *9:00 am*

On-line reaching to perturbed targets in visual form agnosia (patient DF)

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According to Milner and Goodale's model (2006) areas in the ventral visual stream mediate visual perception whereas regions in the dorsal visual stream are closely involved with the visual control of action. Indeed the demonstration of an 'autopilot deficit' in optic ataxia (the inability to update a movement after a target jump as a result of bilateral occipito-parietal damage) has been presumed to reflect damage to the dorsal visual pathway. So far, this has only been shown as a single dissociation, with the strong prediction that the ability to make automatic corrections should be preserved if the dorsal stream is spared, for example in the visual form agnosic patient DF.

Here we investigated whether DF, when compared to age-matched controls, could rapidly adjust or interrupt her ongoing reach in response to a target jump. We found that DF successfully corrected her reaches towards the location shifts. Moreover in the stop condition, unlike optic ataxia patients, she performed involuntary corrections towards the target shifts in spite of being instructed to interrupt her reach.

Our data thus provide evidence for the expected double dissociation, further supporting localisation of the 'autopilot' to the dorsal visual pathway.

Milner, A.D. and Goodale, M.A. (2006). The visual brain in action. OUP.

Acknowledgement: This work was supported by a grants from the Foundation for Science and Technology (FCT, Portugal, (SFRH/BD/23230/2005)) to S. Rossit.

61.14, *9:15 am*

Looking forward to a correction: Obstacle avoidance during online correction

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The dorsal stream codes information crucial to the planning and online control of reaches to targets in dynamic and cluttered environments. Two specific dorsally-mediated abilities are online correction for changes in target location and the avoidance of obstacles. In online correction, abrupt changes in target location occurring during a reach result in automatic corrections toward the new target location (Pisella et al., Nature Neuroscience, 2000). In obstacle avoidance, objects that interfere with a reach are automatically avoided by maximizing the distance away from them (Schindler et al., Nature Neuroscience, 2004). The current study was designed to test whether both of these abilities can be performed concurrently. Participants made reaches to a target that, on two-thirds of the trials, remained stationary and on the other third 'jumped' (at movement onset) to a new location (10cm further in depth and 10cm to the left or right). When present, single objects (i.e. potential obstacles) were placed in one of four positions at a depth beyond the initial target, thus causing no initial interference. Importantly, on trials when the target jumped, the objects sometimes became obstacles that could interfere with the reach. Our results confirm previous findings; first, on the no-jump trials, obstacles positioned beyond a target have no interfering effect (Chapman & Goodale, Experimental Brain Research, 2008); second, on the no-obstacle jump trials, participants made automatic online corrections. Critically, when the target jumped in such a way that an object suddenly became an obstacle, we observed clear – and rapid – avoidance behaviour, an effect that was not present when the target jumped but the objects did not become obstacles. In other words, participants showed exquisite sensitivity to obstacles in their online corrections. These findings suggest that potential as well as current obstacles are automatically coded during movement planning, presumably by the dorsal stream.

61.15, *9:30 am*

Weber's law in action

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According to Weber's law, a fundamental principle of perception, sensitivity to changes in magnitude along a given physical dimension decreases when stimulus magnitude increases. In other words, the increment needed in order to detect a change - the Just Noticeable Difference (JND) - is smaller for weak stimuli compared to stronger stimuli. Although Weber's law governs human perception for visual dimensions, including visual length, there have been no attempts to test its validity for visually-guided action rather than for perception. Based on the notion that visually-guided action and perception are mediated by distinct neuroanatomical systems, we hypothesized that Weber's law does not necessarily hold for visually-guided action. In order to test this idea, we asked observers to either grasp or make perceptual estimations of length for objects varying in length. These measurements served to assess resolution with these two functions of vision. We found that the JND increased with object size for perceptual estimations in accordance with Weber's law. For grasping, however, the JND remained invariant across different sizes of objects, violating Weber's law. In a series of follow-up experiments, we tested the presence of Weber's law in online grasping as compared with that in memory-based grasping as well as under open-loop conditions in which vision was occluded during the grasping movement. Collectively, our findings reinforce the presence of a basic dissociation between the way object size is computed for perception and for action.

61.16, *9:45 am*

Practice does not make perfect: Time allocation in sequential movements

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Dean et al. (2007, JOV/7) found that people could trade off motor uncertainty and movement time to maximize expected gain in an economic task involving a single speeded movement. It came as a surprise that people failed to correctly allocate time between two sequential movements in a similar task (Wu et al. 2007, JOV/6). Why? Perhaps they need to learn how motor uncertainties vary with timings. Or to divide time arbitrarily. We investigated how well people could allocate time in planning a sequence of speeded movements after explicit training in varying timing.

Method: Subjects pointed sequentially to two targets on a touch screen. Successful hits resulted in monetary rewards. There were two sessions. In the practice session, subjects were trained to divide the total movement time (T = 600 ms) in specified ways (Time for the first movement, t1 = 180, 260, 340, or 420 ms). In the following test session, subjects were left to choose freely how to divide the total time. But the rewards for the two targets varied as [10 50], [10 10], or [50 10] points. Four subjects participated, three naïve.

Results: 1) In the practice session, for all subjects, the mean t1/T deviated least from the requirement in the 260/600 condition, and regressed towards 260/600 in the other timing conditions, a tendency hardly affected by practice. 2) In the test session, the three naïve subjects used a constant time division (close to 260/600) for all three reward conditions, even if other timings they had achieved during practice led to greater expected gains. The non-naïve subject varied timings but also failed to choose the best available ones. Our results imply that people may not be able to solve problems involving multiple motor uncertainties.

Acknowledgement: NIH EY08266

Perceptual Learning: High-level Influences

Wednesday, May 13, 8:30 – 10:00 am
Talk Session, Royal Palm Ballroom 4-5
Moderator: Michael Herzog

61.21, *8:30 am*

Top-down interpretation alters low-level visual processing

Po-Jang Hsieh[1] (pjh@mit.edu), Edward Vul[1], Nancy Kanwisher[1]; [1]Brain and Cognitive Sciences, MIT, McGovern Institute

When looking at the classic RC James photograph for the first time, people can only identify the Dalmation after they are told that one exists in the image, or after it is explicitly outlined. In general, recognizing objects in such two-tone 'Mooney' images is the prototypical example of the influence of global, top-down expectations on the interpretation of local, low-level image features – a process required for all image understanding. Here we used functional magnetic resonance imaging (fMRI) while subjects viewed two-tone images to investigate how global, top-down interpretation alters low-level visual processing. We compared the pattern of fMRI response while subjects viewed images in the following three conditions (occurring in this order): (1) viewing an ambiguous two-tone image when the object within it is not identified; (2) viewing the same image in grey-scale so that the object can be clearly identified; (3) viewing the original two-tone image again, but now the pictured object can be easily recognized due to the experience in (2). Our results show that BOLD response patterns in the early visual areas are more similar between conditions (2) and (3) than between (2) and (1). In other words, when participants know what objects are contained in an ambiguous two-tone image, the neural response to that image in early visual cortex becomes more similar to the neural response evoked by unambiguous the grey-scale photograph. The same effect is also observed in the lateral occipital complex. Thus, the high-level interpretation of a visual stimulus influences visual processing in early cortical areas. Our results suggest that the representation measured in low-level visual areas reflects a combination of high-level interpretation and low-level stimulus properties, as would be expected from a Bayesian inference framework.

61.22, *8:45 am*

Learning with attention eliminates attentional blink on a long-term basis

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The capacity of visual information processing is limited in many aspects. Identification of the second visual target (T2) is impaired in rapid serial visual presentation (RSVP) when it is presented within half a second after the appearance of the first target (T1). This deficit in identifying T2, called attention blink (AB), is believed to reflect the capacity limitation in high-level processes such as attention and short-term memory consolidation.

Can training of RSVP tasks reduce or even eliminate capacity limitations? If so, as in perceptual learning, can this occur by mere repetitions of the task? In Exp 1, subjects were trained in a typical RSVP task by repeated performance: for 450 trials per day during a 3-consecutive-days period, subjects reported two digits (T1 and T2) presented with a fixed 200ms SOA (stimulus onset asynchrony) that were embedded in a sequence of alphabetic letters. Despite training, there was no evidence of AB reduction.

In Exp. 2, subjects performed a modified RSVP task identical to that of Exp 1 except that during training T2 was spotlighted red while T1 and all letters were white, thus attracting attention to T2. To assess training effects, AB was measured before and after each training session with an RSVP task in which all items including T2 were white. Surprisingly, AB was eliminated after a single day of training, and was continuously absent for several months.

These results indicate that even the deficit induced by capacity limitations, such as AB, can be overcome by training observers' attention to a blinked item, and that the learning effect lasts for a long time. Contrary to perceptual learning formed by mere exposure to some primitive visual features (Watanabe et al., 2001), reduction or elimination of capacity limitations in high-level processes may require focused attention.

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61.23, *9:00 am*

Covert attention generalizes perceptual learning

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Goal: Perceptual learning is the improvement in performance that results from practice with simple tasks. Such learning is highly specific to basic stimulus attributes, including spatial frequency, orientation and spatial location. Last year we reported that both voluntary and involuntary covert attention can speed and strengthen learning, and transfer it to different target-stimuli. Here we ask whether attention would also help perceptual learning transfer to new spatial locations.

Methods: Observers trained for five consecutive days with an orientation discrimination task (left vs. right) using two Gabor stimuli on the horizontal meridian. For four observers each trial began with a spatially neutral cue. For four other observers an uninformative spatial cue preceded the display; half the time it preceded the target (valid cue) and half the time it preceded the distractor (invalid cue). For a third group of four observers, a spatial cue always preceded the target (valid cue). Critically, the transfer task was identical to the training, except that for five consecutive days, observers reported the orientation of Gabors that were either at the original location or were shifted above and below their original locations.

Results and Conclusion: When observers began the transfer task at the new stimulus locations, nearly all learning was lost for the neutral and invalid cue conditions, as observers' performance levels dropped back to threshold level. However, when valid cues were used, the performance decrement was significantly ameliorated (for observers who trained with valid and invalid cues) and completely absent (for observers who trained only with valid cues). These results support the finding that attention strengthens perceptual learning for simple visual stimuli; crucially, they indicate that exogenous attention transfers learning to new stimulus locations.

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61.24, *9:15 am*

Global motion is processed as the entire unit but learned locally

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A growing body of evidence by human imaging and monkey single-unit recording studies has indicated that global motion such as radial motion (expansion and contraction) and rotation as entire units are processed in MT+ and MST, respectively. Although perceptual learning of global motion is broadly reported, it is still unclear at which stage of visual processing the learning occurs. To address the question, we examined whether perceptual learning occurs on the basis of local or global motion as a result of improvement of performance in detecting a global radial motion in a display in which expanding or contracting dots slightly outnumber oppositely moving dots. First, the results showed improvement in detection performance specifically on the trained motion direction (expansion or contraction). Then, we measured the degree of transfer of the learning effect by presenting test stimuli spatially shifted so that the region of the test stimuli partially overlapped the trained region. We found that the degree of transfer was entirely dependent on similarity of local motion directions in the test stimuli to those in the trained stimulus in the overlapping area, irrespective of whether or not a test stimulus contained the same global motion direction as the trained stimulus. These results indicate that perceptual learning of a global motion stimulus, at least in the present setting, occurs at the stage of local motion processing. Interestingly while global motion is most likely processed as an entire unit in some stage of processing, it may not be learned as an entire unit however.

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61.25, *9:30 am*

Global resistance to local perceptual adaptation in texture discrimination

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Intensive training or testing reduces performance on perceptual tasks (Censor, Karni & Sagi, 2006). These effects are specific to basic image features, implicating early stages of the visual stream rather than general fatigue (Mednick, Arman & Boynton, 2005; Ofen, Moran & Sagi, 2007). Recent results show that such adaptation-like performance decrements are practically eliminated following practice with a small number of trials and sleep (Censor & Sagi, 2008). This long-term learning effect suggests 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. Here we show that such training-induced resistance to perceptual decrements generalizes across retinal locations while effects due to extensive training were shown to be local. 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 target-mask SOA (stimulus onset asynchrony) decreased gradually to obtain a psychometric curve. Subjects practiced the texture discrimination task with 12 trials/block of SOA (~450 trials/session), showing low thresholds (133.4±6.7 ms, mean±SE), and returned for intense test-sessions with 50 trials/block (~1600 trials/session) at both trained and untrained locations. Results showed that the average thresholds in the 50 trials/block test-sessions for both trained (138.8±6.7 ms) and untrained (139.8±7.5 ms) locations were significantly lower than those of naïve subjects trained with 50 trials/block (184.9±14.0 ms). Further experiments revealing the different transfer properties of performance decrements and increments allow us to identify local and global components of perceptual learning and their interactions, suggesting mechanisms that induce modifications of higher brain areas which interact with local early visual networks and enable improvement of perceptual abilities.

61.26, *9:45 am*

Perceptual learning by mental imagery

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In a bisection discrimination task, two vertical outer lines delineate an interval which is bisected by a centre line. Observers indicate whether this centre line is closer to the left or right outer line. Performance in this task improves strongly with training. This perceptual learning is usually assumed to be caused by synaptic changes which are mainly driven by the presentation of the stimuli. Here, we show that perceptual learning can also occur in the absence of physical stimulation via mental imagery. We presented only the two outer lines of the bisection stimulus and asked observers to imagine the centre line to be closer to the left or right outer line. Surprisingly, performance improved. Control experiments show that this improvement cannot be explained by unspecific aspects, such as adaptation to the experimental conditions. Hence, perceptual learning can occur without proper physical stimulation, driven by mental imagery.

Acknowledgement: Pro*Doc opf the SNF

Binocular Vision: Mechanisms

Wednesday, May 13, 11:00 am – 12:45 pm
Talk Session, Royal Palm Ballroom 1-3
Moderator: Laurie M. Wilcox

62.11, *11:00 am*

Are stereoscopic cues ignored in telestereoscopic viewing?

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One hundred and fifty years ago, Helmholtz reported that when viewing the world through a telestereoscope (which increases the effective interocular distance), the scene appears as if the observer were looking "at a very exquisite and exact model". In contrast, Glennerster et al (Current Biology 16 2006 428-432) claimed that observers "failed to notice" the changing size of a scene (altered by a factor of 4:1 in their virtual reality set-up) and they concluded that we "ignore motion and stereo cues in favour of a fictional stable world". Our experiments were designed to resolve these apparently incompatible findings. Using a wide-field stereoscope (70 x 70 deg), observers viewed the captured stereo images of a richly furnished room containing many familiar objects of known size. The telestereoscopic image pairs were created using camera separations of between 0.5 and 4.0 times the usual interocular separation, so that the depicted size of the room could be varied from twice to one quarter the size of the original. Observers were asked to estimate the apparent size of the depicted rooms and the objects within. All observers reported clear differences in the apparent size of the room and the size of objects within the room with changes in camera separation. As a more powerful test of the role of stereo cues in our perception of the differently sized rooms, we asked observers to set a disparity-defined ridge surface so that the flanks appeared to meet at 90deg. Since the disparity gradients of a 90deg ridge surface in a half-sized room are doubled, observers ought to see the flanks as steeper, if no account is taken of room size. In fact, all our observers' settings showed a high degree of constancy (60-80%) and we find no evidence to support the claim that stereo cues are ignored.

62.12, *11:15 am*

Perceptual asymmetry in stereo-transparency: the role of disparity interpolation

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We have previously described a perceptual asymmetry that occurs when viewing pseudo-transparent random element stereograms. That is, the minimum separation in depth needed to segregate two overlaid surfaces in a random-element stereogram depends on the distribution of elements across the surfaces. With the total element density fixed, significantly larger inter-plane disparities are required for perceptual segregation of overlaid surfaces when the front surface has fewer elements than the back surface than vice versa. In the experiments described here we test the hypothesis that this perceptual asymmetry reflects a fundamental difference in signal strength for the front and back surfaces which results from disparity interpolation. That is, we propose that the blank regions between elements are assigned to the back plane, making it appear opaque. We tested this hypothesis in a series of experiments and find that:

i) the total element density in the stimulus does not affect the asymmetry

ii) the perceived relative density of the two surfaces shows a similar asymmetry

iii) manipulations favouring perceptual assignment of the spaces into surfaces other than the two overlaid element surfaces reduces the asymmetry.

We propose that the interpolation of the spaces between the elements defining the surfaces is mediated by a network of inter-neural connections; excitatory within-disparity, and inhibitory across disparity. Our data suggest that the strength of the inhibitory connections is modulated according to mid-level figure ground assignment. We are using our psychophysical results to inform the development of a computational model of this network.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

62.13, *11:30 am*

Differential effects of suppressed visual motion information on perception and action during binocular rivalry flash suppression

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Background and Goal. In binocular rivalry, two different visual stimuli are projected to corresponding retinal areas of the two eyes. Rather than fusing the two images into a coherent percept, observers usually report that the images alternate at a random rate, with one image dominant and the other suppressed. Here we used a binocular rivalry flash suppression paradigm in which monocular presentation of one stimulus results in suppression of that image when it is subsequently paired with a second stimulus. We investigated whether suppressed visual motion information affects perceptual performance and oculomotor behavior similarly.

