VISION & ACQUIRED BRAIN INJURY

KATIE DAVIS, OD, FCOVD

1

TOPICS TO COVER

- Definitions & Anatomy
- The Three 'O's
- What is a neuro-optometric evaluation for patients with acquired brain injury(ABI)?
- Common visual findings after an ABI
- Treatment options
- Case examples

2

EPIDEMIOLOGY

- "Silent epidemic"
- ~5.3 million people are living with a ABI-related disability
- In the US, the following groups are most likely to have a ABI related hospital visit
  - 0-4 years
  - 15-19 years
  - 75 years
- 30-70% of ABI survivors develop depression
- Economic cost of ABI: 56 billion dollars (annual)

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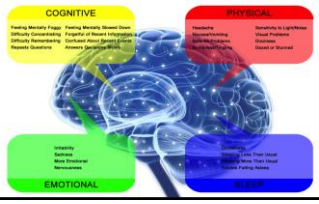
HOW COMMON ARE VISUAL PROBLEMS AFTER AN ABI?

- **50-90%** of individuals with ABI demonstrated visual dysfunction
- **90%** of ABI patients experience 1 or more oculomotor dysfunctions
- **40%** of ABI have visual dysfunctions that persist > 3 months



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WHAT IS VISION?

"A dynamic, interactive process of motor and sensory function mediated by the eyes for the purpose of simultaneous organization of posture, movement, spatial orientation, manipulation of the environment and to its highest degree of perception and thought."

William Padula, OD, FCOVD, FNORA

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WHAT IS THE PURPOSE OF HAVING A VISUAL SYSTEM?

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THE PURPOSE OF VISION

To determine meaning from light--
CONCRETE VISUAL IMAGES

7

THE PURPOSE OF VISION

To determine meaning from light--
SYMBOLIC VISUAL IMAGES

8

THE PURPOSE OF VISION

To determine meaning from light--
ABSTRACT LANGUAGE SYMBOLS

9

THE PURPOSE OF VISION

To guide and direct intelligent movement of the body

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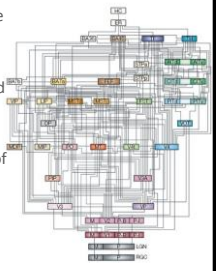
THE VISUAL SYSTEM- AN OVERVIEW

- Optic Nerve: 1,000,000 nerve fibers per eye
- 2/3rd of all sensory processing in the entire body is directly affected by information coming from the two eyes
- Every lobe of the cerebral cortex is involved in processing visual information
- There is more area of the brain dedicated to processing visual information than ALL of the other sensory modalities combined!



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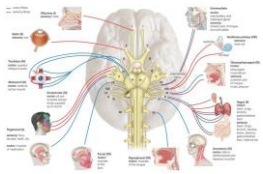
CRANIAL NERVES INVOLVED WITH VISION

- CN II, Optic Nerve
- CN III, Oculomotor (moves eyes/constrict pupil/accommodate)
- CN IV, Trochlear (moves eye up)
- CN V, Trigeminal (corneal sensitivity, maintaining the tear film)
- CN VI, Abducens (moves eye out)
- CN VII, Facial (closes eyelid)
- CN VIII, Vestibulocochlear (VOR)
- CN XI, Accessory (VOR)



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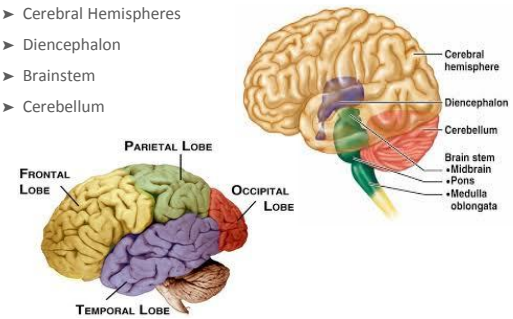
ANATOMY

- Cerebral Hemispheres
- Diencephalon
- Brainstem
- Cerebellum



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ANATOMY

- Frontal Lobe
  - Most complex, largest
  - Last area of the brain to myelinate
  - Not a single functional unit
  - Generally, plays a large role in voluntary movement
  - Involves the ability to project future consequences resulting from current actions
  - Plays an important part in integrating longer non-task based memories stored across the brain

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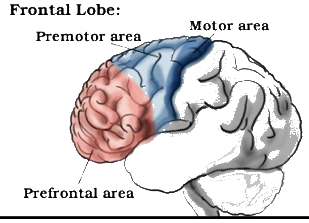
ANATOMY

- Frontal Lobe, three major divisions
  - Precentral Area
  - Premotor Area
  - Prefrontal Area



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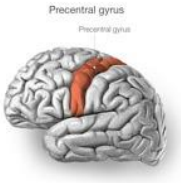
ANATOMY

- Frontal Lobe, three major divisions
  1. Precentral Area
     - Primary motor area of the brain
     - It has important connections with the cerebellum, basal ganglia and motor divisions of the thalamus



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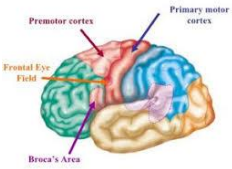
ANATOMY

- Frontal Lobe, three major divisions

  2.Premotor Area
  - Area where motor skills and practiced behaviors are learned
  - Influences movement which needs to involve planning and guidance
  - May have a role in the control of behavior
  - May help in understand the actions of others
  - May be involved in applying abstract concepts to performing specific tasks
- Precentral and Premotor work as a unit to plan and carry out motor behavior (including eye movements)



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ANATOMY

- Frontal Lobe, three major divisions

  3.Prefrontal Area
  - Eye movements
  - Visual attention
  - Working memory
  - Goal-directed behavior
  - Cognitive sophisticated integra
  - Highest level of visual and other sensory modality processing
  - Results in higher action planning (perceptual decision making)
  - Incorporate meaning and intention

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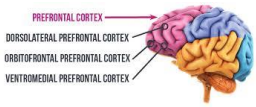
ANATOMY

- Frontal Lobe, three major divisions

  3.Prefrontal Area

  - Dorsolateral Prefrontal Cortex
    - Working memory
    - Executive functioning
  - Orbitofrontal Prefrontal Cortex
    - Personality
    - Self Control
  - Ventromedial Prefrontal Cortex
    - Motivation for goal oriented activities



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ANATOMY

- Temporal Lobe
  - Object Recognition
    - Right temporal lobe
      - Plays a role in naming of objects and recognition of facial expressions
      - Plays a role in spatial, non-verbal and abstract reasoning
  - Emotional Variance
    - Limbic System
    - Attaches an emotional layer to sensory input

