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

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Building a 4-D Brain

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Role of the Therapist in Working with the Strabismic Patient

- It is important to understand the person: Strabismus is not just an "eye problem." It is a "person problem," with emotional and psychological effects.
- You need to get to know your patient.
- Familiarity with your patient's personality and their work/interests will help you to tailor your interaction with the patient in a way that relates directly to their perspective (rather than expecting them to relate to your perspective).
- When you work as a therapist with your patient, you are in a relationship with them and become an integral part of their success. YOU ARE A PARTICIPANT.
- What you bring to the table is unique and is part of what will motivate the patient to work.

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Role of the Therapist in Working with the Strabismic Patient

- Above all, remember, therapy is a collaborative effort.
- You are providing guidance, but your patient is the one who will jump through all the hoops!
- If at any time you get lost, take a step back and refocus on the patient.
- Ask yourself, what is the next, most important factor that will help your patient process 3-D space, or 4-D space/time?
- Use your diagnostic information to help you understand the world ***as seen through your patient's eyes***.
- Envision the world you want to help them perceive, and identify how to bridge that gap.
- 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

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Building a 4-D Brain: Part 1

- **Learn how monocular depth cues and multi-sensory integration techniques provide the scaffolding for understanding a four-dimensional space/time world.**
- **Multi-sensory integration techniques which are ideal for developing 4-Dimensional processing in patients with strabismus or compromised binocularity.**

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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.
  2. Avoid Confusion: The visual direction of the two foveae need to be "uncoupled" in the brain if both foveae are to be used.
  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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SUPPRESSION: Why does "Ignoring the Problem" Work?

- There is a lot of visual information available to the single 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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Understanding Visual Processing through the Eyes of a Strabismic Patient

- **How does the patient with strabismus successfully navigate a 3-D world?**
- **This section explores how monocular depth cues may be harnessed as a comfortable way to develop 3-D & 4-D processing skills in patients with strabismus.**

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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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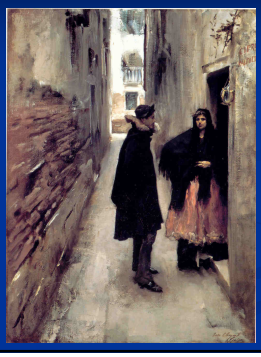
Linear Perspective

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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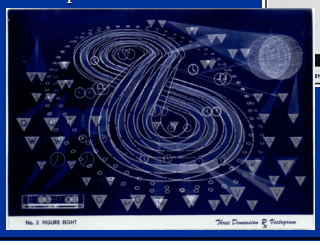
Multiple Monocular Cues in VT

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



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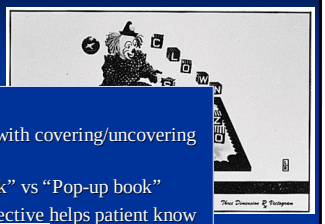
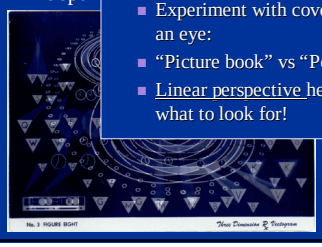
Multiple Monocular Cues in VT

- Vectograms use linear perspective to push the binoc 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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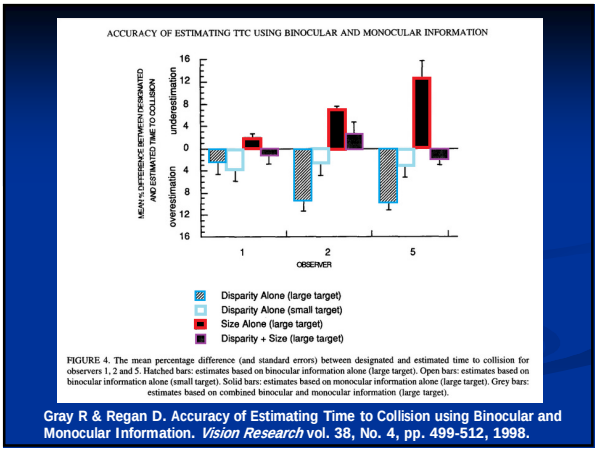
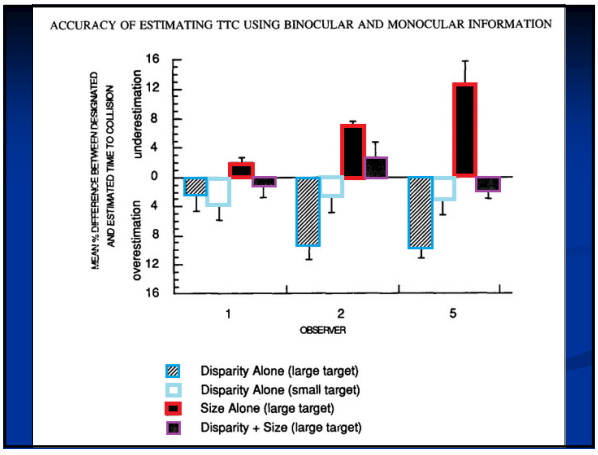
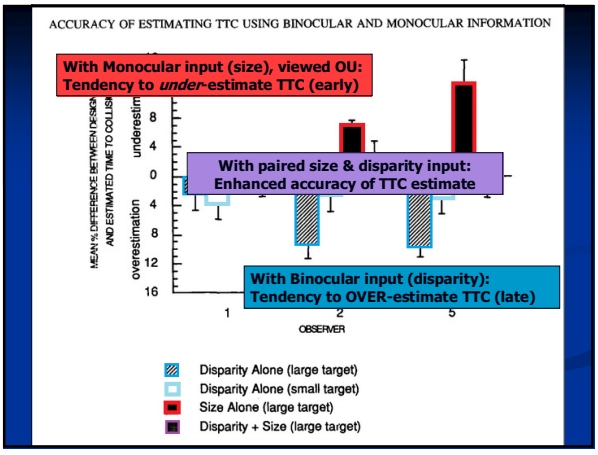


FIGURE 4. The mean percentage difference (and standard errors) between designated and estimated time to collision for observers 1, 2 and 5. Hatched bars: estimates based on binocular information alone (large target). Open bars: estimates based on binocular information alone (small target). Solid bars: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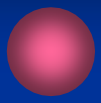
Looming + shading



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Looming + shading + constant motion

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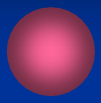
Looming + shading + smooth start



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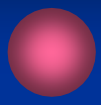
Looming + shading + smooth start + smooth end: curve ball!



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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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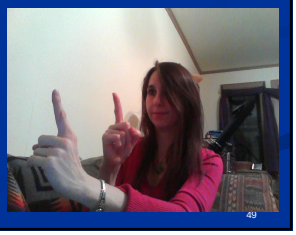
Motion Parallax

- 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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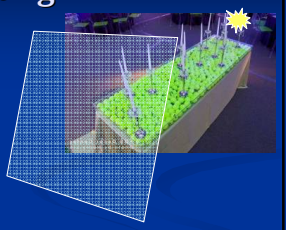
Motion Parallax: Candle Lighting

- 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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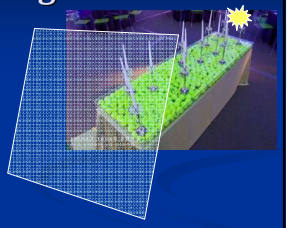
Motion Parallax: Candle Lighting

- 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.
- Thumb rotations
- Walking rail

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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BREAK

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Building a 4-D Brain

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

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

- 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.
- 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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