Method. Stimuli were two large (6.7°) Gabor patterns that moved in orthogonal directions at 5°/s. The luminance contrast of the dominant stimulus was constant (10%), the suppressed stimulus varied in contrast (5 to 50%). Observers reported perceived motion direction at the end of each trial, and eye movements were recorded.

Results. While perceptual judgments exclusively followed the direction of the dominant stimulus, reflexive eye movements reflected the vector average of dominant and suppressed image motion. These findings were confirmed in two control experiments with smaller (1.6°) and faster (10°/s) stimuli. As luminance contrast of the suppressed stimulus increased, eye movements were biased in the direction of the suppressed stimulus.

Conclusion. These results show that reflexive eye movements can be used as a sensitive measure of the depth of suppression, as variations in depth of suppression by manipulations in stimulus weight were reflected in the eye movement response. Our findings imply that perception and action are differentially affected by suppressed visual information. While the action route is susceptible to suppressed visual information and simply averages all available information, the perception route is more resilient to suppressed visual information.

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62.14, *11:45 am*

Numbers with higher magnitude have higher perceptual strength during binocular rivalry

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It has been suggested that human number processing is part of a common cortical system of magnitude processing (Walsh, 2003). According to this idea, the visual system should recruit the same processing structures when confronted with stimuli of different contrast or luminance, as when confronted with numerical information.

In the current study we use a perceptual phenomenon known to reveal abstract magnitude processing properties of low-level features such as contrast and luminance. During binocular rivalry, perception alternates between dissimilar images presented dichoptically. Of particular interest here is the fact that increasing the contrast (or luminance) of only one of the dissimilar images will increase its perceptual dominance. We hypothesize that if numbers are processed by a common mechanism for magnitude processing, numbers of different magnitude should conform lawfully to this contrast-rule of binocular rivalry.

We presented images of the numbers 2, 4 ,6 or 8 to one eye, while presenting a meaningless shape (#) to the other eye. Observers continuously indicated which of the two (the number or the #) was dominant in perception during trials lasting one minute. Importantly, the images used were spatially filtered such that there were no differences in contrast and Fourier-energy.

The results of our study reveal that numbers conform lawfully to the contrast-rule: increasing the magnitude of a digit increased its predominance. Control experiments ruled out the possibility that low-level images features not related to the magnitude of a number were responsible for this result. We conclude that the processing of numbers shares at least some processing structures involved in the analysis of magnitude.

62.15, *12:00 pm*

Binocular rivalry requires visual attention: Evidence from EEG

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It remains an open question whether incompatible dichoptic patterns rival when attention is directed away from them. We used frequency-tagging in a steady state visual evoked potential (VEP) paradigm to track alternations in dominance of each eye's signal with and without attention. Two checkerboard patterns, flickering at different temporal frequencies (6.6 Hz and 7.5 Hz), were presented in the parafoveal visual field. An adaptive filter was used to extract the VEP amplitude of corresponding frequencies in the EEG signals with surface Laplacian spatial filtering. In a dichoptic condition, the two checkerboard stimuli were simultaneously each presented to one eye. Four subjects either attended to the checkerboards (and reported their perceptual dominance), or attended a continuously deforming ellipsoid shape that changed color at fixation (and performed a demanding shape-color conjunction detection task). VEP amplitudes to each monocular stimulus showed strong negative correlations, an indication of alternation in dominance, when subjects attended to the dichoptic checkerboards (r = -0.49). The signals also correlated well with subjects' reports of perceptual dominance. However, no reliable correlation was observed when subjects attended the dynamic ellipsoid at the fixation (r = -0.08). In a monocular "replay" condition, perceptual dominances were simulated by alternatively presenting monocular stimuli. Here VEP amplitudes showed strong negative correlations both while subjects attended to the checkerboards (r = -0.60) and while they attended to the ellipsoid at the fixation (r = -0.43). This control shows that the low correlation in the unattended dichoptic condition was not due to reduced monocular signal; signal-to-noise ratios were comparable between the unattended dichoptic and unattended replay conditions. Our results suggest that dichoptically presented incompatible stimuli only engage in binocular rivalry when attention is directed towards them.

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62.16, *12:15 pm*

Training Improves Orientation-in-Noise Thresholds in an Animal Model of Amblyopia

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Binocular visual experience is necessary for the normal fine tuning of neural circuits in the visual cortex and the emergence of optimal signal-to-noise processing. A number of studies have suggested that the loss of visual acuity and contrast sensitivity after early monocular deprivation are a result of increased neural noise in the visual cortex. Here, our purpose is to determine the long-term effects of early monocular deprivation on neural signal-to-noise and whether intensive training with a visual signal-in-noise stimulus can ameliorate the visual deficits. We reared cats with either normal vision or a short period (2 weeks) of monocular deprivation early in the critical period. We then compared the impact of early training with a noise-free or noisy stimulus by measuring the developmental trajectory for grating acuity from one litter and orientation-in-noise thresholds from the other litter. The short period of monocular deprivation did not alter the developmental trajectory for either stimulus, or the adult grating acuity. Brief deprivation did, however, lead to poorer adult performance on the noise stimulus. Compared to normal cats, the deprived eye of cats with early training on noise required 10-15% more orientation signal to discriminate the target from noise. Surprisingly, even the non-deprived eye was affected, requiring 5-10% more orientation signal at threshold. Next, we measured orientation-in-noise thresholds for cats trained on grating acuity during development. Their thresholds were substantially worse, needing ~ 30-50% more signal to make the discrimination; but after 2-3 weeks of intensive daily training, the thresholds began to improve. These findings reveal a prolonged development for the maturation of visual signal-in-noise processing with the deprived eye deficit not apparent until many weeks after the end of monocular deprivation. Finally, intensive training during development, or in young adults, can ameliorate much of the noise discrimination deficit caused by early visual deprivation.

Acknowledgement: Brett Beston, Olenka Batruch, and Lilia Tcharnaia

62.17, *12:30 pm*

Motion-induced blindness and microsaccades: cause or effect?

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Subjective visual disappearance was suggested to be caused by reduced micro-saccade (MS) rate enabling image stabilization, enhanced adaptation and perceptual fading. We compared the dynamics of MS in Motion-Induced Blindness (MIB) and in physical disappearance. Observers reported the disappearance and reappearance of a single peripheral (2 deg, upper-left) high contrast Gabor patch on a gray background embedded in a rotating grid mask presented for 4 min periods. In a following experiment observers repeated the same task while presented with a stimulus sequence in which the Gabor patch was physically erased and redisplayed according to their MIB reports (Replay). To minimize MIB effects in the replay condition, the mask was slowed down (0.2 deg/sec). Eye movements and pupil size were recorded using a video based eye-tracker. We found a similar pattern and overall level of MS rate in the MIB and Replay conditions. Notably, the MS rates during sustained invisible periods, whether only perceptual or physical, were significantly lower (60%) than the MS rates in the corresponding visible periods. In both MIB and Replay, transitions were accompanied by transient changes in MS rates: decrease and increase with a disappearance and reappearance report respectively. Pupil size dynamics showed a similar trend with a smaller pupil corresponding to a lower MS rate. Additional experiments showed that eye movements induced by tracking a continuously jumping fixation reduce but do not eliminate disappearance. The results suggest that MS do not have a major causal role in MIB since they showed similar dynamics with (Replay) and without (MIB) physical disappearance, and since MIB can survive task-induced eye-movements. The opposite MS dynamics for appearance and disappearance, whether physical or only perceptual, together with a similar trend of pupil size dynamics, suggest that the eye-control mechanisms are informed about visibility.

Attention: Interaction with Memory

Wednesday, May 13, 11:00 am – 12:45 pm
Talk Session, Royal Palm Ballroom 4-5
Moderator: David Melcher

62.21, *11:00 am*

Neural measures of maintaining and updating object information

Trafton Drew[1] (tdrew@uoregon.edu), Todd Horowitz[2,3], Jeremy Wolfe[2,3], Edward K. Vogel[1]; [1]University of Oregon, [2]Brigham and Women's College, [3]Harvard Medical School

Recently, we have reported ERP activity that appears to index both the number of items being maintained in visual working memory (VWM) tasks (Vogel & Machizawa, 2004), and the number of items being tracked during a multiple object tracking (MOT) task (Drew & Vogel, 2008). However, while a similar sustained contralateral negativity is observed for both VWM and MOT tasks, the amplitude of the activity is considerably greater during MOT than during VWM. We hypothesized that this amplitude increase is due to the additional demands of the MOT task over the VWM task. Specifically, while VWM tasks requires mnemonic representations to be maintained for each item, tracking tasks requires these representations to be continuously updated to reflect their present position. We tested this hypothesis by briefly stopping object motion during MOT trials, thus temporarily eliminating the need for spatial updating. This led to a significant decrease in ERP amplitude, which quickly recovered once the objects started moving again. This amplitude change could have been a response to the absence of motion rather than the task demands. In subsequent experiments, we presented subjects with moving displays and required them to either remember the starting values of targets (maintenance only) or to track targets (maintenance + updating). Despite equivalent task difficulty, we found a large amplitude increase in the tracking condition relative to the memory condition. Together, these experiments suggest that VWM and MOT are similar in that both require mnemonic representations of targets, but that MOT requires an additional updating process which leads to an increase in sustained contralateral negativity.

62.22, *11:15 am*

Working memory load alters response to stimuli in early visual cortex

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Previous research has established that load on cognitive control functions such as working memory impairs executive control of selective visual attention. This results in greater distractor interference effects (Lavie, 2000; Lavie et al., 2004) and increased distractor-related activity in category-selective visual association cortex (e.g. fusiform face area response to distractor faces, De Fockert et al. 2001) under conditions of high working memory load. It remains unclear whether these effects reflect a modulation of high-level semantic processing or whether effects of working memory load on attention extend to the processing of distractors in striate and extrastriate visual cortex. We used fMRI to examine this question by assessing the response in retinotopic cortex to irrelevant (but response-competing) distractor objects presented during a selective attention task under either high or low working memory load. Participants held either one digit (low load) or six digits (high load) in working memory while classifying an object as either a household item or a fruit. The target object could be accompanied by a distractor that was either the same object (congruent) or an object from the opposite category (incongruent). The incongruent (vs. congruent) distractors produced greater response competition effects on the target RTs under high load than low load. fMRI results mirrored this behavioral pattern: there was a greater neural response in early visual cortex (areas V1-V4) for incongruent compared to congruent distractors under high compared to low working memory load. These findings support the load theory of attention and cognitive control and are the first to demonstrate effects of high level cognitive control by working memory on distractor-related activity in early retinotopic visual cortex.

Acknowledgement: This work was supported by the Welcome Trust (grant WT080568MA).

62.23, *11:30 am*

A Domain-Independent Source of Cognitive Control for Shifting Attention in Vision and Working Memory

Benjamin J. Rosenau[1] (brosenau@jhu.edu), Michael Esterman[1], Yu-Chin Chiu[1], Steven Yantis[1]; [1]The Johns Hopkins University

Humans and other organisms operate within both a perceptual domain, which contains information about objects and events in the world, and a mnemonic domain, which contains information about past experiences as well as plans and goals. Both domains contain more information than the mind can process at one time; selection of task-relevant external (sensory) and internal (mnemonic) information is therefore required. External selection reflects the influence of top-down (goal-driven) selective attention. Internal selection makes task-relevant information stored in working memory (WM) available for use during ongoing cognitive operations. Using fMRI and a cognitive task that requires voluntary shifts of both external visual selective attention and internal WM selection, we show that similar functional brain networks mediate control of both domains. In a subset of the well-established frontoparietal attentional control network (dorsolateral prefrontal cortex, intraparietal sulcus, superior parietal lobule), these acts of selection are indistinguishable using conventional univariate data analysis. However, using multivoxel pattern classification with a linear support vector machine, we show that shifts of internal and external attention evoke reliably distinct patterns of neural activity in these regions. Thus, while both internal and external acts of selection are mediated by the same domain-independent attentional control brain network, they are deployed through distinct domain-specific modes of brain activity.

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62.24, *11:45 am*

A shared sensorimotor map for visual memory, counting and trans-saccadic perception

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Many common tasks require us to individuate in parallel more than one object in a complex scene. Although the mechanisms underlying our abilities to count the number of objects, remember the visual properties of objects and to make saccadic eye movements towards objects have been studied separately, each of these tasks require selection of individual objects. To investigate the links between the mechanisms underlying these three abilities, we measured the capacity in number of items for counting, visual working memory and trans-saccadic perception, as well as the interference between tasks. The capacity of trans-saccadic perception—as measured by the transfer of adaptation aftereffects across gaze shifts—was around four items. The addition of a VWM or counting task that involved additional stimuli, however, reduced trans-saccadic capacity to only one item. However, a task requiring estimating the numerosity of a large number of dots (16 to 64) did not interfere with remapping four items. Likewise, maintaining a memory set of two or four items impaired the ability to quickly count the number of items in a brief display. Overall, the pattern of results across the four experiments was not compatible with the predictions of either "slot" (fixed number of objects) or "resource" (finite task resources across tasks) models. Instead, our results suggest that our abilities to count and remember small groups of stimuli are grounded in a sensorimotor "saliency map" of the scene which is also used for integrating information across eye movements.

Acknowledgement: Ministero dell'Istruzione, dell'Universitá e della Ricerca

 See page 3 for Abstract Numbering System

62.25, *12:00 pm*

Where's Waldo? How the Brain Learns to Categorize and Discover Desired Objects in a Cluttered Scene

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The Where's Waldo problem concerns how individuals can rapidly detect an object in a cluttered scene. How does the brain locate a desired object while scanning a cluttered scene? In particular, how do the brain mechanisms that govern spatially-invariant object learning and recognition also allow fast detection of objects at specific locations in a cluttered scene? A neural model provides a mechanistic explanation of how spatial and object attention, eye movement search, and invariant object learning and recognition are coordinated to solve the Where's Waldo task. This model builds on the recent ARTSCAN model of how invariant object categories are learned during eye movement search (Fazl, Grossberg, & Mingolla, 2008, Cognitive Psychology), which also simulated reaction time data showing an object advantage during spatial attention shifts (Egly, Driver, & Rafal, 1994; JEP: General; Brown & Denney, 2007, Perception & Psychophysics). The current work clarifies how the mechanisms that lead to learning of spatially-invariant categories in What stream cortical areas, such as anterior inferotemporal cortex, can link to representations of their positions in Where stream cortical areas, such as posterior parietal cortex. Thus, when an invariant object category is activated top-down by a cognitive plan, it can selectively activate the locations of sought-after object exemplars in a cluttered scene and shift spatial attention to rapidly identify them. This proposal shows how the Where's Waldo problem exploits the brain's solution of how to overcome the complementary deficiencies of What and Where stream processes by using inter-stream interactions that allow both invariant object recognition and spatially selective attention and action to occur.

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62.26, *12:15 pm*

Psychophysics of visual memory: What does a memory look like?

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To determine what visual objects' representations in memory "look like", the remembered spatial frequencies of Gabor patches were measured with the psychophysical method of adjustment.

Experiment One: Subjects viewed a single Gabor whose spatial frequency varied over trials, and reproduced its spatial frequency (i) while the Gabor remained visible on the display, or (ii) 1400 or 2400 msec after it had disappeared. In all three conditions, subjects' clustered tightly around the Gabor's actual frequency, although trial-to-trial variability of the reproductions increased by □2× when responses drew on memory rather than perception.

Experiment Two: To determine how a memory changes when multiple Gabors are being remembered, subjects saw and tried to remember two sequentially-presented Gabors on each trial. A post-stimulus cue identified which Gabor, first or second, had to be reproduced from memory. From trial-to-trial, the reproduced frequencies were about as variable as when just one Gabor had to be remembered (Experiment One). However, reproductions of the first Gabor, which had been held longer in memory, were more variable than that of the second Gabor. Moreover, reproductions of the target Gabor tended to be

skewed toward the spatial frequency of the non-target Gabor, and this skew increased with the difference between the Gabor's frequencies. The reproduced frequencies' skew toward the non-target might reflect the extent to which the non-target frequency had successfully infiltrated memory.

Experiment Three: To modulate the non-target Gabor's influence on memory for the target Gabor, a cue presented prior to the two study items rendered the trial's non-target Gabor task-irrelevant. As predicted, this manipulation dramatically reduced, but did not eliminate, the reproductions' skew toward the frequency of the non-target Gabor. We hypothesize that distortions in remembered spatial frequency arises relatively late in processing.