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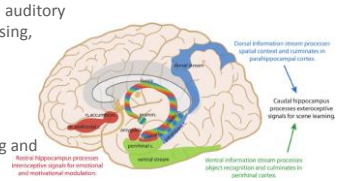
ANATOMY

- Temporal Lobe
  - Auditory Processing
    - Auditory memory, auditory perceptual processing, auditory attention
  - Memory Acquisition
    - Hippocampus
    - Critical for learning and memory
    - Visual Memory



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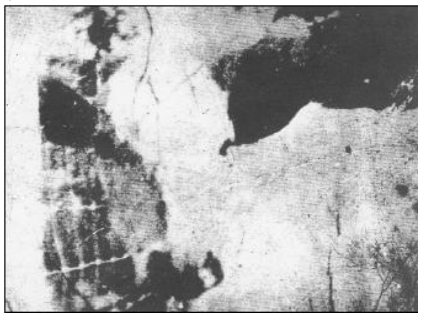
ANATOMY

- Temporal Lobe



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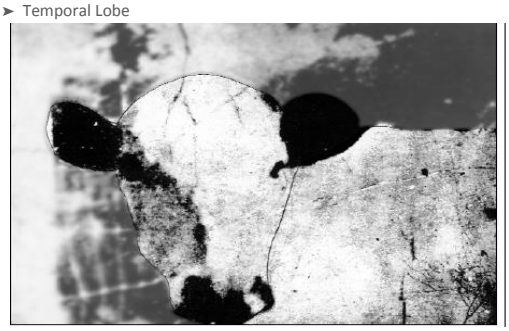
- Temporal Lobe



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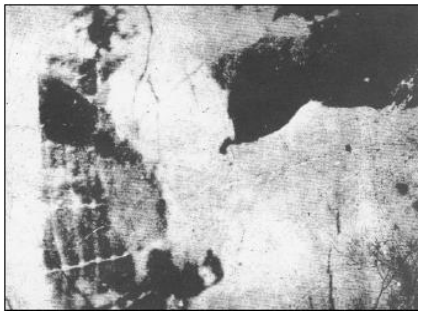
ANATOMY

- Temporal Lobe



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ANATOMY

- Parietal Lobe
  - Processing motion and location
  - Aid in manipulation of objects and in the processing of information relating to the sense of touch
  - Vibratory sense and the fine tactile perception

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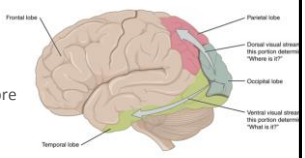
ANATOMY

- Parietal Lobe
  - The left side is concerned in symbolic functions in language and mathematics
    - Understanding numbers and their relations
  - The right hemisphere is more focused on imagery and spatial relationships



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ANATOMY

- Parietal Lobe
  - Posterior Parietal Cortex
    - Center of multi-sensory convergence where visual, proprioceptive and vestibular information are combined
    - Awareness of the movement and direction of movement of objects
    - Localizing objects in space in relation to our bodies
    - Awareness between objects in space
    - Organizing and preparing our bodies for action

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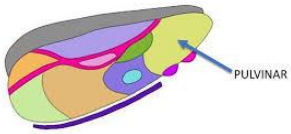
ANATOMY

- Diencephalon
  - Thalamus
    - Pulvinar
      - Integration of somatosensory and visual information
      - Analysis of vision
      - An important component of the visual attention network



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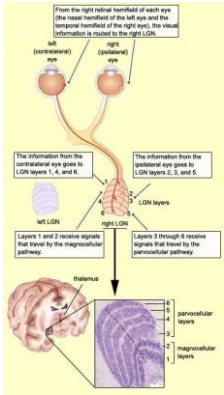
ANATOMY

- Diencephalon
  - Thalamus
    - Lateral Geniculate Nucleus – LGN
      - The LGN is the relay point for 80% of the information that goes from the eyes to visual areas of the brain
      - **Yet at least 80% of the input TO the LGN comes from sources other than the eyes**



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"EYES DON'T TELL BRAINS WHAT TO SEE; BRAINS TELL EYES WHAT TO LOOK FOR"

Dr. Lawrence Macdonald

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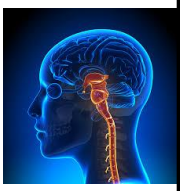
ANATOMY

- Brainstem
  - Transmits all information from the body to the cerebrum and cerebellum and vice versa
  - The cranial nerves III-XII emerge from the brainstem
  - Has autonomic integrative functions
    - Cardiovascular system control
    - Respiratory control
    - Pain sensitivity control
    - Alertness, awareness, and consciousness



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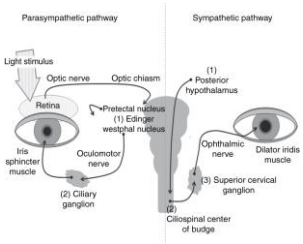
ANATOMY

- Brainstem
  - Autonomic functions
    - Sympathetic Ocular Functions
      - Mydriasis- contract pupillary dilator muscle
      - Contract superior tarsal muscle to hold eyelid open
      - Relax ciliary muscle for distant vision



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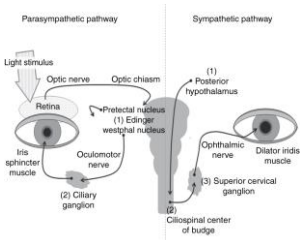
ANATOMY

- Brainstem
  - Autonomic functions
    - Parasympathetic Ocular Functions
      - Accommodate eye for near vision via ciliary muscle contraction
      - Constrict pupil (miosis) via pupillary sphincter contraction



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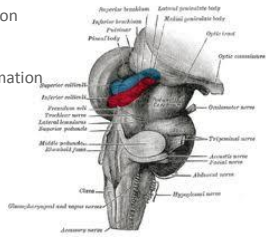
ANATOMY

- Brainstem
  - Superior colliculus in the midbrain
    - Involved in spatial orientation
    - Eye movement control
    - Integration of spatial information with vestibular, tactile and auditory information



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ANATOMY

- Cerebellum
  - Receives information from the sensory systems and the cerebral cortex
  - Controls muscle reaction in relation to equilibrium, movement and postures
  - Controls and smooths coordinated movements
  - Involved language, attention, and mental imagery

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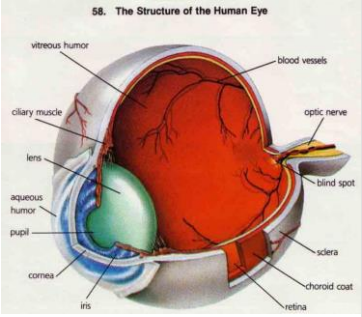
OCULAR ANATOMY

