The Optometrist's Guide to Strabismus:
Reorganizing Space, Time and the Visual Process

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Building a 4-D Brain

Part 1

Learning Objectives

LO's

Participants will be able to:

1. Illustrate how monocular depth cues can be used to prepare the brain for stereopsis development (binocular depth perception).
2. Apply looming as a dynamic (i.e. time-based) monocular depth cue, which can be used to build visual-motor planning skills in the therapy room.
3. Recognise that while looming provides a monocular cue to depth perception in which size changes as an object approaches, depth perception is more accurate when both size and stereo disparity changes occur in coordination, under binocular conditions.
4. Apply monocular depth cues such as motion parallax as a visual feedback mechanism, to help patients with binocular dysfunctions confirm the accuracy of their eye-posture with respect to the target when working independently.

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THE PRIMARY PURPOSE OF THE VISUAL PROCESS IS TO DIRECT ACTION!

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Mis-Directed Action….

- The primary "glitch" for the patient with strabismus is the MISMATCH between the world as they see it and the world as they come into contact with it.

Visual Input ≠ Visual Output

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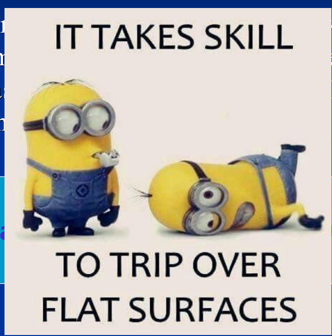
Mis-Directed Action….

- The pri… …ith strabism… …en the world a… …hey come into con…

Visu… …utput



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Preparing the BRAIN

- Successful Vision Therapy for patients with strabismus – and with all other binocular dysfunctions – prepares the brain to:
  - Process SPACE efficiently.
  - Plan visually-guided movements accurately.
  - Process visual information over a VOLUME of space.
  - Engage with both central and peripheral data simultaneously.

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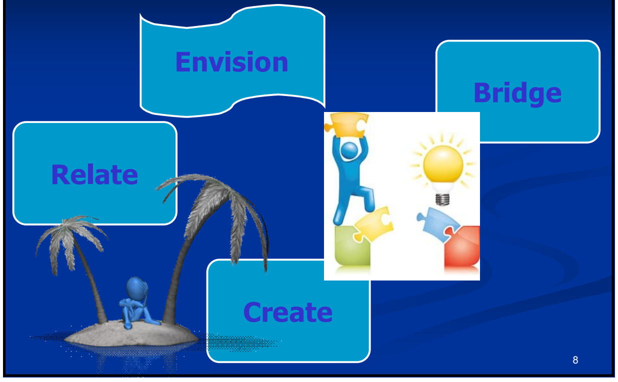
Working from the Outside-In



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Role of the Therapist in Working with the Strabismic Patient

- Get to know your patient, personality, interests:
  - Strabismus is not just an "eye problem."
  - It is a "person problem," with emotional and psychological effects.
- **RELATE:** Use your diagnostic information to help you understand the world ***as seen through your patient's eyes***.
- Tailor your interaction for the patient.
  - Relate it directly to *their* perspective…
  - Don't expect them to relate to *your* perspective.

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Role of the Therapist in Working with the Strabismic Patient

- **ENVISION** the world you want to help them perceive, and identify how to **bridge** that gap.
- If at any time you get lost, take a step back and re-center on the patient.
  - Ask yourself: What is the next, most important factor that will help this patient process 3-D space, or 4-D space/time?

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Role of the Therapist in Working with the Strabismic Patient

- Above all, remember: Therapy is a collaborative effort.
  - You provide guidance, but your patient jumps through all the hoops!
- As the therapist to your patient, YOU ARE A PARTICIPANT.
  - Your relationship becomes an integral part of their success.
  - What you bring to the table is unique and is part of what will motivate the patient.
  - Trust your inner voice.

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Role of the Therapist in Working with the Strabismic Patient

- If a blind person can perceive a 3-D world, so can the patient with strabismus. Your goal is to help them remove the conflicts between the world they see and the world they know exists, via **other senses**.