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62.27, *12:30 pm*

Sometimes change blindness is just visual amnesia

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People often fail to report large changes in visual displays ("change blindness"). One influential interpretation is that perceptual representations are not as rich as people think. However, change detection could fail at any of three stages: perception, memory or comparison. We tested the same stimuli at each stage in three experiments.

All experiments tested both simple (diamonds, circles) and complex (2s, 5s) stimuli. Objects were presented on an imaginary circle around fixation. In Experiment 1 (perception), participants reported which of two forms predominated (e.g., more diamonds or circles?) in displays of 3, 6, or 9 items. For simple forms, reaction times (RTs) were nearly independent of set size (slope = 5.9 ms/item). For complex forms, RT increased with set size (55.1 ms/item). In Experiment 2 (memory), we presented displays of 6 or 9 items for 500 ms. After a 300-1200 ms blank interval, a single location was probed, and participants had to report which item was initially presented there (e.g., diamond or circle?). For simple forms capacity was near ceiling, while for complex forms, capacity was 2-3 items, independent of set size. Experiment 3 (comparison), was similar to Experiment 2 except that instead of a memory probe, a second display appeared 1000 ms after the initial display. Participants indicated whether this display had changed from the first display. For both complex and simple forms participants could access no more than 2-3 items.

For complex stimuli, capacity limits were seen in perceptual processing (steep slopes in Experiment 1). For simple stimuli, perceptual and immediate memory processing were virtually unlimited. The limit in change detection occured in the comparison stage . Either the second display disrupted memory, or the comparison process itself was capacity-limited. We argue that the interpretation of change blindness depends critically on the complexity of the stimuli.

Neural Mechanisms: Visual Representations

Wednesday, May 13, 8:30 am – 12:30 pm
Poster Session, Royal Palm Ballroom 6-8

63.301

Visual image reconstruction using automatically determined image bases

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Image representation based on image bases provides a framework for understanding neural representation of visual perception. We have recently shown that arbitrary contrast-defined visual images can be reconstructed from fMRI activity patterns of early visual cortex, by a combination of multi-scale local image bases (Miyawaki et al., Neuron 2008). Our model assumed fixed multi-scale image bases, whose contrasts were estimated from fMRI activity patterns. Although the multi-scale basis model outperformed single scale models, such heuristically determined image bases may not be optimal for reconstruction. Here, we propose a method for automatically extracting image bases from fMRI data labeled by the stimulus images. We constructed a probabilistic model that relates the fMRI activity space to the visual image space via an intermediate representation. The mappings from/to the intermediate representation were estimated using a Bayesian framework. The mapping from the intermediate representation to the visual image space can be regarded as a set of image bases. Sparseness priors were also introduced for the mappings such that only a small number of fMRI voxels and image elements were related via each unit in the intermediate representation. The proposed model was trained with fMRI data measured while a subject viewed random images. As a result, spatially localized image bases were obtained around the foveal region. The shapes of the bases were similar to those of the fixed image bases used in our previous study. The trained model with automatically determined image bases was able to reconstruct novel visual images including geometric shapes and alphabet letters with higher accuracy, particularly in the foveal region, than our previous model. The results demonstrate that image bases for visual image reconstruction can be automatically determined to achieve higher performance. Our method provides a means to discover novel functional mapping between stimulus features and brain activity patterns.

63.302

A semi-automated solution for increasing the reliability of manually defined visual area boundaries

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Increasing accuracy and reproducibility in determining visual area (VA) boundaries will improve vision studies based on retinotopy. Manual VA definitions are likely to be corrupted by a complex interaction between noisy data and variations in human perception. Semi-automated methods (Dougherty et al., 2003) have the potential to increase reliability of VA boundaries without sacrificing the validity contributed by a human rater.

We present a template-based method that deforms a canonical retinotopy to polar angle and eccentricity data from fMRI-based retinotopy experiments. Here, VA boundaries traced by human experts are used not only in initializing the canonical map, similar to Dougherty et al., but are also directly incorporated in template fitting by probabilistic curve matching. In contrast, Dougherty et al.'s method, after initialization, is driven only by the image data. Thus, our method is unique in that it strikes a balance between user-labeled VA boundaries and the statistically defined quality of the match between the smooth template and the noisy subject data.

This novel methodology improved overall reliability across three raters. Each rater labeled six visual area borders and the foveal confluence on an inflated 3D surface. Despite an effort to use similar segmentation criteria, considerable variability between tracings by different raters existed before template mapping. Template mapping significantly (p=0.002) decreased the variability of the traced borders across a dataset of 12 hemispheres, when variability was measured by the minimum distance sum across VA boundaries. Reliability was highest in dorsal V2 and lowest in ventral V3 both before and after template mapping. In conclusion, combining optimized template-based models with manual

tracings of VA borders can improve the accuracy of retinotopic mapping. However, our work also indicates that fundamental issues of inter-rater reliability should be more carefully considered in retinotopy studies. More effort on defining optimization and evaluation criterion is also required.

Acknowledgement: NIH RO1 EY10016

63.303

Absence of behavioural recovery because of absence of cortical reorganization? An fMRI investigation of a left hemianopic patient

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Following unilateral occipital damage of the primary visual cortex one of the most common visual field defects observed is Homonymous Hemianopia. Most studies have focused on either the visual deficit or the residual capacities in the contralesional visual field in hemianopes. However, visual processing in the central visual field, and its underlying cerebral network, are largely unknown in such patients.

Fourteen healthy males (mean age 55 years ± 11.4) and a left hemianope following a right occipital lesion (male; age 71 years; delay from lesion: 20 months completed natural scene detection and categorization tasks. In the detection task participants had to press a button if a scene was present on the screen. In the categorization task, they had to press a button if the presented scene was a city and another button if it was a highway. Both tasks were performed in a 1.5T scanner to collect anatomical and functional data.

Regardless of task, behavioural data showed poorer performance in the hemianopic patient than in controls regarding either response accuracy (82% vs. 96%; $F(1,42)=20.43$; $p<.0001$) or response time (487.4 vs.391.7ms; $F(1,42)=44.10$; $p<.0001$). In controls, neuroimaging data revealed activation of the extra-striate occipital areas in both hemispheres during the detection task, but only in the left hemisphere during the categorization task. Quite surprisingly, the same networks were involved in the hemianopic patient despite the lesion.

Altogether, our data revealed that even though this patient demonstrates similar cerebral network activation as healthy controls, his poor performance on the tasks suggests: a) visual processing in the central visual field in hemianopic patients may not be as intact as often considered, and b) a lack of behavioural recovery seems to be associated with an absence of cortical reorganization.

Acknowledgement: This research was supported by the Edmond and Benjamin de Rothschild Foundations (Geneva and New York).

63.304

Hemispheric Differences of Color Responses in Human Ventral Visual Cortex

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INTRODUCTION. Human ventral occipito-temporal cortex (VOT) has been shown to contain several visual field maps involved in the color and shape processing pathways (Brewer, et al. 2005; Arcaro and Kastner, 2007). Patient lesion studies indicate that there may be hemispheric differences in the pathways subserving color vision and word form recognition. Here we compare the organization of the color responses between hemispheres in human ventral visual cortex.

METHODS. We first used fMRI to measure angular and eccentric retinotopic organization in VOT to define areas hV4, VO-1, and VO-2. Rotating wedge and expanding ring stimuli consisted of black and white, drifting radial checkerboards 3° in diameter. Next, color-responsive regions were isolated with localizer scans using luminance-matched chromatic and achromatic Mondrian patterns. We measured the color responses with respect to these maps and compared the pattern of the color responses between hemispheres. Finally, we measured and compared the population receptive fields in these maps and the surrounding ventral cortex (Dumoulin and Wandell, 2008).

RESULTS. Our measurements demonstrate a hemispheric difference in the organization of the color-selective regions just lateral to VO-1 and VO-2. The ventral cortex just lateral to VO-1 and VO-2 in the right hemisphere was strongly color-responsive, while the homologous region in the left hemisphere showed no preference between chromatic and achromatic stimuli.

CONCLUSION. These results suggest that there may be a lateralization of the color-processing pathway in human VOT.

63.305

Rod signals in human ventral visual cortex

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INTRODUCTION. The rod and cone photoreceptors of the retina are organized such that the central fovea contains no rod photoreceptors. It is generally accepted that this pattern of organization continues through the input into the early retinotopic visual areas in human occipital cortex. Thus, signals from both rod and cone photoreceptors travel from the retina to the more peripheral regions of primary visual cortex (V1), while the central foveal representation in V1 only receives cone signals.

Most studies of retinotopy have examined visual field map organization under full luminance (photopic) conditions. However, there are controversial reports that there are not inputs from the rod photoreceptors into the color-responsive maps in human ventral visual cortex (Hadjikhani and Tootell, 2000). Here we report new measurements of color-responsive visual field maps in human ventral occipito-temporal cortex (VOT) under low luminance (scotopic) conditions that only activate the rod photoreceptors.

METHODS. We measured angular and eccentric retinotopic organization in human VOT using fMRI at two different luminance levels. Retinotopic stimuli consisted of black and white, drifting radial checkerboards 3° in diameter comprising wedges, ring, or bars. We examined the organization of the responses of the previously defined color-responsive maps in VOT (hV4, VO-1, VO-2; Brewer et al., 2005) to these stimuli under photopic and scotopic conditions. We additionally measured the population receptive fields (Dumoulin and Wandell, 2007) of these regions under both luminance levels.

RESULTS. Our measurements show that, in contrast to previous reports, the color-responsive VOT maps receive rod signals in the peripheral representations of these maps. The central foveal representations of these maps do not contain rod signals. This organization in the ventral color-responsive maps follows that of the posterior visual field maps (V1/V2/V3).

CONCLUSION. These results suggest that VOT color-responsive visual field maps do not only subserve the color-processing pathway.

63.306

Where orientation tuning arises

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Introduction: The neural circuitry underlying orientation selectivity, a fundamental question in vision, remains the center of controversy. Some advocate a modified feedforward model, originating in connections from LGN to V1, while others maintain that intracortical activity plays a crucial role in shaping selectivity. To test the role of intracortical activity in shaping orientation selectivity in humans, we employed TMS to attenuate cortical responses to an oriented stimulus and used noise masking to estimate orientation-tuning curves psychophysically.

Methods: Prior to each block of experimental trials, we applied TMS pulses at 1 Hz continuously for 2.5 minutes, thereby depressing neural activity at a specific retinotopic site in early visual cortex including V1. In each trial, a filtered noise patch appeared inside or outside the visual region corresponding to the TMS site. A vertically oriented Gabor was embedded within the upper or lower portion of this noise patch, for which observers performed a 2AFC location discrimination task. To obtain psychophysical 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 probe. An adaptive procedure produced estimates of contrast thresholds for the probe embedded within varying orientation bandpass noise, yielding tuning curves for conditions when the stimuli appeared within or outside of the TMS site.

Results and Conclusion: Contrast thresholds were elevated for several minutes following TMS (but only at the TMS site), confirming its effectiveness at depressing neural activity at that location. Orientation-tuning bandwidths, however, were unchanged by TMS stimulation. To confirm that TMS disrupts intracortical activity, we found that TMS weakens an illusion known to involve intracortical interactions. These results imply that orientation tuning is governed largely by thalamocortical feedforward signals, with intracortical activity contributing little to the sharpness of orientation tuning.

63.307

Figure-ground signals in early and object specific visual areas: A combined fMRI, EEG and TMS study

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Two processes can be discriminated when distinguishing a figure from its background: boundary detection and surface segregation. The neural origin and temporal dynamics of these two processes is still much disputed. In monkey V1 neural correlates of surface boundary detection have been found, but there is still debate about whether scene segmentation signals can be found in human V1. Here we studied the neural correlates of these two processes using texture and motion defined stimuli that differentiate between surface segregation and edge detection. By this means we were able to generalize figure-ground segregation results across different types of stimuli.

In several ROI's (V1, V2, LO and V5), BOLD-MRI was measured (n=13) to establish whether figure-ground signals are cue independent within these regions. Preliminary data analysis shows that texture defined figure-ground segregation was associated with an increase in BOLD responses in V1, V2 and LO. Interestingly motion defined figure-ground segregation signals were only found in LO. These results suggest that where V5 primarily responds to the actual presence of motion, LO can keep an object active even though the actual motion has stopped. Currently we combine rTMS, EEG and the above-described paradigm to investigate the temporal and spatial dynamics of V1, LO and V5 in figure-ground segregation. The first results indicate that rTMS disturbs figure-ground related processes in V1 when LO and V5 are stimulated.

63.308

Visual field coverage of human V4

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Purpose: Human and macaque have similar topographic organization for V1-V3. The homology of later maps remains less clear. Macaque V4, like V2 and V3, is split into dorsal and ventral subfields. In human, one continuous hemifield map anterior to ventral V3 (V3v) was proposed as a possible homologue to macaque V4 (Brewer et al., 2005). Anterior to V3d, Larson and Heeger (2006) identified two hemifield maps (LO1/2). Hansen et al. (2007) dispute this topography, arguing that human V4, like macaque, is split into two subregions bordering V3v and V3d. We used new, model-based methods (Dumoulin & Wandell, 2007) to characterize human visual maps, population receptive field size and visual field coverage anterior to V3.

Methods: Functional magnetic resonance images were acquired while subjects viewed drifting checkerboards through a slowing moving bar aperture (field of view: 3º or 14º radius; separate experiments). A 2D Gaussian population receptive field (pRF) was fit to each voxel that best predicted the time-series.

Results: All subjects showed an orderly map anterior to V3v. The map was bounded by a lower field polar angle reversal (bordering V3v) and an upper field reversal (anterior/lateral edge). The map extended ventrally to the VO maps (Brewer et al, 2005). pRF-size increased systematically with eccentricity, from $\sigma = 0.9^{o}$ to 1.8º, 0.25 - 2.75º eccentricity (3º stimuli). Visual field coverage, estimated by the overlap of pRFs, varied between subjects and hemispheres, from a little over a quarterfield to a full hemifield.

Discussion: The field map adjacent to V3v appears to represent all of the contralateral hemifield in some hemispheres, but is incomplete in other cases. Further analyses will consider instrumental and biological contributions to variability, and will examine maps anterior to V3d. By estimating pRF size and visual field coverage, any possible gap in the map coverage can be quantitatively constrained.

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63.309

Functional organization of the primary visual cortex (areas 17 and 18) of the tree shrew revealed by optical brain imaging

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The tree shrew is the closest relative to primates and is considered as an excellent model for investigating the structure-function of the visual system. In recent years, optical brain imaging studies have revealed the presence of a clear modular organization for orientation in area 17, as well as a structured visuotopic map. To date, there is no evidence of the functional organization of areas beyond area 17. The aim of this study was to further document the organization of area 17 and uncover that of the neighboring area 18 by recording intrinsic optical signals in anesthetized animals. The visual cortex was exposed and illuminated at a wavelength of 700nm. Functional maps were recorded either through episodic or periodic paradigms. Drifting sine-wave gratings of varying orientations were presented to acquire orientation and direction maps. Bright bars (100% C) drifting periodically along vertical or horizontal axes were used to uncover the visuotopic organization. Robust orientation selectivity maps were obtained in area 17 with both paradigms. The spatial period of orientation modules was ~600 microns, a value inferior to that reported in cats and ferrets. Direction modules were sometimes observed but with a low selectivity. High definition visuotopic maps along azimuth and elevation were obtained with the periodic paradigm. The area activated was greater than that observed for orientation as a second cortical zone (2-3mm in width), lateral to area 17, was visible. This zone exhibited a mirror representation of that in area 17 along the azimuth and corresponded to the anatomically-defined area 18 (revealed by Nissl staining). No orientation and directions maps were observed. These results indicate that optical imaging can be used to visualize area 18 and that this area does not exhibit a modular organization such as the one described in area 17. Supp. by NEI grant R01EY016155.

63.310

The organization of inter-hemispheric projections from areas 17 and 18 in the human splenium, studied with DTI probabilistic fiber tracking

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Animal tracer studies show a clear pattern of organization of intercortical callosal connections between early visual areas of the left and right hemisphere. To investigate if a similar organization is evident for human occipital cortex we performed diffusion tensor imaging with probabilistic fiber tracking in 10 healthy volunteers.

Areas 17 and 18 were defined in two different ways, using high-resolution structural T1-weighted MRI scans: (1) anatomically through defined masks of upper and lower early visual cortex around the calcarine fissure, and (2) through masks of areas 17 and 18 from histological probability maps. Diffusion-tensor imaging data were analyzed by probabilistic tracking methods in FSL.