- Cornea
- Pupil
- Iris
- Aqueous Humor
- Lens
- Vitreous Humor
- Retina
- Macula/Fovea
- Optic Nerve



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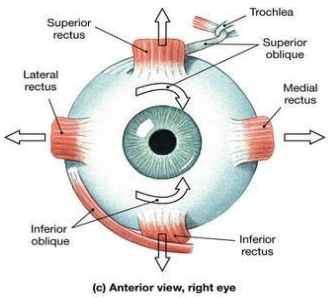
OCULAR ANATOMY

- Four Rectus Muscles
  - Superior
  - Inferior
  - Lateral
  - Medial
- Two Oblique Muscles
  - Inferior
  - Superior



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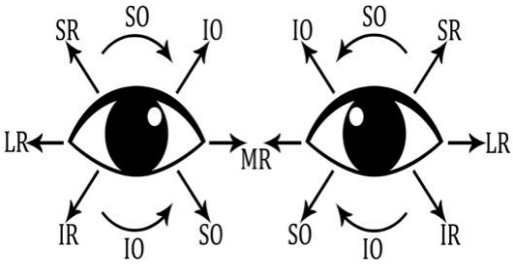
EOM MOVEMENTS



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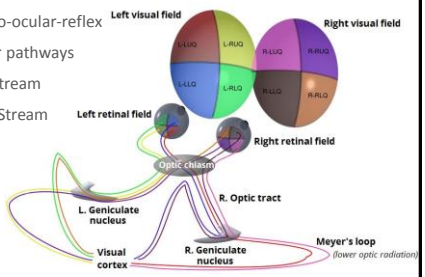
TWO THIRDS OF AFFERENT NERVES ARE FROM OUR EYES

1. ***The sight pathway***
2. The vestibulo-ocular-reflex
3. Oculo-motor pathways
4. The Dorsal Stream
5. The Ventral Stream



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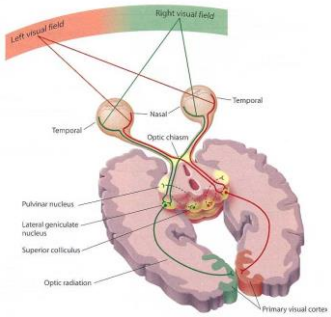
THE SIGHT PATHWAY

- Retina
- Optic Nerve
- Optic Chiasm
- Optic Tract
- Optic Radiations
- Occipital Lobes



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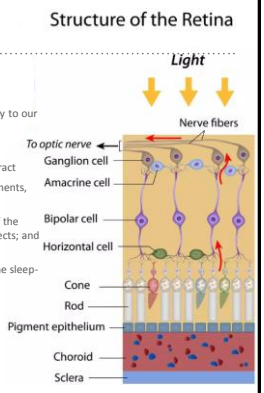
THE SIGHT PATHWAY

- Retina
  - 23 types of retinal ganglion cells (RGCs)
  - Intrinsically photosensitive RGCs contribute minimally to our vision, but play a key role in vision regulation
  - Contain melatonin
  - Photosensitive RGCs form the retino-hypothalamic tract
    - Pretectal nucleus: involved in reflexive eye movements, thereby helping to target what we want to see
    - Midbrain nuclei: involved in controlling the size of the pupil, thus helping to adjust the brightness of objects; and coordinating movement of the eye for focusing
    - Suprachiasmatic nucleus: involved in regulating the sleep-wake cycle



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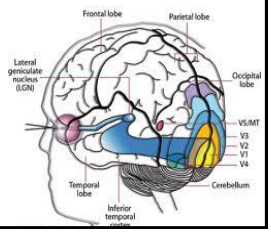
THE SIGHT PATHWAY

- Occipital Lobe
  - Reception and early visual processing
  - V1, V2 – Depth perception
  - V3,V4,V5 – motion detection, size and color
  - V6- unknown
  - V8 – Color analysis



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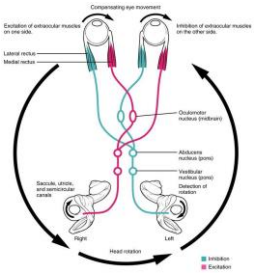

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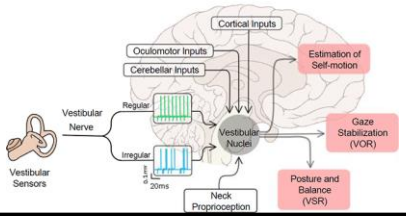
VESTIBULAR PATHWAY

- Vestibular nuclei receive inputs from cortex, oculomotor pathways, cerebellum, neck proprioceptors
- Output regulates gaze stabilization via the vestibulo-ocular reflex (VOR), posture and balance via the vestibulo-spinal reflex (VSR), and contribute to an estimation of self motion



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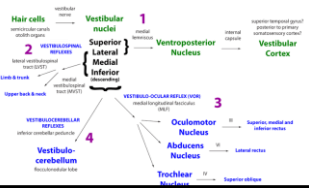
VESTIBULAR PATHWAY

- Visual-Vestibular interaction
  - CN III and VI communicated with CN VIII via the medial longitudinal fasciculus (MLF) to generate the horizontal VOR
  - Improving and stabilizing any oculomotor deficits may facilitate vestibular rehab process



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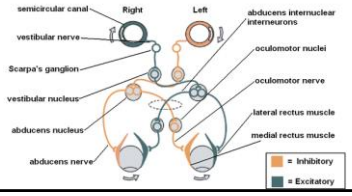
THE VESTIBULO-OCULAR REFLEX

- Activation of the vestibular system causes eye movement
- The eye movements stabilize images on the retinas during head movement by producing eye movements in the direction opposite to head movement
- This preserves the image on the center of the visual field



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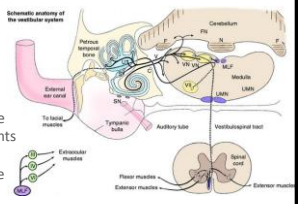
THE VESTIBULO-OCULAR REFLEX

- Head movement must be compensated almost immediately
- To achieve clear vision, signals from the semicircular canals are sent as directly as possible to the eye muscles
- The connection is called the three neuron arc
- Using these direct connections, eye movements lag the head movements by less than 10 ms, and thus the vestibulo-ocular reflex is one of the fastest reflexes



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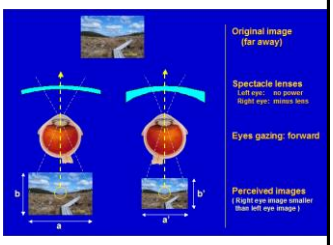
THE VESTIBULO-OCULAR REFLEX