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Esref Armagan, Blind Painter http://www.youtube.com/watch?v=8r-CCFqBjqE 13

Perceptual Therapy Goals

- The strabismic patient already has access to 4-Dimensional processing.
- The goal of **perceptual therapy in strabismus** is to help **expand the 4-D construct** in the **space of the mind.**
- Use top-down processing and discussion to help create the *potential* for 4-D spatial **thinking.**
- **Goal: Visually-directed actions in a continuous, integrated space-world.**

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Perceptual Therapy Goals

- Confirm and reinforce the **top-down scaffolding** with **4-dimensional bottom-up sensory experiences.**
- Use **monocular depth cues** to **reinforce** accuracy/ provide visual feedback on performance in binocular activities.
- Use **sensory integration** to marry other sensory experiences of depth with the ***visual*** sense of depth.
- Transfer depth appreciation from auditory, tactile and ocular proprioceptive senses to visual sense in **real space**.
- Build central-peripheral integration skills to **prepare the brain** for **simultaneous** and **stereoscopic processing** in all real-world arenas.

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Thinking in 4-D

- Build the scaffolding for 4-dimensional processing
- Body organization as a foundation for 4-dimensional concepts: **Where am I?**
- Sensory integration techniques help to **bridge** the connection between 4-D *thinking* and 4-D *seeing*.
- Bond the body sense of depth and the tactile sense of depth with the visual sense of depth.

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Help Your Patient Construct the Scaffolding for a 3-D Worldview

- **The space-world is 3-dimensional.**
- **Movement through space CONFIRMS that the space-world is 3-dimensional.**
- **Tactile experience CONFIRMS that the space-world is 3-dimensional.**
- **Visual cues CONFIRM that the space-world is 3-dimensional.**
- **… Stereopsis is *not necessary for depth perception*.** BUT… when integrated with our other forms of depth perception, it enhances it TREMENDOUSLY.

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Review: THINKING IN 4-D

- ADAPTATIONS for USING TWO EYES which do not point in the same direction:
  1. **Driver/Passenger:** The visual direction of the "passenger" eye can be synced to the visual direction of the sighting/driving eye. *(~AP)*
  2. **Avoid Confusion:** The visual direction of the two foveae need to be "uncoupled" in the brain if both foveae are to be used. *(~Parallel processing)*
  3. **Ignore the problem:** The fovea (or larger area!) of one eye may be **suppressed** as an alternative to remapping the visual direction of the non-favored eye.
- Any of these solutions may be available, in whole or in part, to the *same* patient, at any time!

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Thinking in 4-D

- Both the "Driver/Passenger" and "Avoid confusion" adaptations help the patient with strabismus achieve two-eye seeing from a strabismic posture.
- "Ignoring the problem" tends to result in very poor stereopsis, along with a "tunnel vision" tendency:
  - Central info is processed without peripheral awareness.
- In kind, patients who favor the "ignoring the problem" strategy also struggle with orientation, directionality, efficiency, and flexible problem solving.

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SUPPRESSION: How to perceive depth while "Ignoring the Problem"

- There is a lot of visual information available to the single eye-channel.
- How do 2-D images, taken with a camera, depict:
  - depth,
  - space,
  - perspective?
- What kind of 3-D cues do we have at our disposal, ***before we ever introduce a second channel into our visual process?***

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Help Your Patient Construct the Scaffolding for a 3-D Worldview

- Visually, many patients with strabismus make use of **monocular depth cues** to infer depth and distance.
- Utilization of **monocular depth cues** can support the integration of ***stereopsis*** into depth perception with the use of top-down processing.

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Therapy Tip!

- Utilize a patient's strengths to inform their weaknesses:
- Utilize monocular depth cues to enhance sensory appreciation of binocular depth!

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Monocular Depth Cues

- Relative size (2 balloons; *familiar size:* paper clip in photo)
  - Looming = changing size of single object
- Linear Perspective (receding railroad tracks)
  - Height in field relative to the horizon
- Object occlusion (blocked view of objects)
- Texture gradient (Denser = farther away)
- Clarity (Clearer = closer, not obscured by fog/media)
- Lighting and shadow (creates sense of size)
- Motion Parallax (2 finger demo, with and against motion)
- Optic Flow (Thumb rotations, motion of scene rel. to figure)
- Accommodation (proprioceptive; available, but not likely predominant sense)

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Monocular Cues in VT Activities

- Cues used
- How to apply intentionally
- Explore OU and OD/OS perceptions
  - Comparisons help the patient appreciate the **enhancement** due to **binocular contribution**.