Our results first confirm through cortical-connectivity-based hard segmentation of the entire corpus callosum that connections between areas 17 and 18 of both hemispheres are confined to the lower part of the splenium. Second, there is an orderly representation of the callosal projections of the upper and lower hemifields of both areas 17 and 18 in the splenium. This mirrors the anatomic relations of these regions in the occipital lobe: fibers from dorsal area 18, inferior bank of area 17, superior bank of area 17, and ventral area 18 are layered from antero-dorsal to postero-ventral. We conclude that the quadrantic organization of areas 17 and 18 is preserved in their callosal projections through the splenium.

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63.311

Multivoxel fMRI analysis reveals the representation of spatial frequency information in human primary visual cortex

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Previous research in macaque and cat primary visual cortex revealed columnar organisation of spatial frequency representations [1]. However, previous results from functional magnetic resonance imaging (fMRI) in humans failed to produce evidence for selectivity of spatial frequency in human primary visual cortex [2].

Here, we measured BOLD contrast activity in human primary cortex with high spatial resolution (1.5mm voxels) fMRI during a simple dimming task at fixation, simultaneously presenting humans with a grating with one of two spatial frequencies in the periphery. The spatial frequency of the peripheral grating was either low (1.5 cycles/ degree) or high (4.5c/d). Replicating previous results [2], univariate analysis did not reveal any significant differences between the conditions. However, multivariate pattern decoding (MVPD) from voxels in early visual area V1 reliably distinguished high from low spatial frequency gratings. These results demonstrate that spatial frequency information is represented in the pattern of V1 BOLD responses and MVPD techniques are able to probe this representation. Therefore it extends the reliabily and suitability of the MVPD approach as complementary to univariate fMRI analysis.

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63.312

Receptive field properties of V1 neurons coding for luminance histogram skew

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Previously we presented results of systematic measurements of neural activity in early visual cortex in response to stimuli with skewed luminance histogram. We found that V1 responses to noise images with positively and negatively skewed luminance histogram were significantly larger than responses to images with zero luminance histogram skew. Moreover BOLD response to images with negative contrast was larger than the response to those with positive luminance histogram contrast. In the current study we investigate the receptive field properties of skew sensitive V1 neurons further. Stimuli were arrays of randomly oriented 2 cpd Gabor elements. While keeping mean and standard deviation constant, images' luminance histograms had either positive, negative, or zero skew. Images were vignetted by a circular aperture (r=6.35 deg visual angle) and presented dynamically at either a rate of 10Hz or at rate of 4Hz in a 50% duty cycle (alternating blank and stimulus) in blocks of 18s. In each block only one type of luminance histogram skewness was used. Blocks of stimuli were interleaved with 'blanks', which consisted of 18s presentation of a static image with

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uniform mean luminance. The order of presentation during each scan (TR=2s) was randomized. Each stimulus block was repeated twice during each scan, and there were a total of six scans per session. Observers 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. We find that with these new stimuli the previously observed preferential activity in V1 to negative skew diminished dramatically. Furthermore, our results show a stronger V1 BOLD response to negative skew noise images than to Gabors. However, we do not find such a difference between stimulus type (Gabor vs noise) for positive or zero skew stimuli.

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63.313

Processing animacy in the posterior superior temporal sulcus

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Heider and Simmel (1944) have shown that the motion of geometric shapes can be perceived as animate and goal-directed behavior. Neuroimaging studies have shown that viewing such displays evokes strong activation in temporoparietal cortex, including areas in and near the posterior superior temporal sulcus (pSTS). These brain regions are sensitive to socially relevant information, and have been implicated in the perception of biological motion and in'theory of mind' processing. Further investigation of the function(s) of pSTS, however, have been limited by the complex constructions of previous animate displays that make it difficult to determine which low level visual cues trigger the perception of animacy. Also, these displays elicit uncontrolled shifts of attention, making it hard to distinguish the cues influencing perceived animacy from spatial attentional shifting. In the current fMRI study, both of these issues were addressed. Subjects viewed a display containing four moving darts (or arrowheads). Subjects were required to track all four darts continuously and to covertly count how many dot probes briefly flashed upon them. On different trials, the perceived animacy of the darts was manipulated by varying whether the darts moved along their long axis (facing ahead) or orthogonal to their long axis (sideways). We also manipulated whether one dart (the 'wolf') chased another dart (the 'sheep'). Prior behavior results have shown that both the 'facing ahead' and 'chasing' cues trigger the perception of animacy; however, here both of these animacy manipulations were irrelevant to the dot-probe detection task. Behavioral results revealed no difference in probe detection between conditions, indicating that attention was well controlled. Activation of the pSTS was greater for animate than inanimate displays – suggesting that animacy detection was automatically triggered by these low level cues.

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Face Perception: Experience, Learning and Expertise

Wednesday, May 13, 8:30 am – 12:30 pm
Poster Session, Royal Palm Ballroom 6-8

63.314

Perceptual expertise has an emotional side: Holistic face processing is modulated by observers' emotional state

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Faces are typically processed holistically, in that features and their relations are integrated into a perceptual unit rather than being processed independently. However, in certain cases – such as for other-race faces – holistic processing is diminished (Tanaka, Kiefer, & Bukach, 2004). Notably, positive emotional states have been shown to improve recognition performance for other-race faces (Johnson & Fredrickson, 2005), raising the possibility that such effects are driven by an increase in holistic processing. In the current experiment, we directly tested whether an observer's emotional state impacts holistic processing. Participants were randomly assigned to an emotion induction condition, in which a positive, negative, or neutral emotional state was elicited through the viewing of a short film clip (e.g., from a comedy routine, horror movie, or instructional video). The degree to which faces were processed holistically was assessed both before and after the emotion induction, using a composite task that required participants to make same/different judgments about a cued part (either the top or bottom) of sequentially presented chimeric faces. This task indexes holistic processing by measuring the degree to which performance is impacted by the task-irrelevant face halves. Results revealed that holistic processing was significantly modulated by induced emotional state: participants in the negative emotion condition exhibited decreased holistic processing, whereas participants in the positive emotion condition exhibited an increase. A manipulation check confirmed that participants in the positive and negative emotion induction conditions reported mood changes in the expected directions. These findings suggest that an observer's emotional state can affect the degree to which stimuli are processed holistically. Furthermore, given that a shift to a more holistic processing strategy has been linked with the development of perceptual expertise, these results raise the possibility that the positive emotions typically associated with objects of expertise contribute to this change in processing strategy.

63.315

Expertise CAN explain why face perception is sensitive to spatial frequency content!

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Biederman & Kalocsai (1997) reported that sequential matching of faces, but not that of objects, suffers when the images to be matched are complementary, i.e. filtered so each contains every other combination of spatial frequency and orientation. They argued that faces are special in their reliance on spatial information. Last year, we reported that this complementation effect (CE) is not unique to faces and can be observed for objects such as chairs and cars, as well as upside down faces (Williams & Gauthier, VSS 2008). We also investigated the role of expertise in determining the magnitude of the CE. As in prior work, we measured car expertise by comparing performance on car matching to a baseline of bird matching, and observed no effect of expertise in two experiments. Here, we report new analyses of this dataset whereby we identify a possible source of heterogeneity in our sample. Participants showing high performance on bird matching (despite not being bird watchers) may differ from both typical novices and experts by adopting a perceptual strategy that leads to good performance for any subordinate-level discrimination, regardless of experience. Once such participants were excluded (~23%), the magnitude of the CE for cars was predicted by perceptual expertise in the car domain, across two experiments. This relationship depended on discarding participants with high bird matching scores regardless of whether we used car matching or car-minus-bird matching to define expertise. This suggests that the excluded participants cannot easily be classified as typical car novices or car experts using our measure of expertise. Importantly, sensitivity to changes in spatial frequency is influenced by experience and the particularly large CE observed for upright faces may be explained by our expertise in this domain. In addition, characterizing expertise in a domain could be facilitated by measuring performance for several categories.

63.316

Hitting your peak at age 30: behavioral evidence for extended development of face learning ability

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Face recognition is important over the entire life span, from early infancy to old age. There is an implicit assumption in the literature, however, that perceptual abilities reach their peak at or before the end of adolescence. We investigated face recognition development using a variant of the Cambridge Face Memory Test (CFMT), where subjects are provided with easy practice trials to learn six new faces followed by more stringent tests of recognition under conditions of varied lighting, pose and image degradation (Duchaine and Nakayama, 2006). From the results of 47,000 volunteer subjects on the web, we traced performance, year by year, from early adolescence through middle age. Performance rises steeply post-puberty reaching peak just after age 30. After that, it gradually falls such that performance at age 65 is comparable to performance at age 16. In a second experiment, we administered tests of old/new face recognition and recognition of unfamiliar names. We found the same late performance peak for faces, whereas performance on the names test peaked early (around age 20). In a third and final experiment, we tested whether the late face recognition performance peak (1) is specific to recognition of upright faces and (2) can be explained by a peer-recognition advantage, using tests of upright adult's faces, upright children's faces, and inverted children's faces. A similar late performance peak was found for upright adult's faces and upright children's faces, with an earlier peak (early 20s) for performance on inverted children's faces. Our data provide the first behavioral evidence for late maturation of face processing. This is consistent with recent studies showing slower maturation of face specific areas in the brain (e.g. Golarai et al., 2007). It remains to be determined what causes this late peak and how specific it is to visual recognition of faces.

URL: http://www.testmybrain.org

63.317

Does your height affect the way you represent faces?

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"Embodied Cognition" implies that our own bodies, the way we act with our bodies, and the way our bodies "fit" into the environment, should all have important implications for our mental representation of the world. In the current work, was asked whether height, with respect to other people, would have any influence on face perception. When we stand next to someone who is taller than us, our view of the face of this person is quite different from when we look at someone who is shorter. Could experience, based on our own height, affect the way we represent faces? More specifically, might people who are above average height (Group 1: male observers > 190 cm) be more efficient at processing faces seen from above? Conversely, might people who are below average height (Group 2: female observers <160 cm) be more efficient with faces seen from below? These predictions were tested in two experiments. First, we asked whether efficiency in a speeded sex classification task would be influenced by target face orientation (pitch). In a second experiment, participants were first familiarized with two target faces before performing a speeded visual search task. During familiarization, participants could inspect the faces from any viewpoint. During search, the pitch was identical for all faces, but varied from trial to trial. No clear group differences emerged in either experiment. Thus, at least with the current methods, we could find no evidence that idiosyncratic viewing history, as a result of an individual's height, affects the perception of faces.

63.318

Genetic and environmental contributions to memory for faces: a twin study

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Severe deficits in face recognition, or prosopagnosia, cluster in some families. However, the degree of family resemblance (familiality) for face memory ability in the general population is unknown. Moreover, familiality can result from either genetic or environmental factors shared between family members. We conducted a classical twin study in an unselected population to quantify family resemblance in face memory ability and to parse this resemblance into genetic and environmental components. We measured face memory with the Cambridge Face Memory Test (CFMT), a highly reliable measure (Spearman-Brown corrected split-half reliability=.82) that correlates little with other memory tests or tests of general intelligence. We observed a high correlation in performance among monozygotic (MZ) twins, implying high familiality of face memory (intraclass r(69)=.75, 95% CI=.63-.84); since MZ twins share both genes and environment, the MZ twin correlation indicates total family resemblance. This MZ correlation approaches the ceiling set by the CFMT's measurement reliability, suggesting that most of the reliable variation in CFMT performance is familial. Since both MZ and dizygotic (DZ) twins share family environment, but MZ twins share twice as many genes as DZ twins (100% vs. 50%), any greater correlation in MZ than DZ twins supports an effect of genes. The DZ correlation we observed (intraclass r(21)=.52, 95% CI=.14-.77) was significantly lower than the MZ correlation (p=.05, one-tailed), evidence that genetic factors cause some differences in face memory ability. In sum, our results provide evidence that face memory ability is highly familial and at least partially genetic.

63.319

Differential Sociocultural Experience Moderates Latency of Facial Age Judgments

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Previous studies show that differential sociocultural experiences shape ones visual perception of the world (Miyamoto, Nisbett, & Masuda, 2006; Nisbett & Miyamoto, 2005). In the present study, we investigated whether adults' visual processing of facial age is also influenced by differential sociocultural experience.

The Japanese culture cultivates respect towards older individuals at a behavioral (e.g., bowing) and linguistic (e.g., using titles such as san) level. The Chinese culture cultivates respect towards the elderly only at the behavioral level. In contrast, no behavioral or linguistic markers for such respect exist in North America.

We tested adults in Japan, China, and Canada (i.e., Asian-Canadians and Caucasians). Participants completed a computerized relative age judgment task, during which they saw 840 trials each showing a pair of Asian faces. Participants were asked to decide which face in each pair was older via a key press. Participants then completed an absolute age judgment task, during which they were shown a sequential presentation of Asian faces and asked to record how old each face looked in years.

We found no group differences in accuracy on the relative and absolute age judgment tasks. However, reaction times on correct trials in the relative age judgment task revealed group differences. Japanese participants were the fastest, followed by the Chinese, then the Asian-Canadians, then the Caucasians. These results are consistent with cross-cultural differences in socialization. Relative to Asian-Americans and Caucasians, Asians living in Asia – especially the Japanese – experience a greater need to make quick age judgments for individuals they encounter so that they can show proper respect. In addition, Asian-Canadians' faster response times relative to Caucasians' response times is likely due to their greater experience with own-race Asian faces. Thus, we provide the first evidence to date that differential sociocultural experience influences our visual processing of facial age.

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Face Recognition Subserves Nature not Nurture

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Eye movement strategies employed by humans to identify conspecifics are not universal. Westerners predominantly fixate the eye region during face recognition, whereas Easterners consistently focus more on the nose, yet recognition accuracy is comparable (Blais et al., 2008). However, the face literature has robustly shown that the critical information for face recognition is located in the eyes and partially the mouth, but not the nose. Moreover, since eye movements in natural viewing conditions do not provide unequivocal evidence on the measure of the visual information being used by observers, the question of whether humans universally use similar facial information to recognize faces remains unresolved.

To address this issue, we monitored eye movements during face recognition of thirty Western Caucasian (WC) and thirty East Asian (EA) observers with a novel technique that parametrically restricts information outside central vision. We used 'Spotlights' with Gaussian apertures of 2°, 5° or 8° dynamically centered on observers' fixations. Face recognition performance improved with increasing Spotlight apertures. Regardless of culture, observers actively fixated the eyes and mouth with constrained Spotlights (2°, 5°). In the 8° condition, information from both eyes and mouth was simultaneously available when fixating the nose and, as expected, only EA observers shifted their fixations towards this region. This central location is optimal to integrate information globally, a cultural marker of Easterners' perceptual strategies. WC observers engage in analytic strategies and their facial feature-by-feature strategy was not affected by Spotlight apertures.

Social experience and cultural factors shape the way humans think about the world and regulate the strategies used to extract information from faces. However, these external forces do not modulate the information used to solve this critical biological feat. Human beings rely on identical facial information to recognize conspecifics, a universal law dictated by the evolutionary constraints of nature and not nurture.

63.321

The Information subtending the other-race effect

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Same-race faces are easier to remember than other-race faces, a phenomenon known in the literature as the ''other-race effect''. We investigated whether Caucasian participants use the same visual information when processing Caucasian and African-American faces using Bubbles (Gosselin & Schyns, 2001). We asked five participants to learn face-name associations for ten Caucasian and ten African-American males. Participants were then instructed to decide if a partly sampled (using Bubbles) face was part of the learned set (Caucasian and African-American faces tested in separate blocks). Multiple linear regressions between information samples and accuracy were performed for each race. For African-American faces, observers used mainly the nose in the spatial frequencies (SF) between 10- 82 cycles per face width (cpf), the left eye in the highest SF band (between 41-82 cpf), and the region comprising the eyes and the nose in the second coarsest SF band (between 5-10 cpf). For Caucasian faces, observers employed the eyes in the SF between 10-82 cpf and the mouth in 5-41 cpf SF band. We argue that this difference in the information used to recognize Caucasian and African-American faces is the basis for the other-race effect observed in Caucasian observers.

63.322

Inverting Faces Elicits Sensitivity to Race on the N170 Component: a Cross-Cultural Study

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Human beings are experts at processing faces, with a striking impairment for other-race (OR) faces, the so-called other-race effect (ORE). Despite the robustness of the ORE at the behavioural level, Event Related Potential (ERP) studies have failed to consistently show sensitivity to race for the early category-specific N170 component. The observed discrepancy between electrophysiological findings is currently unresolved. Such inconsistency could be related to the heterogeneity of the task constraints, as well as to the lack of control for evident differences in low-level properties across races. In addition, most of these studies have only adopted one group of observers (usually, Western Caucasians). These limitations question whether previous findings can be generalized to the entire population and leave debate on the sensitivity of the N170 to race wide open. Surprisingly, no ERP studies have attempted to investigate the ORE with a well established marker of visual expertise, such as the Face Inversion Effect (FIE).