- Optical concerns
  - Anisometropia
  - Uncorrected astigmatism especially at axis 90
  - Latent hyperopia
  - Multifocal/progressive lenses



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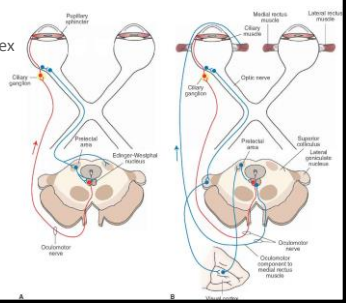

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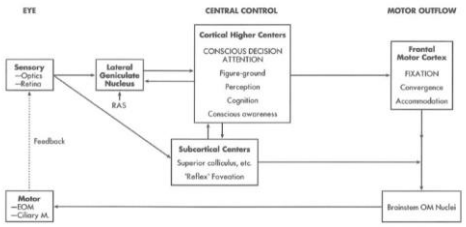
OCULOMOTOR PATHWAY

- CN III, CN IV, CN VI
- These are the efferent parts of sight



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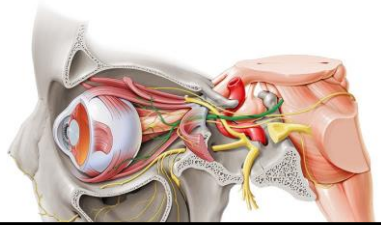
OCULOMOTOR PATHWAY

- CN III, Oculomotor Nerve
  - Mostly efferent information, contains some afferent information
  - Controls five extrinsic muscles
  - Controls two intrinsic muscles



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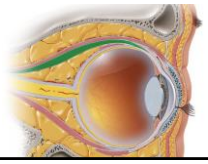
OCULOMOTOR PATHWAY

- CN III, Oculomotor Nerve- Five Extrinsic Muscles

1. Superior Rectus
   - Origin -Superior part of the common tendinous ring
   - Insertion- Sclera on the top of the eyeball, posterior to the corneoscleral junction
   - Action- Elevation, adduction, medial rotation of the eyeball



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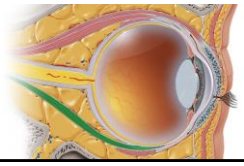
OCULOMOTOR PATHWAY

- CN III, Oculomotor Nerve- Five Extrinsic Muscles

2. Inferior Rectus
   - Origin- Inferior part of the common tendinous ring
   - Insertion- Sclera on the bottom of the eyeball, posterior to the corneoscleral junction
   - Action- Depression, adduction, lateral rotation of the eyeball



53

OCULOMOTOR PATHWAY

- CN III, Oculomotor Nerve- Five Extrinsic Muscles

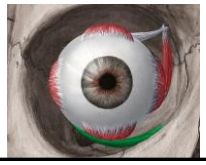
3. Medial Rectus
   - Origin- Medial part of the common tendinous ring
   - Insertion- Sclera on the medial aspect of the eyeball, posterior to the corneoscleral junction
   - Action- Adduction of eyeball

54

OCULOMOTOR PATHWAY

- CN III, Oculomotor Nerve- Five Extrinsic Muscles

4. Inferior Oblique
   - Origin- Anterior aspect of the floor of the orbit
   - Insertion- Sclera of the eyeball, deep to the insertion of the lateral rectus on the lateral aspect of the eyeball
   - Action-Abduction, elevation, lateral rotation of the eyeball

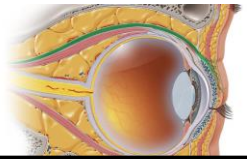


55

OCULOMOTOR PATHWAY

- CN III, Oculomotor Nerve- Five Extrinsic Muscles

5. Levator Palpabrae Superioris
   - Origin- Anterior and superior to the optic canal on the lesser wing of the sphenoid bone
   - Insertion- Superior tarsus and skin of the upper eyelid
   - Action- Elevation of the upper eyelid

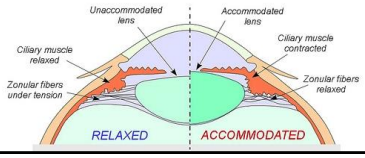


56

OCULOMOTOR PATHWAY

- CN III, Oculomotor Nerve- Two intrinsic muscles
- Located within the eye itself
- Supplied by parasympathetic fibers of the oculomotor nerve

1. Ciliary Muscle
   - Contracts and relaxes to alter the shape of the crystalline lens allowing for accommodation

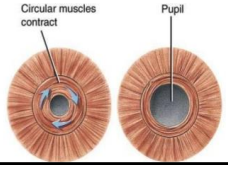


57

OCULOMOTOR PATHWAY

- CN III, Oculomotor Nerve- Two intrinsic muscles

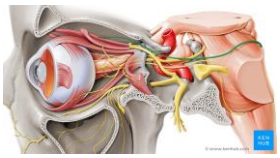
2. Sphincter Pupillae
   - Muscle fibers arranged in a circular pattern around the pupil
   - Activation causes contraction and the pupil is decreased in size or constricted

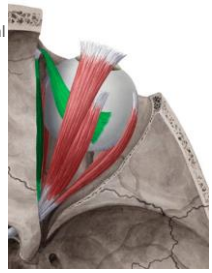


58

OCULOMOTOR PATHWAY

- CN IV, Trochlear Nerve
- Inferior colliculus -> Superior orbital fissure -> Superior oblique muscle
- Function: Abduction, depression, internal rotation of the eye

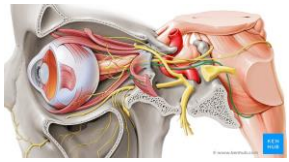


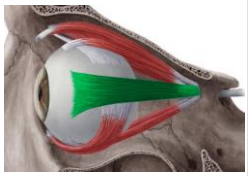


59

OCULOMOTOR PATHWAY

- CN VI, Abducens Nerve
- Facial colliculus -> Superior orbital fissure -> Lateral rectus muscle.
- Function: Abduction (lateral movement) of the eye





60

TWO THIRDS OF AFFERENT NERVES ARE FROM OUR EYES

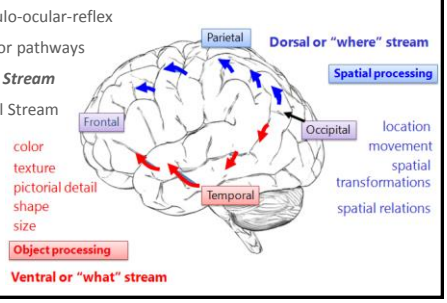
1.The sight pathway

2.The vestibulo-ocular-reflex

3.Oculo-motor pathways

4.The Dorsal Stream

5.The Ventral Stream



61

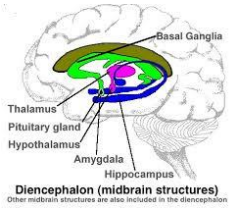
DORSAL STREAM- WHERE AM I? WHERE IS IT?