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Harnessing Monocular Depth Cues

- Discussion available at http://visionhelp.wordpress.com/2011/06/17/the-dual-nature-of-stereopsis-part-2/
- View the following pictures OU first, then experiment with OD or OS perceptions.

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Linear Perspective

- Monocular vs Binocular viewing changes experience of depth

Note clarity of background gradually reduced in the fog relative to distance

Paris Street: A Rainy Day by Gustave Caillebote

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Linear Perspective

Explore difference in appearance:

OU
vs
OD or OS

Arnolfini Newlyweds, or *Wedding Portrait*, 1434 by Jan Van Eyck

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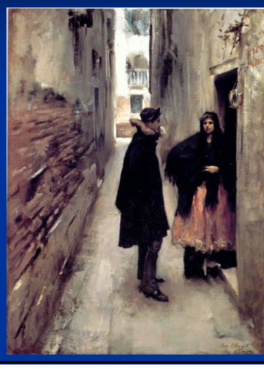
Linear Perspective

Explore difference in appearance:

OU
vs
OD or OS



Note the change in slope of the floor on monocular view

A Street in Venice, 1882 by John Singer Sargent

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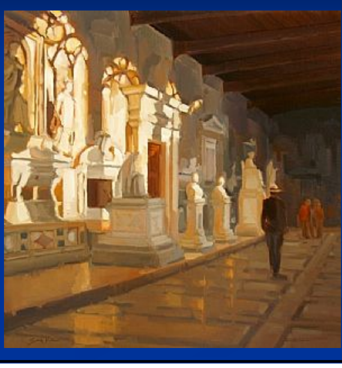
Linear Perspective

Explore difference in appearance:

OU
vs
OD or OS



Note change in **angle** of floor on monocular view.

Note shift in **relative size** of large sculpture (same linear size as man in mid-ground)

Pisa, 2011 by Sara Kidner

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Linear Perspective

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Linear Perspective

Explore difference in appearance:

OU
vs
OD or OS

Alan Carroll

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Linear Perspective

Conversely:

Monocular attention to linear perspective *dampens* the depth of this sidewalk chalk art.

Julian Beever

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Monocular Cues in VT

- Several vectograms utilize monocular depth cues in concert with binocular stereoscopic targets.

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Example: Chicago Skyline vectogram

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Monocular Cues support Stereopsis

- Relative size (larger buildings in front)
- Linear Perspective
  - Height in field relative to the horizon
- Object occlusion (blocked view of buildings)
- Texture gradient (Denser = farther away)
- Clarity (Clearer = closer, not obscured by fog/media)

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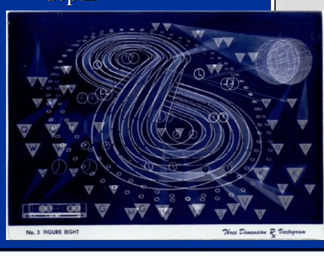
Multiple Monocular Cues in VT

- Vectograms use linear perspective to push the binocular percept of depth



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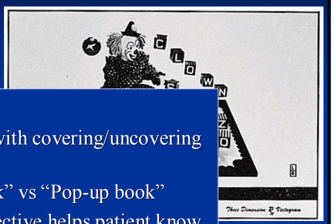
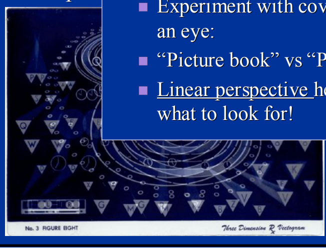
Multiple Monocular Cues in VT

- Vectograms use linear perspective to push the binocu... depth





- Apply it:
  - Experiment with covering/uncovering an eye:
  - "Picture book" vs "Pop-up book"
  - Linear perspective helps patient know what to look for!