Here we exploited the FIE to investigate whether the N170 is sensitive to race. We recorded electrophysiological signals of 15 Western Caucasian and 15 East Asian observers while presented with Western Caucasian, East Asian and African American faces in two orientations (i.e., upright and inverted). To control for potential confounds in the ERP signal relating to differences in low-level properties across the race of the faces, we normalized amplitude-spectra and contrast across all images. Given the heterogeneous nature of the distributions, statistical analyses were performed using both classic statistical tests and robust approaches (i.e., percentile bootstrap). No differences on the N170 were observed in the upright conditions. Critically, inverting faces elicited larger amplitudes on the visual category of greater expertise (i.e., SR faces). These observations indicate a finer-grained neural tuning for SR faces at early stages of face processing.

63.323

Dissociating contributions of configural and component information to the own-race advantage in face recognition

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Across many different races, people are better at recognizing own-race faces than faces from other races. Recently, we (Hayward, et al., 2008) reported that, following study of whole faces, performance in an old-new memory task for scrambled (to isolate component processing) and blurred (to isolate configural processing) faces showed an own-race advantage (ORA) in both conditions. In addition, memory for blurred faces was better than for scrambled faces, supporting the importance of configural processing in judgments of facial identity. Here, we present further investigation of these effects. In Experiment 1 we replicated our earlier experiment but inverted the stimuli; participants saw inverted normal faces at study and inverted blurred or scrambled faces at test; this manipulation eliminated the difference between blurred and scrambled faces, consistent with the assumption that face inversion differentially impairs configural processing. However, across both conditions, an own-race advantage was still observed. In Experiment 2, we wanted to test memory performance when participants encoded only one type of information; participants studied upright scrambled or blurred faces, and then were tested with the same type of image, or with normal faces. Study of blurred faces led to a small ORA for blurred and normal test images, but study of scrambled faces led to an own-race disadvantage, where old-new discrimination was better for other-race scrambled and normal faces than for own-race images. Taken together, these results suggest a dissociation in processing of configural and component face information in the ORA; configural information leads to an own-race advantage regardless of study conditions, but the component ORA appears to require encoding of the whole face, upright or inverted. Intriguingly, the lack of whole face information may impair the encoding of face components from own-race faces, as compared with other-race faces.

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63.324

Holistic gender perception for both own-race and other-race faces

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It has been well documented that faces are processed holistically; nonetheless, this conclusion is primarily based on studies of facial identity processing. Whether or not identity-independent aspects of face processing (e.g., gender perception) show similar holistic effects has not been clearly established. Here we tested the role of holistic processing in the perception of face gender by selectively disrupting holistic face processing in a number of ways. First, we found that gender judgments for both own- and other-race faces were dramatically decreased when faces were inverted. Furthermore, the decrement did not result from a difficulty in processing inverted face features, because scrambling a face into parts, which left upright feature processing unaffected, produced a similar disruption in gender perception to inversion. More importantly, gender perception also showed the face composite effect. Judging the gender of the top half of a face was more severely disrupted when it was fused together with a bottom half face of a different gender than when not, demonstrating further evidence for holistic gender processing. Finally, gender perception was more severely affected by scrambling of a face, which selectively disrupted the processing of holistic face information, than by blurring a face, which selectively disrupted the processing of featural information, suggesting that gender perception relies more on holistic than part-based face processing. Expertise with faces of one's own race, in contrast to its role in identity processing, affected neither the overall performance nor the holistic processing effect on gender perception. All these findings indicate that the processing of face gender is holistic in nature, and is similar for both own-race and other-race faces.

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63.325

Forgetting faces in a crowd: Faster memory decay for other-race faces?

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Adults recognize own-race faces more accurately than other-race faces, a pattern called the other-race effect. We previously reported that Caucasian adults were more sensitive to differences among faces in both feature shape (e.g., eyes) and feature spacing (e.g., the distance between the eyes) for Caucasian faces than for Chinese faces. However these effects were surprisingly small (M difference = 5.6% and 9.9%) given the difficulty adults experience in recognizing other-race faces on a daily basis. Here we tested whether storage is better for own-race than other-race faces by varying the delay (1s, 5s, or 10s) in a delayed match-to-sample task. In Study 1 (n=24) we used featural and spatial manipulations of a single identity per race and a blank screen was presented during the delay. There was an effect of delay for both face sets, ps <.01, but no face race x delay interaction, ps > .5. To more closely mimic the real world, in Study 2 (n=24) we presented altered versions of two identities per race and a screen comprised of multiple Chinese and Caucasian faces was presented during the delay. The effect of delay and the face race x delay interaction were significant only for the spacing set, ps <.02. The drop in accuracy in the 10s-delay condition relative to the 1s-delay condition was larger for other-race (12%) than for own-race faces (6%). Collectively, these results suggest that the own-race advantage for feature shape occurs at the encoding stage, whereas the own-race advantage for the spacing set may occur at both encoding and storage (see Freire et al., 2000 for similar analyses of the inversion effect). The own-race advantage may be small in lab studies because cues that adults might normally rely on when encoding other-race faces (e.g., hair, clothing) are removed.

Attention: Resource Competition

Wednesday, May 13, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

63.401

More Wheels Makes Attention Spin Slower

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Observers viewing a periodic motion stimulus frequently experience illusory reversals of the direction of motion despite continuous lighting conditions (the continuous wagon-wheel illusion or c-WWI). This illusion is maximal at temporal frequencies around 10 Hz, and is limited to the object of attention. It has been proposed, therefore, that this phenomenon reflects periodic sampling of motion information by attentional processes. What is not known, however, is how such periodic sampling behaves when multiple objects are attended simultaneously. In order to address this question, we presented participants with 40 s sequences of rotating gratings during which several actual motion direction reversals occurred, and asked them to report the number of reversals in each sequence. Both the number of gratings (set sizes 1 to 4), and the temporal frequency at which they rotated, were varied from trial to trial. We considered overestimations of the number of reversals as manifestations of the c-WWI, and fitted the temporal frequency tuning of the illusion for each set size with a Gaussian function. Preferred frequency decreased consistently with increasing set size, from approximately 10 Hz for set size one to about half that for set size four. The fact that preferred frequency (which we take to reflect the rate at which attention samples each individual stimulus) decreases when attention is divided constrains the underlying mechanisms of attentional deployment. Neither a simple parallel model, whereby sampling rate would be independent of set size, nor a strictly serial model, whereby sampling rate would be inversely proportional to set size, can account for this finding. An imperfect serial strategy, in which a variable number of samples are taken from each successively attended stimulus, could be one of several alternative models.

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63.402

Between-Object Superiority in Divided Attention

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Is spatial attention directed to locations in space, or to objects? Evidence for "object-based attention" is that two features of the same object are often processed more efficiently than two features of two different objects. However, experiments in which subjects judge object features as "same" or "different" often find the opposite result (Davis & Holmes, 2005; Neill et al., 2008 VSS), i.e., "between-object superiority" (BOS). Over multiple experiments, we find robust BOS when target features are square or triangular notches in the object outlines, weaker effects when the target features are square or triangular shapes within the objects, and no effects when target features are letters within the objects. These results obtain even when types of target feature are randomly intermixed over trials. The results suggest that BOS depends on the degree to which target features are perceived as "parts" of the objects rather than as additional objects superimposed on the larger objects. But why does BOS occur at all, when other procedures typically yield within-object superiority? We consider three theoretical explanations: (1) parts of the same object compete for attentional capacity allocated to that object; (2) two parts of the same object cause the entire object to be represented in working memory; (3) target features on different objects permit wholistic comparison of the two objects.

63.403

Dividing Attention between Two Simultaneous Visual Tasks: the Magnocellular System

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Attending to two simultaneous visual tasks results in varying degrees of interference. One model posits that the detection of parvocellular and magnocellular stimuli may require different amounts of attentional resources (Bonnel et al., 1992). Previous research (Maeda & Nagy, 2008) showed that simultaneously searching for two transient targets, coded by the magnocellular pathway, resulted in very little dual-task interference. However, though attention modulates motion cells in V1 (Watanabe et al, 1998) and MT/MST (Treue & Maunsell, 1999), mechanisms tuned to temporal frequency are partially separable from those tuned to velocity (e.g. Smith & Edgar, 1999). Thus we investigated the effect of dividing attention using both motion and transient stimuli to examine whether both types of magnocellular tasks would result in very little dual-task interference. In one experiment, observers simultaneously searched for a luminance transient target in each of two spatially separated, briefly presented arrays of stimuli. Luminance transients that resulted in 75% correct performance for each array in single-task conditions were then used in the dual-task conditions. In a second experiment, observers judged the direction of two simultaneously presented trajectories, one to the left and one to the right side of fixation, embedded in the random motion noise. Target trajectories appeared in one of 8 directions at 45-degree intervals. The number of noise dots that yielded approximately 75 % correct identification accuracy in single-task conditions was used in the dual-task conditions. Preliminary data show that two motion identification tasks result in more dual-task interference than two transient search tasks. The results will be discussed further in terms of a multiple resource model (Navon & Gopher, 1979), a shared resource sampling model (Miller & Bonnel, 1992), and a switching competition model (Duncan, 1980) of divided attention.

63.404

Dividing Attention between Two Simultaneous Visual Tasks I: the Parvocellular System & the Koniocellular System

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Previous research has shown that attending to two simultaneous visual tasks results in varying degrees of interference depending on the nature of the two tasks. One model postulates that different feature-coding mechanisms are equipped with independent finite pools of attentional resources (Morrone, Denti, & Spinelli, 2004). The present study extends our previous research (Maeda & Nagy, 2008 VSS) and tests the hypothesis that the parvocellular and the koniocellular pathways in the lateral geniculate nucleus tap independent pools of attentional resources. Observers searched simultaneously for a target in each of two spatially separated arrays of stimuli that were presented briefly. Targets that resulted in 75% correct performance for each array in single-task conditions were then used in the dual-task conditions. Based on the independent resource pool hypothesis, we predicted that searching for two targets that are coded by the feature-coding mechanisms within one pathway (within-pathway condition) would lead to more dual-task interference than searching for two targets that are coded by feature-coding mechanisms in two different pathways (between-pathway condition). Results yielded varying degrees of dual-task interference depending on the task combinations (i.e. within- or between pathways, target-distractor relationship and target appearance). Between-pathways task pairs generally resulted in very little interference (88% of single-task performance). Some within-pathway task pairs also resulted in very little dual-task interference (92 % of single-task performance), while other within-pathway task pairs produced substantial interference (69 % of single-task performance). Overall, results generally did not support the independent resource pool hypothesis. Results will be discussed further in terms of a multiple-resource model (Navon & Gopher, 1979), a shared resource sampling model (Miller & Bonnel, 1992), and a switching competition model (Duncan, 1980) of divided attention.

63.405

Bilateral Attentional Advantage in Gabor Detection

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Introduction: In principle, visual performance could be uniform within (unilateral) and across (bilateral) the left and right hemifields. However, previous research has revealed bilateral advantages on relatively high level visual tasks, such as letter identification (Awh & Pashler, 2000; Chakravarthi & Cavanagh, 2006), and motion tracking (Alvarez & Cavanaugh, 2005). Last year we reported that this bilateral advantage extends even to the elementary task of detecting Gabor targets among Gabor distracters (Matthews, 2008). Here we investigated whether this bilateral superiority reflects attention or surround suppression.

Method: Thirteen Denison University undergraduates completed a 2x2x3 within-subject experiment. The independent variables were laterality (bilateral versus unilateral), Gabor distracter (present versus absent), and foveal letter duration (67, 117, or 167 msec). Each trial began with a pair of bilateral or unilateral cues indicating the peripheral positions (14.55 deg diagonally from fixation) at which a Gabor target (183 msec) would appear, if present. Half the trials contained Gabor distracters horizontally or vertically displaced (by 7.1 deg) from the cued target positions. After correctly identifying a foveally flashed letter, participants judged whether a Gabor target had been present or absent at either cued peripheral position.

Results: Peripheral Gabor detection (d') increased with foveal letter duration. At the briefest letter duration, false alarm rates were significantly higher unilaterally than bilaterally. This difference was more pronounced when distracters were present, and declined as foveal letter-duration increased. By contrast, bilateral and unilateral hit rates were statistically indistinguishable from each other across duration-by-distracter pairings.

Discussion: The data indicate that a neural resource shared by the fovea and the periphery constrained performance. Relative to the bilateral response, the unilateral response exhibited a failure to exclude distracters –not a failure to detect contrast. This pattern implicates bilateral superiority in attention, even on this most elementary visual task.

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63.406

Enumerating visual items within and across hemifields

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Previous studies point to the existence of two qualitatively different enumeration processes in vision: a fast and efficient process specialized for small numbers of items (<4 items) known as subitizing, and a slow and less accurate process for large number of items (> 4 items), counting. Enumerating visual items requires the integration of the items into a single quantity. Previous findings have suggested temporal and qualitative differences between the integration of visual information within and across the hemifields, with within-hemifield integration preceding (Large & al., 2008) or at least being more efficient (Pillow & Rubin, 2002; Humphreys & al., 2000) than across-hemifield integration. Accordingly, one might expect enumeration to be more efficient when the items are presented in one hemifield only. Against this, the present study reveals that enumerating is more accurate when the visual items are split between the left and right visual fields than when they are all presented within the same hemifield. This finding is consistent with the notion of independent resources in the left and right hemispheres (Luck & al., 1989) and with recent data that have shown that parallel processing by the two hemispheres can expand the capacity of visual processing (Alvarez & Cavanagh, 2005; Delvenne, 2005; Scalf & al., 2007).

63.408

Vision and audition do not share attentional resources in sustained tasks

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Our perceptual capacities are limited by attentional resources. One important question is whether these resources are allocated separately to each sense or shared between them. We addressed this issue by asking subjects to perform a double task, either in the same modality or in different modalities (vision and audition). The primary task was a motion object-tracking task (Pylyshyn & Storm, 1988), in which observers were required to track between 2-5 dots for 4 seconds. Concurrently, they were required to identify either which out of three gratings spaced over the interval differed in contrast or, in the auditory version of the same task, which tone differed in frequency relative to the two reference tones. The results show that while the concurrent visual contrast discrimination reduced tracking ability by about (1.5 d'), the concurrent auditory task had virtually no effect. This confirms previous reports that vision and audition use separate attentional resources, consistent with fMRI findings of attentional effects as early as V1 and A1. The results have clear implications for effective design of instrumentation and forms of audio-visual communication devices.

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63.409

Decision-relevant Contextual Constraints on Human Decision Behavior

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How do concurrent decisions interact with each other? Gorea and Sagi (PNAS, 1999; Nature Neuroscience, 2001) found observers adopted identical false alarm rates during concurrent contrast detection or discrimination tasks with different contrast increments applied to baseline stimuli in two spatial locations. They concluded that subjects used the same contrast criteria, c1=c2 in two concurrent tasks with different contrast increments. Kontsevich et al (Nature Neuroscience, 2002) pointed out that the observation of same false alarm rates only shows $c_1\sigma_2=c_2\sigma_1$, where σ_1 and σ_2, expressed in contrast units, are the (unknown) standard deviations of the noise distributions for the two contrast increment conditions. In this study, we investigated these two theoretical positions by explicitly manipulating signal and external noise characteristics in a dual contrast detection task. Observers monitored a screen while stimuli for two independent signal detection tasks appeared concurrently to the left and right of fixation. A simultaneous arrow at central fixation cued observers to provide a confidence rating for one of these targets. Holding the characteristics of the signal and noise in one component task constant, we studied three experimental conditions in which the other target stimulus had greater signal contrast, greater noise contrast, or both relative to the first target. We also looked at control conditions in which stimulus characteristics were identical for the two targets. Consistent with Gorea and Sagi, we found that the false alarm rates across all the confidence levels were virtually identical for the two concurrent tasks in all the experimental conditions. We concluded that a unique criterion constraint holds true for multiple criteria in the decision stage, where signal-to-noise ratios are extracted before criteria application, consistent with the contrast-gain control perceptual template model (Dao, Lu & Dosher, 2006).

63.410

The effects of fixation and passive attention on the object recognition

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This study investigates the effects of fixation and passive attention on object recognition task. It is known that attention and fixation play an important role for object recognition, but it is unclear yet that the interaction between fixation and passive attention. Attention can shift to another location independently without eye movement (Posner, 1980). We controlled the observers' fixation and passive attention to test the interaction on the recognition task. In the experiments, observers asked to gaze the one of two boxes indicated by the arrow on the display. In the course of fixation, one box color changed in order to capture passive attention. After the cue lead time, we presented an object in the one of two boxes followed by the mask. When a test stimulus was shown observers were required to report whether the test stimulus was the same object as presented before. There were four experimental conditions: (a) fixation/cue-valid, (b) fixation/cue-invalid, (c) no-fixation/cue-valid, (d) no-fixation/cue-invalid. Under the conditions of no-fixation (c, d) the performances dropped in comparison with the fixation conditions (a, b). However there are two different kinds of mis-judgements at incorrect responses. First, observers responded as "same" when the target and test stimulus were different. It means that the failure of the change detection occurs. Second, observers gave their responses as "different" when the same objects were presented, this suggests that human visual system could not occasionally integrate the representations of two objects.