- More primitive visual system is present at birth
- An unconscious function that links vision and motor
- Composed of magnocells that respond to large and fast moving stimuli
- Must match with kinesthetic, proprioceptive, vestibular, and even tactile systems
- Responsible for spatial orientation, general awareness, balance, posture, movement detection, localization

62

DORSAL STREAM- WHERE AM I? WHERE IS IT?

- 20% of the nerve fibers from the eye do not go to the occipital cortex—goes to midbrain
- Midbrain delivers SENSORIMOTOR!
- Spatial visual processes include:
  - Preconscious and proactive
  - Receives feedback from the cortex
  - Brings forward all possibilities for neuro-organization



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DORSAL STREAM- WHERE AM I? WHERE IS IT?

- Allows for the development of concepts of midline, position, and orientation
- **Feed-forward phenomenon**
  - Visual information relayed from the midbrain to the occipital cortex to pre-program the higher cortical areas to *first evaluate visual information spatially before focalizing on detail*
- This release from focalization allows for movement
- Frees up higher level process from postural organization and control
- Has major contributions to the overall cognitive function
- Suppresses background information to allow for attention

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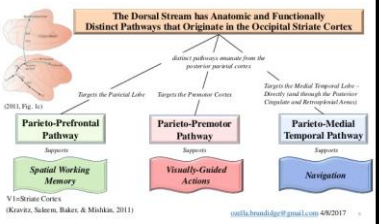
DORSAL STREAM- WHERE AM I? WHERE IS IT?

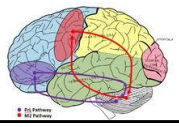
- Dorsal Stream splits into 3 pathways at Posterior Parietal Cortex
  - Parieto-Prefrontal Pathway
  - Parieto-Premotor Pathway
  - Parieto-Medial Temporal Pathway



65

DORSAL STREAM- WHERE AM I? WHERE IS IT?

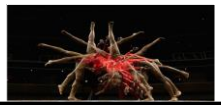
- Dorsal Stream splits into 3 pathways at Posterior Parietal Cortex
  - Parieto-Prefrontal Pathway
    - Initiation and control of eye movements important for reading
    - Spatial working memory, which is important in determining where to look next
    - Important for navigating through new environment
    - This pathway provides input to the prefrontal cortex necessary for top down control of visuospatial processing



66

DORSAL STREAM- WHERE AM I? WHERE IS IT?

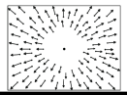
- Dorsal Stream splits into 3 pathways at Posterior Parietal Cortex
  - Parieto-Premotor Pathway
    - Has projections to both dorsal and ventral premotor cortex, receiving vestibular input from the cerebellum
    - Visually guided action for integration of body movement and vision, visually guided reaching and grasping
    - Provides coordinated maps of body position
    - Integration of body movements with vision for navigation



67

DORSAL STREAM- WHERE AM I? WHERE IS IT?

- Dorsal Stream splits into 3 pathways at Posterior Parietal Cortex
  - Parieto-Medial Temporal Pathway
    - Connections to limbic areas (learning from past visual experiences)
    - Specialized for processing distant space
    - Sensitive to speed of optic flow that is used in updating one's position during navigation
    - Appropriate coordinated head and body postural reflexes are generated as information flows through the vestibulocerebellar and vestibulospinal tracts



68

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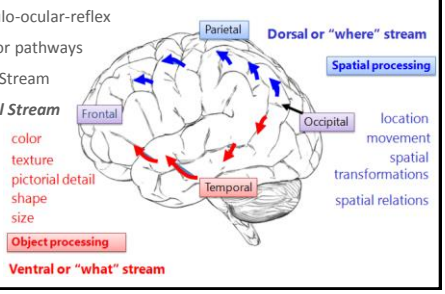
5. ***The Ventral Stream***



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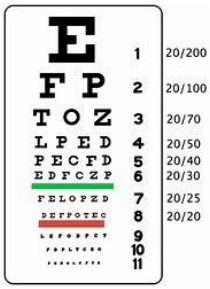
VENTRAL STREAM- WHAT IS IT?

- The ventral system is associated with the primary visual pathway
- Develops after birth
- Much slower than the dorsal system
- Mediated by the parvocellular cells
- Cells that react to stationary small targets, detail and color



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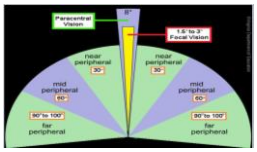
VENTRAL STREAM- WHAT IS IT?

- 80% of fibers
- Responsible for detail, identification, texture, color, attention
- It is part of our conscious perceptions
- Traditional ophthalmic and optometric exam



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DORSAL AND VENTRAL SYSTEMS— SENSORY COHERENCE

- Need to work in harmony, are not isolated systems
- Must be processed and combined efficiently, and simultaneously
- Neurological events may affect the balance between these two systems
- An imbalance between the two processes results in information being received by the occipital cortex without spatial pre-programming

72

DORSAL AND VENTRAL SYSTEMS

- DORSAL/M Pathway
  - AMBIENT
  - Proactive
  - Lightning fast
  - Subconscious
  - Movement
  - Spatial Localization
  - Figure ground segregation
  - Larger impact on balance, posture & function
- VENTRAL/P Pathway
  - FOCAL
  - Reactive
  - Slower
  - Detailed
  - Object identification
  - Secondary to ambient process

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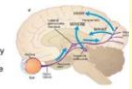
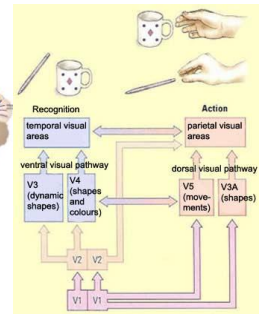
DORSAL AND VENTRAL SYSTEMS— SENSORY COHERENCE

- To see **WHAT** things are
  - Ventral Stream: Visual Sensory
- To see **WHERE & HOW** things are
  - Dorsal Stream: Visual Motor
- To see **WHY & HOW** things relate
  - Coordinating the entire process: Visual Thinking