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Looming in VT

- ***Thinking in 4 dimensions!***

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Looming and Time-to-Collision

- Looming brings up the challenge of THINKING IN 4 DIMENSIONS: **The TIME Element!**
- Studies have shown that when humans observe "large" looming objects*, we make an internal calculation on "Time-to-Collision" (TTC).
- TTC is an estimate of the amount of time it will take before collision with the object.
- We assess objects as approaching based on the rate of:
  - Size change (available monocularly and binocularly)
  - Disparity change (available binocularly only)

**Large= Visual angle 0.7 deg; **Small = Visual angle 0.03 deg*

***Monocular cues are INSUFFICIENT for judgment of TTC with "small" targets: Rate of size change is apparently imperceptible (Gray & Regan 1998).*

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Looming and Time-to-Collision

- Gray & Regan (1998): Experiments, static observer. Targets were optically created moving images beginning at 21.5 m until 1.7 m.
- Created experiments which removed the subjects' ability to respond from affecting the study (i.e., no pressing buttons!):
  - Subjects are shown image of approaching target.
  - Light is switched off.
  - Subsequently, a beep is sounded.
  - Subject responds to say *whether the beep came before or after* the anticipated TTC.
  - Each Subject's TTC was bracketed (similar to visual field - staircase method).

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Looming and Time-to-Collision

- Gray & Regan (1998): Experiments, static observer. Targets were optically created moving images beginning at 21.5 m until 1.7 m.
- Experiments created to evaluate:
  - Monocular cues (size change) vs
  - Binocular cues (retinal disparity change, size constant) vs
  - Both cues synchronized in combination.

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ACCURACY OF ESTIMATING TTC USING BINOCULAR AND MONOCULAR INFORMATION

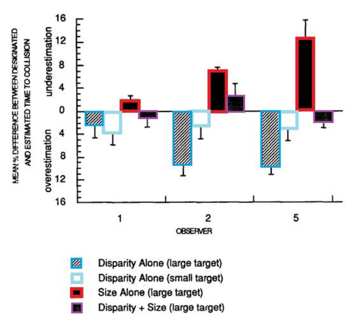
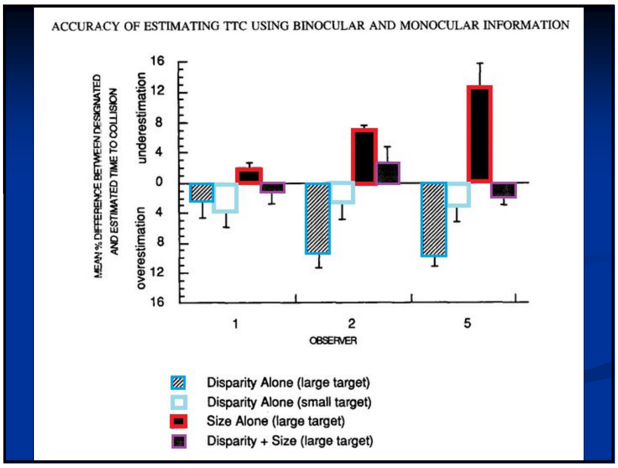
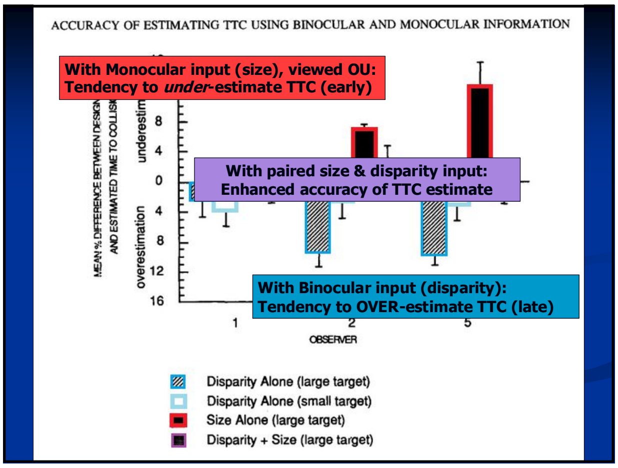


FIGURE 4. The mean percentage difference (and standard errors) between designated and estimated time to collision for observers 1, 2 and 5. Hatched bars: estimates based on binocular information alone (large target). Open bars: estimates based on binocular information alone (small target). Solid bars: estimates based on monocular information alone (large target). Grey bars: estimates based on combined binocular and monocular information (large target).

Gray R & Regan D. Accuracy of Estimating Time to Collision using Binocular and Monocular Information. *Vision Research* vol. 38, No. 4, pp. 499-512, 1998.





Looming and Time-to-Collision

- With Monocular input (size), viewed OU: Tendency to under-estimate TTC (early)
  - *Is this protective??*
- With Binocular input (disparity, size held constant): Tendency to OVER-estimate TTC (late)
  - *Does this relate to phoric posture?*
- With paired size & disparity input: Enhanced accuracy of TTC estimate
  - How does our accuracy change when we "close the loop," and add motor interaction with the target?
  - How can we translate this information to utilize in VT?