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63.411

Effects of spatial attention on contrast sensitivity for motion discrimination revealed by center-periphery dual visual task paradigm

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It has been shown that spatial attention influences low-level visual performance such as contrast sensitivity. Recently we have shown that attentional influences on stereoacuity are much larger than that on sensitivity to detect luminance differences, suggesting that the magnitudes of attentional influences depend on the dimension of visual tasks. In the present study, we measured contrast sensitivity to discriminate motion direction to examine attentional influences on motion perception. A random dot pattern of 50% contrast subtending visual field of 29 deg was presented for 0.2 s while the observer fixated at the central fixation point. In a square-shaped target region, a sinusoidal grating modulated in luminance (the first-order motion) or contrast (the second-order motion) drifted horizontally. The observer's task was to indicate the direction of motion. We used the following four experimental conditions. The first two provided the baseline performance. In the center-only condition the target was of 1 deg size and presented at 2 deg eccentricity. The position of the target relative to the fixation point was either one of eight directions in 45 deg steps. In the periphery-only condition the size of the target was 2 deg and the eccentricity was 10 deg. In these conditions the spatial wavelength of the sinusoidal grating was the same as the width of the target and the temporal frequency was 5 Hz. In the center-priority condition the central and peripheral targets were presented simultaneously while the observer paid more attention to the central target. In the periphery-priority condition more attention was paid to the peripheral target. The results show that contrast thresholds for the dual-target conditions were not larger than those for the single-target conditions despite the previous studies showing threshold elevation accompanied by attentional load. It appears that motion signals from wide visual field are processed in parallel fashion.

63.412

Localized attentional interference reflects competition for reentrant processing

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Visual performance is compromised when attention is divided between objects that are near one another in the visual field. This effect, termed localized attentional interference (LAI), has been hypothesized to reflect competition between visual object representations for the control of cortical neural responses (McCarley, Mounts, & Kramer 2007). To determine whether LAI arises during the feedforward sweep or during reentrant processing, the present study examined the influence of poststimulus pattern and four-dot masks on the strength of the effect. Experiment 1 found that pattern masks, which are believed to compromise feedforward processing, do not produce stronger LAI than do four-dot masks, which are believed to leave feedforward processing undisrupted. Experiment 2 found that LAI is weaker when reentrant processing is interrupted shortly after initiation than when reentrant processing is allowed to run to completion. Results suggest that LAI emerges from competition between objects during reentrant processing.

63.413

Reporting two simultaneous targets: Competition, bias, and temporal displacement

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When monitoring two RSVP streams of letters for one or two targets indicated by one or two green annulus cues, is attention to two cues independent? Letter streams were presented above and below a fixation cross for 80ms/letter. On a given trial there was one cue, two simultaneous cues, or two cues presented sequentially at 80 ms SOA in the two streams. Trials were intermixed.

Single-cue trials showed bias toward the top stream, in report of the true target (the modal report) and in reports of letters in neighboring positions. The modal report of single bottom cues was the +1 letter (following the annulus). In the simultaneous condition reports from the top stream were highly similar to top stream reports with a single top cue. In contrast, report from the bottom stream was much worse in the simultaneous-cue than the single-cue case. Sequential trials showed that report from the first cued stream (top or bottom) was similar to a single cue condition, especially for the top stream, whereas there was an overall decrease in report of letters from the second cued stream, as well as a displacement towards the +1 letter.

The evidence suggests that attention was not evenly divided between the two streams but could be focused rapidly on one stream for single cues or first sequential cues. The probability of reporting cued letters from both streams (including letters in the neighborhood) was lower than predicted by multiplying the probabilities of getting top and bottom singletons, showing that processing of the two streams was not independent. Moreover, the reported letters showed more temporal displacement in the simultaneous condition than the single condition. We will report results of a second experiment in which the streams were placed to the left and right of fixation.

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63.414

Detecting the presence of a singleton does not require focal attention

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Feature Integration Theory (FIT, e.g., Treisman & Gelade, 1980) suggests that the presence of a feature singleton can be detected preattentively based on activity in a feature map. We first replicated a result of Theeuwes, Van der Burg, and Belopolsky (2008) which seems to refute this prediction of FIT. Subjects responded to the presence or absence of a single red letter in a circle of gray letters surrounding fixation. Subjects were faster to indicate the presence of a red letter when that letter's identity was repeated from the previous trial, even when spare attentional capacity was occupied by a demanding second task. There was no repetition priming when a gray letter was repeated. Assuming that the letter form of the color singleton could only be picked up by focal attention, these results suggest that focal attention was directed to the letter, even in a simple feature detection task. However, the use of letters may have biased the outcome. It has been suggested that in some circumstances alphanumeric characters may elicit "compulsive encoding" so it is possible that participants were involuntarily directing their attention to the red letter in order to read it even though the task simply required detection of a color (Teichner & Krebs, 1974; see also Stroop, 1935). In a subsequent experiment, we replaced the English characters with unfamiliar symbols (Chinese letters). This eliminated intertrial priming effects in both single and dual task conditions. Detection of the red letter remained highly accurate, as with the English characters. A control experiment confirmed that intertrial priming effects are possible in the same task with Chinese characters when attention was directed to them with a spatial precue. The results suggest that the detection of a feature singleton does not require the application of focal attention.

Eye Movements: Mechanisms

Wednesday, May 13, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

63.415

Functional MRI Analysis of Cortical Activation During Saccadic Adaptation

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Saccadic adaptation is a mechanism to preserve accuracy during changes in the oculomotor system. Adaptation occurs when a visual target is repeatedly displaced during a saccade, so that the original saccade either overshoots the target or falls short of it. Though many primate studies emphasize the role of the cerebellum in this process and a PET study revealed activation in cerebellar neurons (Desmurget et al. Nat Neurosc., 1998, 1, 524-8), the exact neuronal substrate of saccadic adaptation remains unclear. We investigated the neural correlates of inward and outward saccadic adaptation using a gaze-dependent visual display in fMRI. Subjects were asked to saccade from fixation to a target as quickly as possible. Saccadic gain adaptation was experimentally induced using the double step paradigm: During the adaptation phase, the target was displaced peri-saccadically by 30%. In control condition, however, the displacement was done post-saccadically, delayed by 300 ms related to saccade onset. The experiment comprised 480 trials in all, arranged in (a) pre-adaptation (control), (b) adaptation and (c) post-adaptation (control) phases. Functional MR images (Siemens 3T) and eye movements from 12 subjects were recorded simultaneously. Data was preprocessed and statistically analysed using SPM5. The SPMs which resulted from our random effects analysis were initially thresholded with p uncorrected<0.001. Clusters surpassing a threshold of p corrected<0.05 were considered as significantly activated. The eye movement data indicate a significant ($T = 2.57$; $p < 0.05$) decrease in gain (12 percent on average) during (b), which was accompanied by bilateral enhanced activity in the posterior parieto-insular cortex when compared with (a). This region is involved in processing of vestibular information in primates and part of a cortical network labelled parieto-insular vestibular cortex (PIVC; Eickhoff et al. Hum. Brain Mapp., 2006, 27, 611-21). The enhanced activation probably reflects an integration of information regarding head position and oculomotor information.

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63.416

Monkey and human performance in a chronostasis task suitable for neurophysiology

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Psychophysical studies suggest systematic changes in the perception of brief durations around the time of eye movements. Specifically, perceived time is elongated just after a saccade (i.e., "chronostasis"). Chronostasis has been demonstrated in a number of studies but little is known about the neural bases of this saccade-induced duration illusion. We trained a monkey to discriminate whether interstimulus intervals (ISIs) ranging from 50-250 milliseconds (ms) were shorter or longer than a learned reference duration of 150 ms. Stimuli consisted of two spatially-identical, successive flashes of light. The monkey first made a single saccade to a fixed target location. In most trials ("baseline"), the interval appeared 700 ms after saccade offset. The monkey then reported whether the ISI was shorter or longer than the reference duration by making an eye movement to one of two choice targets. To test for time illusions, in a small percentage of trials, stimuli were presented just after saccade offset (10-500 ms). The monkey's choices during these trials were compared to those in the baseline trials. As predicted, the monkey increasingly overestimated the duration of a given ISI as the postsaccadic presentation time decreased. Intervals presented just after saccade offset (10 ms) were perceived as lasting roughly twice as long as the same intervals presented during baseline conditions. We have begun investigating human duration discrimination using the same neurophysiologically-compatible paradigm, which will allow us to validate the apparent duration illusion seen by our monkey and make cross-species comparisons for follow-up studies. Given the integral role of the neural circuitry between the frontal eye field and superior colliculus in maintaining visuospatial stability (Sommer and Wurtz 2006), it is likely that neuronal activity in these structures also plays a critical role in maintaining visuo-temporal stability around the time of eye movements. Future work will directly test this hypothesis.

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63.417

Eye movements when viewing natural scenes with normal vision and simulated scotomas

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Purpose: Age-related macular degeneration (AMD) results in central retinal defects due to photoreceptor degeneration (dry AMD) or photoreceptor distortion by abnormal blood vessel growth (wet AMD). Individuals with AMD must compensate by making use of the unaffected peripheral vision. Consequently, this might lead to alternative eye movement (EM) strategies when performing visual search tasks, resulting in an increase in EM frequency. Methods: We recorded binocular EM (Eyelink 1000 tracker) while observers performed two natural tasks: visual search and free-viewing. Using the recorded eye position, images at the current fixation were either distorted (wet AMD), removed (dry AMD) or left intact (control, no AMD). Results: Under the simulated AMD conditions, fixation frequency and duration increased, and saccades were of greater amplitude. Behavioural results show that it took longer to find the target with simulated AMD conditions in comparison to the control condition. Type of AMD also has an effect on the EMs, with fixation duration being longer, and saccade amplitudes being smaller for wet AMD in comparison to dry AMD. In the free-viewing experiment, similar results were obtained. Conclusions: These results imply that while visual tasks can still be performed with central vision loss, they lead to impaired visual performance. In addition, different EM strategies between wet and dry AMD lead us to the conclusion that visual aids and training programs designed to incorporate remaining peripheral vision must take into consideration the cause of the scotoma.

63.418

Allocentric spatial information improves saccadic accuracy under task conditions that load spatial memory or limit saccade preparation time

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Many visual stimuli remain fixed spatially relative to the environment and/or to objects within it and the brain may exploit these regularities when localizing them. Recent work in our lab suggests the saccadic system can use distant stable landmarks and nearby shifting objects to guide saccades accurately to memorized locations (Mitchell & Edelman, SfN 2006). In this prior study saccades to environment-fixed targets were accurate regardless of landmark target distance. Saccades to targets fixed relative to a shifting object were inaccurate with only large objects. We hypothesized that using a long instructed delay (~750 ms) and requiring only 1 target location to be memorized freed up sufficient resources for distant stable or nearby shifting references to aid targeting. Increasing task demands by decreasing motor preparation time or increasing memory load would then make performance more dependent on distance from and size of the reference. We varied task demands and measured saccade error when saccades were directed to a memorized target visible only after the saccade; target location was environment-fixed or object-fixed across a trial block. Reference objects were circles of 3 sizes (radius = 3.25°, 6.5°, 13°). Task demands were increased by 1) requiring 3 targets fixed to the environment to be memorized (3-targ) or 2) using a reactive saccade task to a target fixed relative to a shifting reference object. Saccade endpoint error was substantially higher in the 3-targ task than in the 1-targ task when no reference objects were present and moderately higher when the largest (13°) reference object was present. As reference object size decreased performance improved, approaching that of visually-guided saccades. In the reactive task we found a similar dependence of endpoint error on reference object size. These results demonstrate the saccadic system can use allocentric references to improve saccadic targeting under increased task demands.

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63.419

Covert Orienting Reflex: Involuntary pupil response predicts microsaccade production

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Vision is suppressed during gaze shifts, and so visual perception is largely shaped during moments of fixation. However, if during fixation an unexpected event draws attention, miniature eye movements, known as microsaccades, are often produced (Hafed and Clark, 2002; Engbert and Kliegl, 2003). Microsaccades are known to play a role in enhancing perception (Martinez-Conde, et al., 2006), but the mechanism by which attention modulates the production of these movements is not known.

Here we report that when an unexpected peripheral stimulus is briefly flashed during fixation, the stimulus triggers a reflexive pupillary response that predicts the onset of microsaccades. In the case of a bright flash against a dark background, the pupil will constrict beginning ~180ms after the flash, coinciding with the time when microsaccade production is inhibited. The rate of pupil change peaks ~380 ms after stimulus onset, at a time that coincides with an observed overshoot in the microsaccade production rates. A pupillary response is also observed when the stimulus is purely auditory or visual equiluminant, but the dynamics of the response differs in these cases.

The pupil shares pre-motor circuitry with systems for vergence and accommodation (Mays and Gamlin, 1995). Therefore, the observed pupillary reflex may signpost a general release of tension in the extraocular muscles used to maintain fixation. If so, the observed overproduction of microsaccades following an exogenous stimulus may be the result of an orienting reflex (Sokolov, 1963) triggered by the stimulus that is imperfectly inhibited during this period of relaxation.

These findings are potentially important because microsaccades (as well as pupil size changes) are known to affect perception (Martinez-Conde, et al., 2006). Thus, interactions between a reflexive ocular response and the biomechanical constraints of fixation may underpin the earliest stages of exogenous attention.

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63.420

Eye movements and visuospatial perceptual extrapolations compete for common resources

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Although there is evidence for multiple spatial maps in the brain, including in posterior parietal cortex, it is not clear to what extent visuospatial perceptual and motor tasks rely on common neural representations and attentional resources. Using a dual-task interference paradigm we tested the hypothesis that shared resources are competed for during eye movements and perceptual extrapolations that require access to simultaneously presented visuospatial information. Observers undertook judgements of stimulus collinearity (perceptual extrapolation) using a pointer and Gabor patch and performed saccades to a peripheral dot target alone and in combination whilst their eye movements were recorded. In addition, observers performed a non-spatial control task (contrast discrimination) in order to distinguish between the general effects of dividing attention and the more specific effects of inter-task interference. Whilst contrast discrimination performance was unaffected by eye movements perceptual extrapolation acuity was significantly reduced. In addition, although significant effects were not seen at the group level, trends both in group and individual data suggest that perceptual extrapolations may disrupt saccadic profiles to a greater extent than do judgements of relative contrast. These data show that eye movements and perceptual extrapolations share common neural / attentional resources that are largely independent of those involved in encoding / comparing stimulus contrast. Future studies are planned to determine whether tasks requiring attention to other spatial attributes of a stimulus (e.g. spatial frequency or size) exhibit a similar interference effect, or whether in fact visuospatial extrapolation is unique in its association with eye movement / motor resources.

63.421

The global effect induced by ''blind'' distractors in visual hemifield defects

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Visual information in blind regions may still be processed in patients with hemifield defects after cerebral lesions (''blindsight''). Recently, we tested the hypothesis that, in the absence of retinogeniculostriate processing, residual retinotectal processing may still be detected as modifications of saccades to seen targets by irrelevant distractors in the blind hemifield (Van der Stigchel et al., 2008). Patients with hemifield defects were presented with distractors in both the blind and intact visual field and participants were instructed to make eye movements to targets in the intact field. Eye movements were recorded to determine if blind-field distractors caused deviation in saccadic trajectories. In one of these experiments, two patients were tested with the target and the distractor closely aligned. Both patients showed saccades that deviated toward the blind-field distractor (i.e. global effect). This finding might be a typical phenomenon in patients with hemifield defects. Here we present four new cases in which we tested with the same paradigm whether a distractor presented in the blind visual field induces a global effect when target and distractor are closely aligned. Results showed that the blind-field distractor did not cause a deviation in saccadic trajectories in two of the four patients, although the distractor in the intact field caused a consistent global effect. Interestingly, in the two patients in whom an effect of a blind-field distractor was observed, the direction of the deviation was different from the previous study as eye movements deviated away from the blind-field distractor. Whereas this study again confirms that distractor effects on saccadic trajectories can occur in some patients with damage to the retinogeniculostriate visual pathway but preserved retinotectal projections, it reveals that the direction of this effect differs between patients, reflecting differences in oculomotor inhibition of blind-field distractors.

63.422

Relationship between eye movement and filling-in time

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The ultimate aim of this study is to elucidate the mechanism inducing perceptual filling-in from the viewpoint of spatio-temporal frequency characteristics in vision. In our preliminary study (yokota, VSS 2005), we found that incomplete fixation distributes filling-in time. Furthermore, that we can see nothing by restraining eye movement artificially is well known. Therefore, we can consider that time to filling-in is influenced by eye movement. Although it has been recently reported that eye movement influences the filling-in occurrence (Matinez-Conde, neuron 2006), the relation between eye movement and the filling-in time has rarely been reported.