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PERCEPTION

- Definition: a way of regarding, understanding, or interpretation something using the senses; a mental impression.
- Definition #2: the process by which people translate sensory impressions into a coherent and unified view of the world around them.
- The organization, identification, and interpretation of sensory information — Objective versus Subjective — these do not always match
- What happens when they don't match?
- Perception is dependent on cognition so that we can derive understanding and meaning from what we experience

75

VISUAL-INFORMATION PROCESSING

- Speed and span of perception
  - Amount of visual information acquisition during an eye fixation
- Visual Discrimination
  - The ability to discriminate similarities and differences in shapes, letters, or forms
- Visual closure
  - Recognition of objects within complete visual information
  - To mentally be able to "fill in the blank" or close an incomplete picture/image/concept when analyzing or organizing information

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VISUAL-INFORMATION PROCESSING

- Visual figure ground
  - Ability to determine where the scene is separated into the main figure and background
  - The ability to discriminate an object, shape, word or letter from the background in which it is embedded

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FIGURE GROUND

- May impact the ability to attend to individual letters and words presented on a page full of sentences and paragraphs
- Can lose your place while reading
- Difficulty with competing information on the television or computer screen
- More easily distracted, overwhelmed and needs extra time getting ready or performing ADL/IADLs
- Can be conceptual as well, meaning an inability to distinguish between primary and secondary information
- Can be unable to determine what should be prioritized, or what needs to be acted on immediately vs in a little while

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VISUAL-INFORMATION PROCESSING

- Laterality
  - Using the concept of midline to divide the body in half. Creates an awareness of "sidedeness" or the separation of left and right.
- Directionality
  - The understanding of where everything else in space is positioned in relation to the left or right side of the individual.

79

LATERALITY & DIRECTIONALITY

- Reversal of letters or words when reading
- Difficulty reading maps
- Difficulty filling out forms or putting information in the right location
- Can make a person more indecisive as they figure out what they should do or where they should go
- Slower physical reaction time, may often move in the wrong direction or move too slowly as they decide which way to go
- Return to drive?

80

VISUAL-INFORMATION PROCESSING

- Visual memory
  - Store an image and retrieve it for later use
- Visual sequential memory
  - Recall a sequence of visually presented characters or forms
- Visualization
  - Did you picture the name Carolina in your head to help spell it backwards?
  - How do we use visualization to help with cognitive tasks?
  - ***aniloraC***

81

VISUAL MOTOR INTEGRATION

- Requires efficient interaction between multiple systems: Vision, Vestibular, Proprioceptive
- This is how individuals plan, execute and monitor motor tasks
- If the information is not perceived correctly, the muscles will get the wrong message and produce the wrong motor response
- If we have to devote attention to posture and movements we cannot attend to other things

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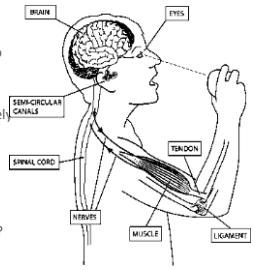
VISUAL MOTOR INTEGRATION

- This can impact Eye/hand coordination, Eye/foot coordination, Bilateral coordination, Body awareness
- Which in turn impact a persons ability to participate in their ADLs and their daily roles
  - How can a person safely and effectively interact with the world around them when he is not able to accurately process where objects are located in space?
  - Or understand the relationship between the objects and themselves?



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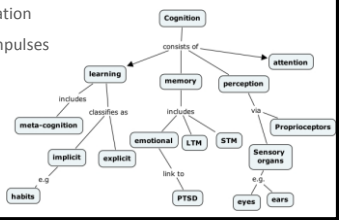
ASPECTS OF COGNITION

- Attention: sustained, selective, divided, alternating
- Memory: long term, short term/working memory
- Processing speed
- Executive function: Reasoning, Planning, decision making
- Auditory and communication
- Emotional: controlling impulses
- Visualization



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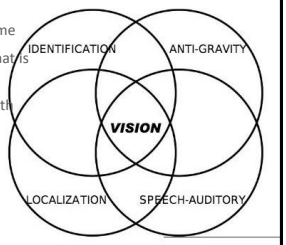
MCGURK EFFECT

85

VISION, AS A PROCESS, EMERGES

- Move the eyes to look at a target across different distances
- Maintain clarity of the image over time
- Attend, comprehend and process what is seen
- Coordinate the visual information with the hand and body
- Maintain upright and stable body position
- Communicate what is seen and understood



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THE VISUAL ILLUSION

- Sensory Coherence
- Clarity, singleness, stability, sensory integration
- These are NOT true, yet when we have a well-working visual system, this is what we perceive
- Often with brain injury, this illusion is shattered

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THE VISUAL ILLUSION

"Herein lies the paradox of coherence. The pattern of raw data sent to the brain is a shaky, fragmented picture. The brain processes the data, combining input from both eyes, and filling in gaps in spatial vision with parallel streams of multisensory information. The result is a happy and competent being living under the compelling illusion that vision is clear, single, simultaneous, and stable. Compelling, that is, until brain injury shatters the illusion"

- Lenard Press, OD, FCOVD

88

WHAT MIGHT HAPPEN IF…

- You could see but could not perceptually interpret what was being seen?
- You were unable to accurately locate objects in space, judge the space between objects or understand the relationship of the objects to oneself?
- You had trouble directing the eyes to a desired location?
- You had a lack of coherence within visual pathways but also between vision and other systems (auditory, vestibular and somatosensory)

89

THE THREE O'S

OPTICIAN, OPHTHALMOLOGIST, OPTOMETRIST

90

THE THREE O'S: OPTICIAN

- Fills prescription for glasses and contact lenses
- Frame and Lens Specialists
- What prescription is best in which frame
  - Lightest and Thinnest Lenses
  - Best Clarity and Optics

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THE THREE O'S: OPHTHALMOLOGIST

- Important for Eyesight Threatening Problems
- Concerned with Structure of the eye
- Assess for eye diseases to ensure ocular health
  - Cataracts, Glaucoma, Red Eyes, Diabetes, Retinal tears, Blunt Trauma, Macular Degeneration, etc
- Surgery of eye structures

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THE THREE O'S: OPTOMETRIST

- Primary Care Eye Doctor
- Concerned with how you use your eyesight in every day life
- Prescribes glasses or contact lenses to correct eyesight
- Assess for eye diseases to ensure ocular health
  - Cataracts, Glaucoma, Red Eyes, Diabetes, Macular Degeneration, etc
- Refers for surgery or vision therapy

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THE THREE O'S: NEURO-OPTOMETRIST

- "FCOVD" Fellow of the Optometrist in Vision Development or "FNORA" Fellow in Neuro-Optometric Rehabilitation
- Specialty trained to address patients after a brain injury with their functional needs
- Help with visual problems that can interfere with the rehabilitative process
- Evaluation/Treatment catered to patient symptoms, needs, and goals-Reading, Walking, Driving, Shopping, etc.
- Typically not the first referral in the rehabilitation process: but often is a crucial piece to the rehab team

NORA
NEURO-OPTOMETRIC REHABILITATION ASSOCIATION

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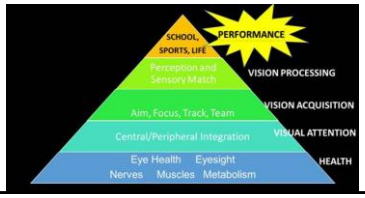
THE NEURO-OPTOMETRIC EVALUATION

- Determine the visual problems.
- Determine the visual demands.
- Determine if there is a match.
- Consult with patients and other professionals as to ways to address any mismatch neuro-optometric or otherwise.