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Looming Demonstration

- Next series of slides demonstrates the looming effect with size changes (**monocular** input).
- Each slide adds additional monocular depth cues to support the appearance of looming.
- How does this impact your perception of depth when viewed monocularly?
- How about when viewed binocularly?

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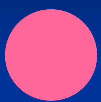
Looming



Try this series MONOCULARLY first!

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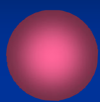
Looming + shading



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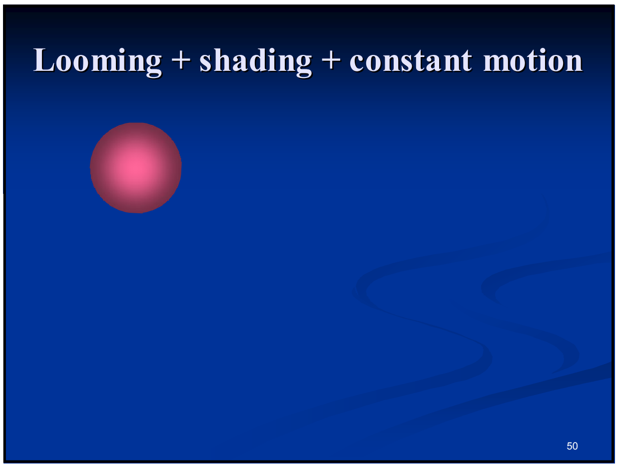
Looming + shading + constant motion
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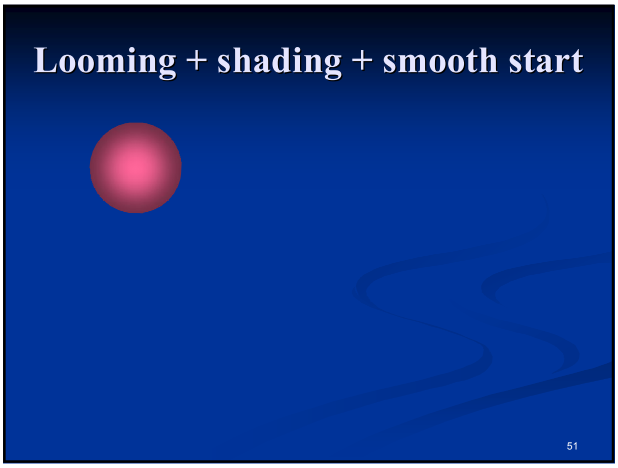
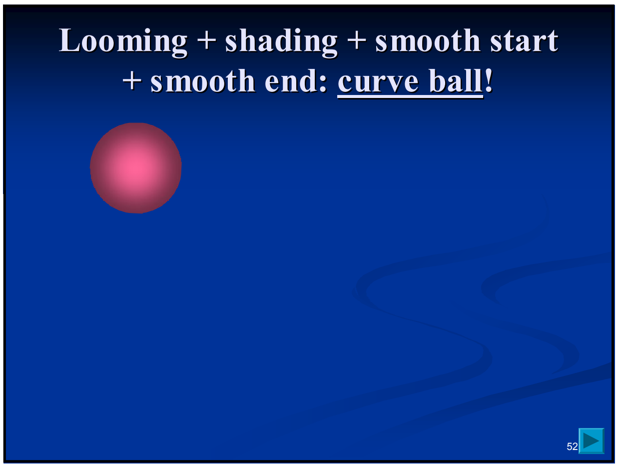