For this study, we measured the filling-in time for three subjects, for four surrounding textures, with simultaneous recording of eye movement. The results show that the filling-in time correlates the standard deviation of the distance from the eye position to the fixation point. Furthermore, we found relatively strong correlation between the filling-in time and the power of high frequency range between 50-200 [Hz] in the eye movement, though the correlation of the power of low frequency range between 10-50 [Hz] is not so high. Thus we suppose that filling-in is inhibited by small involuntary eye movement.

63.423

Static and Dynamic Visual Acuities of Athletes

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The ability to see details of objects during athletic participation is required in almost every sport, and is advantageous for successful competition. Elevated visual skills are essential for seeing objects in motion during athletic competition; requiring both excellent static visual acuity (SVA) and dynamic visual acuity (DVA). The purpose of this retrospective study was to examine SVA and DVA performance in an athlete population.

SVA and DVA of athletes were measured at a sports performance facility. This athlete population included both genders and ranged from 13 to 38 years of age (N=186). SVA was measured with a Snellen chart. DVA was measured with the inVision™ DVA Test from NeuroCom International, Inc. Two methods of testing DVA are reported here – target following (pursuit movement) and target acquisition (horizontal and vertical saccadic movement).

Athletes were divided into six age groups. SVA increased (better acuity) for each ascending age group up to the oldest age group ($p<0.0001$). DVA involving pursuit eye movement increased in younger age groups, peaking at 19 to 24 years of age, and decreased with the older age groups ($p=0.024$). DVA involving horizontal saccadic movement (target acquisition) increased in younger age groups, peaking at 22 to 27 years of age, and decreased with the oldest age group ($p=0.005$). For vertical saccadic movement, a strong trend of the same pattern as the horizontal direction was found ($p=0.06$).

SVA generally improved with age in this athlete population, but DVA declined with age after peaking in the 20's. This agrees with existing literature whereby DVA performance becomes less correlated with SVA at higher target speeds. Comparing pursuit vs. saccadic DVA, the pursuit DVA peaked in the early 20's while saccadic DVA peaked in the mid- to late 20's. This suggests target following and target acquisition skills have different patterns of development.

63.424

Stereo-depth with dichoptic perisaccadic spatial distortions illustrate a head-centric disparity mechanism

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Visual directions of foveal targets flashed just prior to the onset of a saccade are misperceived in head-centric space as shifted in the direction of the eye movement. In previous studies, we demonstrated unequal monocular perisaccadic spatial distortions of two sequentially presented pre-saccadic foveal flashes whose magnitude depended on luminance, temporal interactions and the saccade suppression (VSS 2007,VSS 2008,JOV). These effects were interpreted as a consequence of integrating estimates of eye position with retinal image position over the interval of the temporal impulse response function. We have also demonstrated that two sequentially presented dichoptic pre-saccadic foveal flashes appeared diplopic (in head-centric space) and this zero-retinal image disparity produced stereo-depth eye (SFN 2006). The current study examined whether the perisaccadic stereo-depth percept with dichoptic sequentially flashed pre-saccadic foveal stimuli could be predicted by the direction and magnitude of perisaccadic spatial distortions found with monocular sequentially flashed pre-saccadic foveal stimuli.

Two sequential pre-saccadic flashes (1 ms duration; 50 ms stimulus onset asynchrony) presented monocularly within 20ms prior to saccade onset, produced larger displacements of the first than second flash. The corresponding disparity predicted for two sequentially presented dichoptic pre-saccadic foveal flashes was consistent with the direction of empirically measured peri-saccadic stereo-depth percepts. These results can be interpreted as demonstrating stereo-depth from zero-retinal disparity associated with a non-zero head-centric disparity that results from the combination of retinal image location with independent estimates of each eye's position over the interval of the temporal impulse response.

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63.425

Effects of saccadic adaptation on visual localisation

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Saccadic adaptation affects the visual localisation of stimuli presented before an adapted saccade. The perceived location is shifted in the direction of adaptation. Factors that may be involved in the generation of the adaptation-induced shift include post-saccadic visual references, an efference copy signal, and adaptation of spatial localisation. If spatial localisation adapts concurrently with the saccade, a mislocalisation should be observable also during fixation. Most former studies, however, found only negligible shift during fixation in the adapted state. We studied visual localisation in a novel saccade adaptation paradigm in which a constant visual error is maintained throughout an extended session of 1000 adaptation trials. In this paradigm, the saccade landing position is predicted online during the saccade, and the target is jumped to a location that creates a fixed visual error. An initial target eccentricity of 13° and a constant visual error of 3° resulted in adaptation to a landing position near 10°. Localisation trials were intermixed in the course of adaptation. While the subject fixated a stimulus bar was flashed. The subject then reported the perceived location of the bar with a mouse pointer. Using this procedure we found mislocalisation during fixation that increased over the first 600 trials and reached up to 1.5°. We conclude that the adaptation of saccade amplitudes is accompanied by a partial adaptation of visual localisation that develops more slowly over time.

63.426

The main sequence of human Optokinetic Nystagmus

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Optokinetic nystagmus (OKN) is a reflexive eye movement stabilizing the retinal image e.g. during head movements. It consists of two alternating phases: a slow phase in direction of the stimulus motion and a fast phase in the opposite direction. Two kinds of OKN can be distinguished. A stare-nystagmus is observed when subjects view the stimulus passively. If subjects intentionally follow single stimulus elements they perform a look-nystagmus. The functional relationship between the two forms of fast phases (stare vs. look) and various forms of saccades is as of yet unclear. In this study we therefore compared the main sequences of fast phases elicited during stare- and look-nystagmus, as well as those of spontaneous and visually guided (reflexive and voluntary) saccades. Eye movements were recorded at 500 Hz with an infrared eye tracker. Optokinetic eye movements were elicited by a random dot pattern (RDP) moving horizontally at 10°/s. Subjects were either instructed to stare at the screen without following individual dots (stare-nystagmus condition) or to track individual dots (look-nystagmus condition). Spontaneous saccades were recorded while subjects looked at a homogeneous gray screen without any instructions concerning their eye movements. Finally we recorded visually guided (reflexive and voluntary) saccades. A moving RDP with identical properties as in the OKN experiment served as background in this condition. Across subjects, fast-phases during stare-nystagmus had longer durations and lower peak-velocities than fast-phases during look-nystagmus. Similarly, spontaneous saccades lasted longer and had lower peak-velocities than visually guided saccades. This indicates that fast eye movements towards visual targets are faster than those without a visual target. Direct comparison of the main-sequence of fast-phases during look-nystagmus with saccadic main-sequences revealed largest similarities to visually guided as compared to spontaneous saccades. Therefore our data support the notion of a close functional relationship between look-nystagmus and voluntary eye movements.

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63.427

Sensitivity to chromatic contrast at the time of saccades

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During saccadic eye movements luminance contrast sensitivity is reduced by up to ten times (for low spatial frequencies), while chromatic contrast sensitivity is enhanced by about a factor of 3, mainly after saccadic offset (Burr et al., Nature 1994, Diamond et al., J.Neurosci. 2000). While the origin of luminance suppression is well explained by an early inhibitory effect on the magnocellular pathways, the enhancement of chromatic sensitivity is still unexplained. Here we demonstrate that the enhancement is not mediated by an active extra-retinal signal, but rather by a facilitation generated by the spurious retinal motion.

Color discrimination (red/green) thresholds were measured for a 1° red-green Gaussian blob equiluminant with the background (Luminance: 18.1 cd/m2; C.I.E. coordinates: x = 0.470; y = 0.452). The stimulus was flashed for 10 ms at various spatial locations along or just above the saccadic path. In the active condition, subjects performed a 15° saccade; in the passive condition they maintained fixation on a mirror (reflecting the monitor) that rotated at saccadic speeds to simulate saccade-induced retinal motion.

Real and simulated saccades produced similar effects on discrimination thresholds. During the actual saccade (real or simulated), sensitivity was enhanced only for stimuli located along the trajectory of the fovea, otherwise it was unaffected. In the period immediately following the saccade sensitivity at all locations was enhanced by about 0.2 log-units (~factor of 1.6), peaking 100 ms after saccadic onset. The decay of the enhancement lasted longer for the simulated than real saccades (the major difference between the two conditions).

The results demonstrate that saccadic modulation of chromatic sensitivity is not caused by active processes accompanying the execution of eye movements, but is rather a byproduct of the spurious retinal motion that seems to enhance color detection, for reasons yet to be understood.

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63.428

Measuring the properties of the post-saccadic visual error calculation

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Introduction and Motivation. When saccadic eye movements become inaccurate –be it through fatigue, injury, or artificially induced error– automatic motor learning mechanisms gradually adjust the saccadic end-point to compensate for consistent post-saccadic visual errors; this is referred to as saccadic adaptation. Many researchers now believe that a post-saccadic visual error calculation compares the intended and actual post-saccadic retinal images, possibly utilizing the anticipated retinal image found in the parietal cortex, to determine the visual error vector. In the present experiment we attempt to measure the properties of the visual error calculation directly by trans-saccadically replacing the saccade target (Gabor patch) by two alternative targets that are systematically varied in frequency, contrast, and orientation. Error calculation in the visual system is studied by measuring the probability of the subsequent, corrective saccade selecting a specific target as a function of the feature differences between the initial target and its two replacements.

Methods. Participants completed 100 trials in which they made a 20° left-to-right saccade to the target. During their saccade, the target was replaced by two alternative targets randomly positioned on opposite sides of an invisible circle centered at the initial target position. Each of the alternative targets varied only in a single dimension from the initial target, and this dimension differed between the two targets. Gaze selection was determined according to the distances between the endpoint of the following saccade and the centers of the alternative targets.

Results. Before it is possible to determine the properties of the visual error calculation, we must first verify that participants are systematically selecting one of the two alternative targets based on their visual appearance rather than on their position. Preliminary results do suggest feature-based selection, but further studies are necessary to determine the experimental configuration of minimal target-position interference with gaze selection.

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63.429

Error in localising a target that is flashed near the time of an isolated saccade is not identical to the error found near the time of the last of a sequence of saccades

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Flashes presented around the time of a saccade are often mislocalized. The precise pattern of mislocalization is influenced by many factors. Here we study one such factor. In daily life we make saccades in various directions in rapid succession in response to the content of the scene and in accordance with our intentions. In contrast, most studies of peri-saccadic mislocalization impose a very simple pattern of saccades in order to reduce the variability between trials. Participants are instructed to fixate a dot at a fixed position on the screen. When the dot disappears the participant has to make a horizontal saccade towards a second dot: the saccade target. Here, we compare mislocalization near the time of saccades in this commonly used design with mislocalization when the participant more or less automatically follows a randomly jumping dot with his or her eyes. Saccade amplitude and most other details were the same in both conditions. A black dot was flashed at various locations in the vicinity of the saccade target. By estimating the saccade latency we were able to present the flash near the time of saccade onset. The participants were asked to localize the flash by touching the appropriate location on the screen. Our results show that there is a difference between the peri-saccadic mislocalization under the two conditions, especially when the flash is presented more eccentrically.

63.430

The Role of Visual Working Memory in Establishing Object Correspondence across Saccades

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Intelligent behavior requires directing the eyes efficiently to goal-relevant objects. However, with each eye movement, vision is interrupted, and the retinal locations of objects change. How does the visual system establish correspondence between objects visible before and after a saccade, so that perceptual continuity is maintained? Object correspondence across saccades is particularly challenging, because saccades are often inaccurate, with the eyes failing to land on the intended target object. In previous work, we demonstrated that visual working memory (VWM) is used to store saccade target properties across the eye movement, so that after an errant saccade, object correspondence can be established, and a rapid corrective saccade to the target generated. Here we show that objects near the landing position of an errant saccade compete for selection as the goal of the corrective saccade and that this competition is modulated by the content of VWM. Participants viewed an array of colored disks while maintaining a secondary color memory load. During the saccade to a target disk, the array was rotated so that the eyes landed midway between the target object and an adjacent distractor object, necessitating a second saccade to foveate the target. When the color of the distractor matched a color maintained in VWM, execution of this secondary saccade was impaired, indicating that the contents of VWM biased saccade targeting mechanisms that ordinarily direct gaze toward the target object. These data demonstrate that VWM plays an important role in ensuring that the eyes are ultimately directed to the intended object.

63.431

Look at the Choices: An Examination of Looking Behaviours in a Multiple Choice Test

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Research has shown that the perception of test difficulty can alter performance on multiple choice tests (Weber & Bizer, 2006). The current study explores whether or not perceived test difficulty also has an effect on looking behaviours during testing. Specifically, we were interested in students' fixation and pupil size when participating in a multiple choice test where they were informed that the test would either be easy or difficult. It was hypothesized that when students were informed that the test would be easy, they would generally show less looking behaviours overall. In particular, that these students would look less at the choices following the correct answer.

A sample (N = 24) of undergraduate students participated in this study. Students were given a short article to read and were told that they would be tested on its contents. The test consisted of 12 multiple choice questions with four possible answer choices, and was administered using a desktop mounted eye tracker system (EyeLink 1000). We measured fixation duration, fixation count, and pupil size in four areas of interest; when students looked at the question, the correct answer, the choices preceding the correct answer, and the choices following the correct answer.

Our general hypothesis was supported; students receiving the easy instruction showed lower levels of fixation duration, fixation count and smaller pupil size in general. In contrast to our second prediction, they tended to have longer fixation durations for the choices following the correct answer.

In light of these initial findings, further analysis based on students' actual responses to the questions rather than the correct answers will be examined. Additionally, the results from a questionnaire administered after testing will be discussed.

Visual Search: Mechanisms and Special Populations

Wednesday, May 13, 8:30 am – 12:30 pm
Poster Session, Orchid Ballroom

63.432

Reward Modulation of Search and Priming of Pop-Out

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As Kahneman and Tversky pointed out, gains and losses are relative: the amount of reward earned on the previous task affects perception of current task earnings. Too often psychological studies only compare high- and low-reward conditions without considering reward history. We examined participant responses to trial-by-trial reward variations within the priming of pop-out paradigm, where people detect targets faster following trials with the same-colored targets over trials with different-colored targets (Maljkovic & Nakayama, 1994; 2000). Participants were cued with expected reward magnitude starting 400 ms prior to trial onset. Independent of reward history, we confirmed that high-reward trials produced faster search times than low-reward trials. When reward history is considered, we observed that there was facilitation only when rewards increased from the previous trial. Interestingly, the facilitation occurred for targets that were colored differently from the previous trial, but not for targets that were colored the same, resulting in a net reduction in the priming of pop-out effect. Thus, in addition to absolute effects of reward, relative increases in reward from one trial to the next influence search performance. The effects of these relative variations in gains and losses over time merit further study.

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63.433

Spatiotopic Priming in Visual Search

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Visual search is faster if the target appears in the same location on consecutive trials than if it appears in different locations. In this study, we investigated how this location priming is affected by eye movements. Subjects were asked to report the orientation of a T-shaped target embedded among L-shaped distracters in a 2 x 4 array. Trials were organized in pairs and subjects had to perform the task while fixating at a red dot. In the first trial of each pair the fixation point was placed on the left side of the screen and on the second trial it was moved to the right side of the screen. Reaction time of the subjects was analyzed to determine if the location priming in visual search follows a retinotopic reference frame or a spatiotopic one. Results showed a non-specific effect of eye movement direction on the reaction time profile: regardless of the location of the target in the first trial, reaction times significantly decreased along the direction of the saccade ($p<0.05$). To factor out this general effect each location was compared to the vertically aligned control (previously non-target) location having the same horizontal position. Subjects were significantly faster ($p<0.05$) in finding a target when it was presented in the same spatiotopic location than in the control location with similar eccentricity. There was no significant difference between the reaction time of the subjects for the retinotopic location compared to control ($p=0.1$). These results suggest that the visual attention maintains a spatiotopic representation for the attended object's location across eye movements.

63.434

No need for inhibitory tagging of locations in visual search

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Many models of visual search assume that the visual system uses a salience map during difficult search. This salience map encodes the conspicuity of items and is used both to guide attention to potential targets and to keep track of items that have already been visited and rejected. It has been argued that the latter is achieved by placing an inhibitory tag at the item's location.

Without this inhibitory tagging, difficult visual search should become less efficient and slower, because previously inspected items would be revisited, increasing the time it takes to find the target. Inhibitory tagging of locations, as implemented in models of visual search, leads therefore to a clear prediction: if items change position during difficult visual search, search performance should suffer and search slopes should become steeper.