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FROM THE AMERICAN OPTOMETRIC ASSOCIATION

Box 2: Comprehensive Eye Health and Vision Evaluation

1. Ocular Health Evaluation
   a. Anterior segment evaluation
   b. Pupillary response
   c. Posterior segment evaluation
   d. Visual field
   e. Intraocular eye pressure
2. Refractive Status
   a. Retinoscopy and Manifest Refraction
      i. Amblyogenic risk factors
         - Isometric (Hyperopia:>+5.00, Myopia:>-8.00, Astigmatism:>-2.50)
         - Anisometric (Hyperopia: >+1.00, Myopia:>-3.00 Astigmatism:>-1.50)
3. Binocular Status-Strabismic vs. Non-Strabismic
   a. Unilateral cover test to diagnose strabismic deviations (ET, XT, HyperT, HypoT)
   b. Alternating cover test to diagnose non-strabismic deviations (EP, XP, HyperP, HypoP)
4. Sensory Fusion Evaluation
   a. Suppression
      i. Worth 4 Dot
      ii. Vecto Targets
   b. Anomalous Correspondance
      i. Worth 4 Dot with unilateral cover test
      ii. Bagolini Lenses
      iii. Maddox Rod
5. Motor Fusion
   i. Vergence Ranges at Distance and Near-Base In, Base Out, Base Up, and Base Down
6. Stereopsis-Distance and Near
7. Accommodation
   i. Accommodative Amplitudes OD, OS
   ii. Negative Relative Accommodation (NRA)
   iii. Positive Relative Accommodation (PRA)
   iv. +2.00/-2.00 Accommodative Flipper Facility Testing
   v. Monocular Estimation Method (MEM)/Fused Cross Cylinder (FCC)
8.) Oculomotor Testing
   i. Saccades
   ii. Pursuits

From Cooper, J., Burns, C., Cotter, S., Daum, K., Griffin, J., & Scheiman, M. Optometric Practice Guideline Care of the Patient with Accommodative and Vergence Dysfunction (18th ed.). St. Louis, MO: American Optometric Association; 2011:50-57.
Rouse M, Cooper J, Cotter S, Press L, Tannen B. Optometric Clinical Practice Guideline Care of the Patient with Amblyopia. *American Optometric Association*. 2004: 1-54.

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THE NEURO-OPTOMETRIC EVALUATION

1. Extensive Case History
2. Visual Acuity (D & N)
3. Dynamic Visual Acuity
4. Ocular health exam
5. Refraction
6. Visual Field assessment
7. Cover test (D & N) and in all fields of gaze
8. Sensory fusion (Worth 4 Dot)
9. Near Point of Convergence
10. Red lens near point of convergence

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THE NEURO-OPTOMETRIC EVALUATION

11. Comfort point of convergence
12. Stereopsis (Depth Perception)
13. Vergence Ranges (D & N)
14. Standardized oculomotor testing (DEM or KD Test)
15. Pursuits and Saccades
16. Accommodative Abilities
17. Visual Midline Shift test
18. Spatial Localization
19. Posture/Gait evaluation (out of the exam room)
20. Visual Neglect

98

THE NEURO-OPTOMETRIC EVALUATION

21. Visual information processing
    - Motor-Free Visual Perceptual Test, Third Edition (MVPT-3)
    - The Test of Visual Perceptual Skills, Third Edition (TVPS-3)
    - Wach's Cognitive Battery
22. Visual motor integration
    - Beery VMI
    - Motor Speed/Motor Precision

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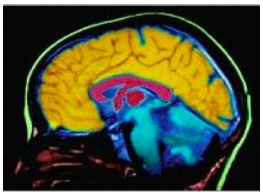
THE NEURO-OPTOMETRIC EVALUATION

- Like other rehab professionals, evaluations consider the patents ability, skill, and endurance

100

WHO CAN BENEFIT FROM A NEURO-OPTOMETRIC EVALUATION?

- Concussion
- Acquired brain injury
- Stroke
- Multiple Sclerosis
- Cerebral Palsy
- Brain Tumor
- Developmental disorders
- Dizzy patients



101

COMMON FINDINGS WITH AN ABI

- Many patients with head injury have characteristic visual sequelae
- These include problems with field of vision loss, headaches, spatial localization, reduced cognitive abilities and concentration, balance difficulties, and difficulty visual motor tasks
- Treating vision must be considered along with PT, OT and ST, if the patient is going to make a good recovery

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COMMON FINDINGS WITH AN ABI

- They have a disconnect between the 80% oculomotor and 20% proprioceptive
- After a neurological event, a vision dysfunction will directly influence posture, balance and movement
- If there is a mismatch between vision and sensorimotor information, balance, posture, movement and spatial orientation dysfunctions will arise (hallucinations, false sense of movement, etc)
- After a vision impairment, patients may experience anxiety, loss of independence, decreased socialization

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CONVERGENCE INSUFFICIENCY SYMPTOM SURVEY (CISS)

- Developed with over 20 years of NEI/NIH research: Published with CITT Study in 2008.
- Now using for research with attention and reading.
- CI or Convergence Insufficiency is the number one visual problem found with TBI and concussion patients.
- Referral if:
  - Double vision or
  - Total Score > 16 in kids
  - >21 in adults
- https://wowvision.net/wp-content/uploads/2014/08/CI-Screening-and-symptom-survey.pdf

Clinician Instructions: Read the following subject instructions and then each item exactly as written. If subject responds with "yes" - please qualify with frequency choices. **Do not give examples.**
Subject Instructions: Please answer the following questions about how your eyes feel when reading or doing close work.