Looming + shading + smooth start
51


Looming + shading + smooth start + smooth end: curve ball!
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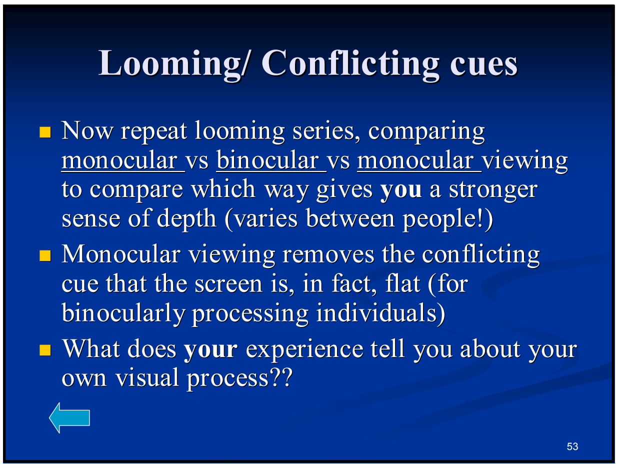
Looming/ Conflicting cues
Now repeat looming series, comparing monocular vs binocular vs monocular viewing to compare which way gives you a stronger sense of depth (varies between people!)
Monocular viewing removes the conflicting cue that the screen is, in fact, flat (for binocularly processing individuals)
What does your experience tell you about your own visual process??
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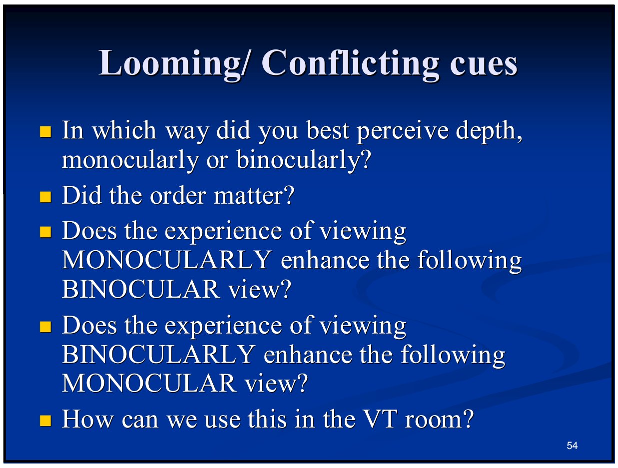
Looming/ Conflicting cues
In which way did you best perceive depth, monocularly or binocularly?
Did the order matter?
Does the experience of viewing MONOCULARLY enhance the following BINOCULAR view?
Does the experience of viewing BINOCULARLY enhance the following MONOCULAR view?
How can we use this in the VT room?
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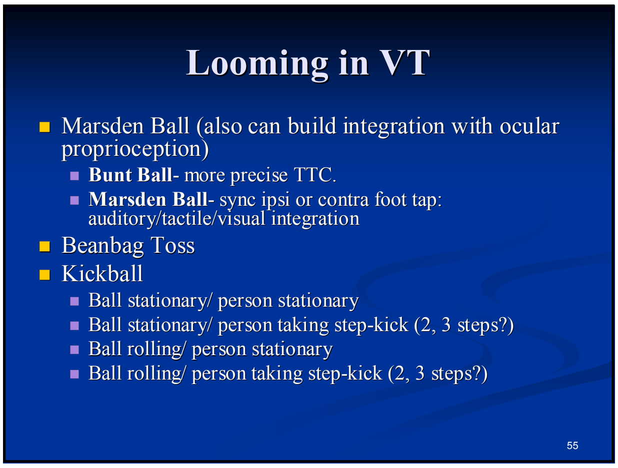
Looming in VT
Marsden Ball (also can build integration with ocular proprioception)
Bunt Ball- more precise TTC.
Marsden Ball- sync ipsi or contra foot tap: auditory/tactile/visual integration
Beanbag Toss
Kickball
Ball stationary/ person stationary
Ball stationary/ person taking step-kick (2, 3 steps?)
Ball rolling/ person stationary
Ball rolling/ person taking step-kick (2, 3 steps?)
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Applying monocular/binocular synergy

- Draw attention to the difference between monocular cues and binocular cues.
- E.g., observe **Marsden Ball** motion with patch for a few cycles.
- Estimate TTC with **Bunt Ball OD/OS**, simply make collision (do not push ball away).
- Repeat *without* patch, just to emphasize difference in appearance.
- Repeat bunting OU to observe TTC.

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Motion Parallax in VT

- Motion parallax can be used as a **monocularly available test** of the separation of two objects along the Z-axis.
- Employ motion parallax in VT by providing a binocular task, and enabling the patient to use monocular cue biofeedback to test their own performance.
- Note the **4-D** aspect: Change over time!