However, I will report the results from several visual search experiments (using up to 18 items) which show that:

(1) Participants do not find it harder to search for a T amongst L's when the items smoothly moved around at velocities up to 10.8°/s than when the items remained static.

(2) Information about the moving items accrues over time

(3) There is no tagging of the moving items

These results provide a challenge to any model of visual search that uses a fixed location as the index during accumulation and storage of information about search items.

63.435

Saccadic target selection and crowding

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Camouflage is a well-known practice to avoid detection. Similar surroundings impair the recognition of an object, a phenomenon called crowding. However, knowledge about camouflage is often common ground and an observer could search first among similar surroundings, even though an object is more difficult to distinguish there. Here we ask how visual information surrounding search elements affects selection of locations through eye movements.

Our search stimulus consisted of a vertical Gabor (target) and 11 slightly tilted Gabors (distractors) on a hexagonal grid. Each of these Gabors is flanked by 4 Gabors, rotated 45°, resulting in a display with 12 individual clusters. In two experiments we used color and spatial frequency, respectively, to vary similarity between target and flankers.

In the first experiment the target was a red Gabor, either flanked by red or green Gabors. The spacing between clusters was such that the target could not be distinguished peripherally. Search times were shorter when a red target was placed among red flankers than when it was placed among green flankers. Fixation data showed that locations with red flankers were selected far more frequently than locations with green flankers, explaining the difference in search times.

In the second experiment we showed that saccadic selection differs when the target is not completely masked. A vertical low spatial frequency target Gabor was placed among high or low spatial frequency flankers. In this experiment contrasting results were found. Search times were now shorter when a low spatial frequency target was located among high spatial frequency Gabors.

These results suggest that saccadic target selection is the outcome of a combination of two factors. Surroundings similar to the target impair its peripheral recognition, but can also attract eye movements, as more of the target property is present at the location.

63.436

Oculomotor and manual search compared: The role of cognitive complexity and memory load

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Visual search and classification require several cognitive processes to work together, such as visual memory, decision-making, and hypothesis-testing. How are cognitive resources allocated dynamically to these processes during natural tasks? In the current study, a natural search and classification task was devised in which cognitive complexity was varied and both manual and oculomotor search performance were used to assess memory load.

Subjects had to find 3 objects in a field of 9 hidden objects that belonged to a given category. Five categories, defined over some subset of the objects' four features, were varied systematically in their complexity. In the manual search task, subjects clicked on object locations with a mouse to reveal the object in that location. In the eye movement task, an object was visible only when its location was fixated. In both experiments, objects were only visible one at a time and revisits were permitted. Stimuli were chosen randomly such that the performance of an ideal searcher (no memory loss) would be the same across category complexity.

Search performance reflected memory and cognitive load: the frequency of revisits to previously viewed objects (double-checking) increased as complexity of the category increased in both the manual search (R^2=.873) and the eye movement tasks (R^2=.892). However, subjects in the eye movement task, who searched with saccades requiring less motor effort than moving a mouse, produced an average of 52% more revisits overall (p=.03), reflecting a preference for more frequent double-checking over finishing the task more quickly. These results indicate that cognitive complexity significantly affects memory load as reflected in search behavior, which suggests a unitary pool of resources that must be strategically managed during natural tasks involving several cognitive processes.

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63.437

From lab to life: Cognitive strategy fails to influence real-world search

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We perform numerous visual searches every day, from looking for our car keys to finding a book on a shelf. When searching meaningless stimuli (i.e. circles interrupted by gaps) on a computer display, passively allowing the target to pop into view leads to more efficient search than actively directing attention to locate the target (Smilek et al., 2006). Here we ask whether this finding extends to search in a real-world environment. Participants were instructed to use either a passive or an active strategy while searching in a cluttered office for five common objects (e.g. keys, coffee mug). The time to find the target items was measured and head and body movements were filmed during search. Search time varied systematically across participants, with some objects and locations resulting in generally easy search and others in more difficult search. Participants also differed systematically from one another, with some finding all the objects more quickly than other participants. However, response latencies failed to show a difference between passive and active cognitive strategies, in contrast to the benefit of a passive search strategy in the computer-based search task. There remain many questions concerning why the effect of cognitive strategy did not transfer from lab to life. For example, perhaps strategies are most effective when all items are present within a very small field of view, as they are in computer-based search tasks, and less effective when large head and eye movements must be made to bring a target into view. These and other possibilities will be investigated in additional studies. We will also be reporting on our analyses of the video recordings in an effort to identify behavioral features of participants who were more versus less efficient in real-world visual search.

63.438

Contextual cues facilitate search in real world 3-D environments

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Introduction: There is a growing literature showing how contextual cues guide and facilitate visual search (Chun & Yiang, 1998; Chen & Zelinsky; 2006; Eckstein et al., 2006; Torralba et al., 2006). However, all of these studies used 2-D images and a limited field of view. Here, we investigate the effects of contextual cues on search times and eye movements in a real 3-D scene. Methods: Observers were instructed to search for low visibility objects (e.g., straw, knife) placed on one of four elongated tables. Other distracting objects also cluttered the tables to increase the difficulty of the task. For each observer half the target objects were placed next to highly visible contextual cues (contextual condition; e.g., straw next to a red cup, knife next to plate) while the other half were placed on other table locations surrounded by unrelated items (non-contextual condition). Retinal eccentricity and local salience of the target against the background were matched for each object across conditions. Eye movements were monitored using an Applied Science Laboratories (ASL) mobile eye tracker which monitored the position of the right eye at an effective sampling rate of 30 Hz. Results: Mean human search times to fixate the target were shorter when the object co-occurred with a highly visible contextual cue than when it appeared elsewhere (1.97 vs. 3.8 seconds, $p < 0.05$). In addition, fixations were often directed to contextual cues even when the target object appeared elsewhere. Conclusions: The results extend previous work with 2-D images to show that contextual cues also aid search in a more ecologically valid 3-D environment.

63.439

The Effects of Task Demands on the Dynamics of Visual Search in Virtual 3D Displays

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Background and Goal. In easy visual search tasks, the target is often detected after a few, quick eye movements toward the most salient display locations, whereas difficult tasks typically lead to more systematic scan paths. Such findings have been obtained almost entirely in 2-dimensional search spaces, disregarding potential effects concerning depth. The few search studies involving depth have typically presented search objects in distinct depth planes with depth serving as a known target feature. Search for conjunctions such as depth and color is extremely efficient, suggesting a special role of depth in guiding attention. Here we studied the dynamics of overt attention in 3-dimensional search spaces under the more natural conditions of a continuous depth (binocular disparity) dimension, with shape and color being the only known target features.

Method. Observers searched stereoscopic displays while their eye movements were recorded. Two search tasks (easy: color-orientation conjunction search; difficult: search for the only mirrored instance among otherwise identical objects) in four display sizes (4, 8, 16, and 32 objects) were employed to manipulate task demands.

Results. In the horizontal and vertical dimensions, the easy task was dominated by an eccentricity effect (greater RT with more eccentric target), and the difficult task revealed a reading-direction effect (greater RT with target on the right or at the bottom). In the depth dimension, the only effect was a bias of the initial saccade toward near objects, which occurred under the least difficult task demands (4 objects, easy task).

Conclusions. Search dynamics appear to operate almost exclusively in the horizontal-vertical plane, where they systematically depend on task demands. Binocular disparity seems to be virtually disregarded by the mechanisms guiding attention. However, in real-world search, additional depth cues and the need for lens accommodation may give depth a greater impact on search behavior than binocular disparity alone.

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63.440

Novice and expert performance on a computerized lifeguarding task: A second look

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Last year, we reported data from a study where trained lifeguards and non-lifeguards (who were taught the behaviors associated with drowning) monitored 60 short video clips of varied swimming scenes for drowning behavior while an eye-tracker monitored their gaze position. Due to time constraints, last year's analysis focused on "critical events" - events that indicate a potential drowning or an increased risk for drowning - and found that lifeguards monitored more of these events than non-lifeguards. A limitation of that analysis was that only one fixation of the critical event was necessary to demonstrate monitoring of each event. A good lifeguard should continue to monitor an ongoing critical event to ensure that the situation is resolved with the patron safe. A good lifeguard should also have a gaze pattern consistent with being thorough and on-task, attending to all parts of the scene that will allow him/her to assess patron safety, and only those parts. To assess re-fixations and overall gaze patterns, a second analysis was performed on the data collected last year. Each fixation lasting one-third of a second or longer was examined, and the focus of that fixation was coded. So far in the analysis, the lifeguards did not outperform the trained non-lifeguards on re-fixations of critical events. This suggests that both lifeguards and trained participants were cognizant of the hazardous situations. As expected, the lifeguards had a wider spread of fixation locations compared to the non-lifeguards, suggesting that they had better coverage of the entire body of water in the scene. Also as expected, the lifeguards spent more time fixating the water, suggesting that they were better able to stay on-task than the non-lifeguards. These results suggest that although a simple training exercise may improve non-lifeguard monitoring of critical events, it does not yield true lifeguard performance.

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63.441

We Find Before We Look: Neural Signatures of Target Detection Preceding Saccades During Visual Search

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We investigated neural correlates of target detection in the electroencephalogram (EEG) during a free viewing search task and analyzed signals locked to saccadic events. We adopted stimuli similar to ones we used previously to study target detection in serial presentations of briefly flashed images. Subjects performed the search task for multiple random scenes while we simultaneously recorded 64 channels of EEG and tracked subjects' eye position.

For each subject we identified target saccades (TS) and distractor saccades (DS). For TS, these were always saccades which were directly to the target and were followed by a correct behavioral response (button press); for DS, we used saccades in correctly responded trials having no target (these were 28% of the trials). We sampled the sets of TS and DS saccades such that they were equalized/matched for saccade direction and duration, ensuring no information in the saccade properties themselves was discriminating for their type. We aligned EEG to the saccade and used logistic repression (LR), in the space of the 64 electrodes, to identify components discriminating a TS from a DS on a single-trial basis. Specifically, LR was applied to narrow time windows (50ms) and discrimination was done for windows having varying latencies relative to the saccade. We found that there is significant discriminating activity in the EEG both before and after the saccade—average discriminability across 7 subjects was AUC=0.64, 80 ms before the saccade, and AUC=0.68, 60 ms after the saccade ($p<0.01$ established using bootstrap resampling). Between these time periods we saw substantial reduction in discriminating activity (for 7 subjects, mean AUC=0.59). We conclude that that we can identify neural signatures of detection both before and after the saccade, indicating that the subject anticipates where the target is before he/she makes the last saccade to foveate and respond.

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63.442

Imagined Perspective Modulates Cue Effectiveness in Visual Search of Air Traffic Control Displays

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Air traffic control (ATC) displays render a 3D air traffic situation on a 2D planview map. In this projection, altitude is represented only alphanumerically in data tags associated with each aircraft. Controllers must integrate graphical and alphanumeric information channels to represent the true 3D positions of aircraft and search for potential mid-air collisions (conflicts). Palmer, Clausner & Kellman (2008) showed that adding altitude-correlated size and grayscale cues to aircraft icons improved conflict detection performance when observers imagined looking at the ATC scenario from above and the guiding features of size and grayscale were consistent with depth. Here, we show that imagined perspective modulates the effectiveness of these guiding features in ATC displays. The assignment of size and grayscale values to altitudes is the same when observers imagine looking from above and the cues are consistent with depth as it is when observers imagine looking from below and cues are inconsistent with depth. Despite the fact that the ATC displays were identical in these two conditions, observers performed better in the from-above, depth-consistent condition than they did in the from-below, depth-inconsistent condition. We show that improved performance is not due just to depth-consistency, assumed perspective, or larger/darker icons being conceptualized as MORE, but rather to the confluence of all three factors. A second experiment examined the effectiveness of grayscale cues to altitude vs. equiluminant color cues. It was hypothesized that grayscale cues would be more effective for quantitative variations in altitude whereas color cues would be more effective for qualitative variations. We found that equiluminant color cues were indeed more effective at conveying qualitative altitude relations than grayscale cues. We are currently investigating the relative effectiveness of color and grayscale cues for aircraft that quantitatively vary in altitude as when aircraft ascend or descend during flight.

63.443

A new step towards understanding Embedded Figures Test performance in the autism spectrum

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Individuals with autism often perform better on the Embedded Figures Test (EFT) than typically developing individuals. However the underlying skills, used to identify a constituent part of a complex stimulus, are poorly understood. A visual search task was designed which employed a well-studied global shape primitive: radial frequency (RF) patterns. A single RF3 (one with 3 cycles of modulation of the radius in 360o) was easily detected amongst different RF patterns (shallow slope as a function of element set size) consistent with narrow tuning for RF. To approach the EFT, RF patterns were combined into pairs or quads of overlapping RF patterns in the display. Performance declined with increasing overlap. This format was selected to investigate individuals with high and low Autism Quotients (AQ). The high AQ group performed significantly faster on the EFT relative to the low AQ group. Further, the EFT and the increase in reaction time with set size in the singles, pairs and quads conditions was significantly correlated, suggesting the search task measures related skills. In all conditions, the high AQ group was faster detecting the target and significantly less affected by set size in singles, pairs, and quads conditions, relative to low AQ scorers. Thus the search task demonstrated performance differences between these groups, and provides a useful foundation to explore the impact of further manipulations.

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63.444

Visual Field Loss, Eye Movements and Visual Search

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Objectives: In performing search tasks, the visual system encodes information across the visual field and deploys a saccade to place a visually interesting target upon the fovea. The process of saccadic eye movements, punctuated by periods of fixation, continues until the desired target has been located. Loss of peripheral vision restricts the available visual information with which to plan saccades, while loss of central vision restricts the ability to resolve the high spatial information of a target. We investigate visuomotor adaptations to visual field loss with gaze-contingent peripheral and central scotomas. Methods: Spatial distortions (peak frequency 2 cpd) were placed at random locations in 25deg square natural scenes, with transitions from distorted to undistorted regions smoothed by a Gaussian (sd = 2 deg). Gaze-contingent central or peripheral simulated Gaussian scotomas (sd =1 2 or 4 deg) were updated at the screen rate (75Hz) based on a 250Hz eyetracker. The observer's task was to search the natural scene for the spatial distortion and to indicate its location using a mouse-controlled cursor. Results: As the size of central or peripheral scotomas increased, so followed an increase in mean search times and the mean number of saccades and fixations. Fixation duration, saccade size and saccade duration were relatively unchanged across conditions. Conclusions: Both central and peripheral visual field loss cause functional impairment in visual search. The deficit is largely attributed to an increase in the number of saccades and fixations, with little change in visuomotor dynamics. Subjects frequently made saccades into blind areas and did not modify fixation durations to compensate for reduced acuity or change in temporal integration, suggesting that adaptations to visual impairment are not automatic and may benefit from rehabilitation training.

63.445

Relationship of visual search performance to Schizotypal personality measures for normal observers

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Introduction: Schizophrenia and schizotypy (a genetic predisposition to schizophrenia without the environmental factors leading to schizophrenia) can cause disruptions in basic attentional tasks (e. g.: cueing, Posner, et al., 1988; visual search, Alain, Bernstein, et al., 2002). It has been suggested that schizophrenia and schizotypy are not discrete disorders, but fall along a spectrum or continuum that includes non-schizophrenic/non-schizotypal populations (Baron & Risch, 1987; Johns & van Os, 2001). We assessed this suggestion by comparing non-schizotypal participants' performance on visual search with scores on a standard schizotypy questionnaire (Schizotypal Personality Questionnaire-B, Raine & Benishay, 1995).

Method: 43 participants completed the SPQ-B questionnaire and a series of yes/no feature and conjunction visual searches of spatial frequency and orientation. The target for all conditions was a high-contrast (46.7%) vertical Gabor (1 cpd, 1-octave bandwidth, full-width half-height). The orientation distractor Gabors differed in orientation (10°), and the spatial frequency distractor Gabors differed in spatial frequency (1.3 cpd, 0.757-octave bandwidth, full-width half-height). Searches were defined by presenting either one (feature) or both types (conjunction) of distractors. The total number of items (set size) was 2, 4, or 6; stimuli were presented for 250 ms at 10° eccentricity, with 100 trials/condition.

Results: Non-schizotypal participants' results were compared to their overall and three subscale scores (Cognitive/Perceptual, Interpersonal, Disorganized) of the SPQ-B. A median split of scores found that percent correct for orientation was lower for high (more indicative of schizotypy) Cognitive/Perceptual scorers ($F(2, 41)=3.323$, $p<.05$). Also, there were small but significant negative correlations between the Cognitive/Perceptual subscale and percent correct for orientation at each set size (set size 2, ($r=-.366$, $p<.05$); set size 4, ($r=-.354$, $p<.05$); set size 6 ($r=-.341$, $p<.05$)). These results suggest that disruptions of basic attentional processing associated with schizophrenia/schizotypy may comprise a continuum extending into populations having no diagnoses for the disorders.

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