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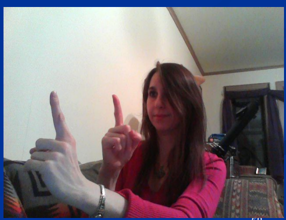
Motion Parallax

- 2 finger demo, with and against motion
- Hold 2 fingers out, view with one eye, fixate one finger.
- Turn head side to side.
  - Background moves with
  - Foreground moves against



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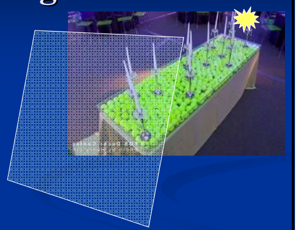
Motion Parallax: Candle Lighting

- Plexiglass, transilluminator, pointers/pick-up-stix on opposite side of glass.
- Light shined at glass makes a **real image** on opposite side of the glass.
- Biofeedback from body localization while moving the transilluminator and controlling image placement.



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Motion Parallax: Candle Lighting

- Also **sensory integration**: body localization creates a projection of spatial change which can be seen visually with light image.
- Hold light still and move head side to side while viewing target of interest. Any relative motion between light/stick indicates non-coincident location of light and stick.

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Optic Flow

- Evolution of ground relative to figure
- Requires peripheral awareness during central fixation.
- Expansion with FORWARD motion: Move THROUGH space.
- Effectively provides reinforcement for directing of eyes FORWARD.
- Walking rail
- Thumb rotations (for Figure/Ground challenges)

References:

- Len Press' blog pieces on **Eco-Optics**, **Parts 5-7**: https://visionhelp.wordpress.com/2014/09/07/eco-optics-part-5/
- Fixing My Gaze, Susan Barry, p. 84-85… "…use optic flow to gauge and, better yet, control the speed of my car." "… felt myself moving smoothly in a large, stable and stationary world."

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Accommodation as a Monocular Depth Cue in VT

- Images viewed both inside and outside of a lens have a natural separation of image planes.
- Movement of the lens emphasizes localization differences, consistent with **motion parallax** principles.
- Monocularly, these real images can be appreciated to have separate localization planes.
- **Focusing** (OD/OS) on one and then the other, **in turn**, exaggerates the appreciation of image separation.
  - **Ocular proprioception of accommodation**
  - **Ocular proprioception of binocular posture changes.**
- Recommend semi-occlusion (hand @ 45°) to perform as MFBF.

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Accommodation in VT: Add depth change awareness into activity

- Monocular lens Rock
  - Lens(es) on and off at spectacle plane
- Split pupil Rock
  - Use Marsden Ball: slight sway yields motion parallax info
  - Loose lens at 3 different distances:
    - Full arm extension
    - Half this distance
    - Half again (1/4 extension)
- Near-far Rock
  - Leave "distance" target mid-room, on clear unit
  - Opportunity to project *beyond* target
  - Bulls-eye rock/ transparent card to build awareness of **z-axis change** in localization.
    Isolate accommodative change, minimize ocular motility.

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Accommodation in VT: Add depth change awareness into activity

- In each activity, emphasize **ocular proprioception**:
  - Internal (accommodative)
  - Binocular posture
- Note that as images are compared in *sequence* with accommodative activities, we are making comparisons not only across **space**, but also across ***time***: 4-D thinking!

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Building a 4-D Brain

Part 2
Activities to support:
Sensory Integration
Central-Peripheral Integration
Simultaneous Processing/ Visual Memory

Learning Objectives

LO's

Participants will be able to:

1. Construct sensory integration activities to provide opportunities for agreement between visual input and other forms of sensory input (tactile, auditory, vestibular, proprioceptive, etc.).
2. Recognise that peripheral vision is critical for all stereoscopic experiences. Therefore, activities which promote simultaneous visual information processing skills over an area help to prepare the brain for stereoscopic perception.
3. Prescribe tachistoscopic visual spatial memory activities to reward simultaneous perception over an area, and support visual processing of areas (whether conducted monocularly or binocularly).
4. Administer central-peripheral integration activities to help patients to develop and internalize visual spatial organization skills.

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Sensory Integration Activities

- WHY?
  - To harness depth and localization information arising from other senses…
  - … which **patients with strabismus** have learned to **trust** (auditory, tactile, etc.),
  - … to integrate these perceptions with **visual** input,
  - … and ultimately… to *transfer* these perceptions so that they may become available to the patient **via visual input alone.**

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Sensory Integration Activities

- HOW?
  - Stimulate multiple senses in parallel.
  - Provide depth and localization information so that is available to multiple senses, especially:
    - Stereo-Tactile
    - Stereo-Auditory
    - Ocular proprioception
    - Help patients *transfer* depth perception arising from non-visual senses to visual depth perception and stereopsis.

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Sensory Integration in VT: Examples

- VMI: "Ready Aim Fire," monocular, ipsi & contra hand
- Thumb-Pinky Vergence Rock
- Pointer and straw (or Menorah Explorah)
  - Hold straw parallel to facial plane; do not limit to primary gaze
- (R/G) Keystone Basic Binocular Series
  - Use tactile feedback, touching picture
- Bilateral integration: Chalkboard circles/ walking rail
- Gross motor: Marsden Ball/ Bunt ball (Discussed w looming)
- Ocular Proprioception/ Visual:
  - Monocular Lens Rock (Discussed under Monocular Depth cues)
- Vectograms: with tactile counterparts … or dual pointers
  - Visual/**TACTILE** feedback… Visual/**AUDITORY** feedback

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Building a 4-D Brain

- Include perceptual and oculomotor training techniques supportive of patients with strabismus or compromised binocularity.
- Emphasize central-peripheral integration.
- Include computer-aided perceptual training for tachistoscopic presentation, as well as free-space techniques.
- Encourage visual imagery with visual memory activities.
- Combine different processing modes: passive, active, bottom-up, and top-down.

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Central-Peripheral Organization

- Develop visual-spatial organization skills in order to build an **internal** construct of their 4-D space/time world.

WHY?

- VT activities which build central-peripheral organization create the potential for stereoscopic vision.
  - Stereopsis begins with the use of non-central retina.
  - Simultaneously *seeing* center and periphery engages active use of peripheral retina.
- Enables them to use *top-down processing* to integrate their spatial perception with how the world is "supposed to look," facilitating the development of stereopsis.

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Central-Peripheral Integration in VT: Examples

- Look Ready Touch Back (Schrock)
- Slotnick Scramble
- Eyeport (Liberman)
- Visual-spatial memory games
  - Simultaneous or sequential, with delay or distraction
- Side-by-Side Vectograms
  - relative depth – different vectos sliding by each other: Topper/Clown, Qts/Clown, Qts/ No.9
  - relative size – the same vecto (Clown/Clown)
- Vectos with pointer
  - Diplopia on pointer or image: inaccurate localization.
- Oculomotor:
  - Eye excursions: Greenwald ball track/ Hart chart (Nasal to temporal for ET's, Temporal to nasal for XT's)
  - Wayne Saccadic Fixator/ Accuvision board

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Stimulate Simultaneous Processing: Supports Thinking in 4 Dimensions

- Necessary to simultaneously process:
  - Center and periphery
  - Figure and ground
  - Part and whole
  - Spatial and sequential

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Central-Peripheral Integration in Visual Processing/ Memory

- The advantage of the Visual Process is the ability to process a set of data simultaneously.
- Any procedure which builds simultaneous visual processing supports the building of a 4-D brain.
- Central-Peripheral Integration activities help a patient learn to process detail as well as context (figure as well as ground) over a large area of space.

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Central-Peripheral Integration in Visual Processing/ Memory

- VT Examples:
  - Multi-Matrix Game
  - Puzzle Art and Puzzle Art 3-D
  - www.Lumosity.com:
    - Birdwatching; Eagle Eye
    - Space Junk
    - Top Chimp
    - Memory Matrix
    - Monster Garden

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Summary

- The strabismic patient already has access to 4-Dimensional processing.
- The goal of **perceptual therapy in strabismus** is to help **expand the 4-D construct** in the **space of the mind.**
- Use top-down processing and discussion to help create the *potential* for 4-D spatial **thinking.**
- **Goal: Visually-directed actions in a continuous, integrated space-world.**

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Summary

- Confirm and reinforce the **top-down scaffolding** with **4-dimensional bottom-up sensory experiences.**
- Use **monocular depth cues** to **reinforce** accuracy/ provide visual feedback on performance in binocular activities.
- Use **sensory integration** to marry other sensory experiences of depth with the ***visual*** sense of depth.
- Transfer depth appreciation from auditory, tactile and ocular proprioceptive senses to visual sense in **real space**.
- Build central-peripheral integration skills to **prepare the brain** for **simultaneous** and **stereoscopic processing** in all real-world arenas.

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Feedback Appreciated!

Thank you

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