		None	Hardly ever / often / sometimes	Sometimes	Fairly often	Always
1.	Do your eyes feel tired when reading or doing close work?					
2.	Do your eyes feel uncomfortable when reading or doing close work?					
3.	Do you have headaches when reading or doing close work?					
4.	Do you feel sleepy when reading or doing close work?					
5.	Do you lose concentration when reading or doing close work?					
6.	Do you have trouble remembering what you have read?					
7.	Do you have double vision when reading or doing close work?					
8.	Do you see the words move, jump, swim or appear to float on the page when reading or doing close work?					
9.	Do you feel like you read slowly?					
10.	Do your eyes ever hurt when reading or doing close work?					
11.	Do your eyes ever feel sore when reading or doing close work?					
12.	Do you feel a "pulling" feeling around your eyes when reading or doing close work?					
13.	Do you notice the words blurring or coming in and out of focus when reading or doing close work?					
14.	Do you lose your place while reading or doing close work?					
15.	Do you have to re-read the same line of words when reading?					
		x 0	x 1	x 2	x 3	x 4

Total Score: ____

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BRAIN INJURY VISUAL SYMPTOMS SURVEY (BIVSS)

- Post TBI and Post Concussion Visual Visual Symptom Survey Questionnaire
- 2016 Research on Validity:
  - A promising tool for better understanding the complex and diverse nature of vision symptoms that are associated with brain injury
- Useful for referrals
- https://noravisionrehab.org/uploads/media/brain_injury_vision_symptom_survey.pdf

Please rate each behavior. **How often does each behavior occur?** (circle a number)	Never	Seldom	Occasionally	Frequently	Always
EYESIGHT CLARITY					
Distance vision blurred and not clear – even with lenses	0	1	2	3	4
Near vision blurred and not clear – even with lenses	0	1	2	3	4
Clarity of vision changes or fluctuates during the day	0	1	2	3	4
Poor night vision / can't see well to drive at night	0	1	2	3	4
VISUAL COMFORT					
Eye discomfort / sore eyes / eyestrain	0	1	2	3	4
Headaches or dizziness after using eyes	0	1	2	3	4
Eye fatigue / very tired after using eyes all day	0	1	2	3	4
Feel "pulling" around the eyes	0	1	2	3	4
DOUBLING					
Double vision – especially when tired	0	1	2	3	4
Have to close or cover one eye to see clearly	0	1	2	3	4
Print moves in and out of focus when reading	0	1	2	3	4
LIGHT SENSITIVITY					
Normal indoor lighting is uncomfortable – too much glare	0	1	2	3	4
Outdoor light too bright – have to use sunglasses	0	1	2	3	4
Indoors fluorescent lighting is bothersome or annoying	0	1	2	3	4
DRY EYES					
Eyes feel "dry" and sting	0	1	2	3	4
"Stare" into space without blinking	0	1	2	3	4
Have to rub the eyes a lot	0	1	2	3	4
DEPTH PERCEPTION					
Clumsiness / misjudge where objects really are	0	1	2	3	4
Lack of confidence walking / missing steps / stumbling	0	1	2	3	4
Poor handwriting (spacing, size, legibility)	0	1	2	3	4
PERIPHERAL VISION					
Side vision distorted / objects move or change position	0	1	2	3	4
What looks straight ahead—isn't always straight ahead	0	1	2	3	4
Avoid crowds / can't tolerate "visually-busy" places	0	1	2	3	4
READING					
Short attention span / easily distracted when reading	0	1	2	3	4
Difficulty / slowness with reading and writing	0	1	2	3	4
Poor reading comprehension / can't remember what was read	0	1	2	3	4
Confusion of words / skip words during reading	0	1	2	3	4
Lose place / have to use finger not to lose place when reading	0	1	2	3	4

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Occurrence of oculomotor dysfunctions in acquired brain injury: A retrospective analysis

Kenneth J. Ciuffreda, O.D., Ph.D., Neera Kapoor, O.D., M.S., Daniella Rutner, O.D., M.S., Irwin B. Suchoff, O.D., D.O.S., M.E. Han, O.D., and Shoshana Craig, O.D.

State University of New York State College of Optometry, Raymond J. Greenwald Rehabilitation Center, New York, New York.

KEYWORDS
Acquired brain injury; Traumatic brain injury; Cerebrovascular accident; Stroke; Oculomotor dysfunction; Strabismus; Accommodation; Eye movements; Cranial nerve palsy

Abstract
BACKGROUND: The purpose of this retrospective study was to determine the frequency of occurrence of oculomotor dysfunctions in a sample of ambulatory outpatients who have acquired brain injury (ABI), either traumatic brain injury (TBI) or cerebrovascular accident (CVA), with associated vision symptoms.
METHODS: Medical records of 220 individuals with either TBI (n = 160) or CVA (n = 60) were reviewed retrospectively. This was determined by a computer-based query spanning the years 2000 through 2003, for the frequency of occurrence of oculomotor dysfunctions including accommodation, version, vergence, strabismus, and cranial nerve (CN) palsy.
RESULTS: The majority of individuals with either TBI (90%) or CVA (86.7%) manifested an oculomotor dysfunction. Accommodative and vergence deficits were most common in the TBI subgroup, whereas strabismus and CN palsy were most common in the CVA subgroup. The frequency of occurrence of versional deficits was similar in each diagnostic subgroup.
CONCLUSION: These new findings should alert the clinician to the higher frequency of occurrence of oculomotor dysfunctions in these populations and the associated therapeutic, rehabilitative, and quality-of-life implications.
Optometry 2007;78:155-161

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2007, RETROSPECTIVE STUDY OF 200 CHARTS

- TBI
  - 41.3% accommodative dysfunction (insufficiency)
  - 56.3% vergence dysfunction (convergence insufficiency)
  - 51.3% ocular motility dysfunction (deficits of saccadic eye movements)
- CVA
  - 12.5% accommodative dysfunction (infacility)
  - 56.7% vergence dysfunction (convergence insufficiency)
  - 56.7% ocular motility dysfunction (deficits of saccadic eye movements)
  - 36.7% strabismus at far

Ciuffreda KJ, Kapoor N, Rutner D, Suchoff IB, Han ME, Craig S. Occurrence of Oculomotor Dysfunctions in Acquired Brain Injury: A retrospective analysis. Optometry 2007; 78: 155-161.

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CONCUSSION

- An estimated 3.8 million sports and recreation related head trauma annually in the United States
- US emergency departments treat an estimated 135,000 sports- and recreation-related head trauma annually
- Concussion from falls in the elderly and the workforce occur at a much higher incidence than in sports-related activities
- It's estimated that >50% of adolescents athletes will sustain a concussion by the time they graduate from high school

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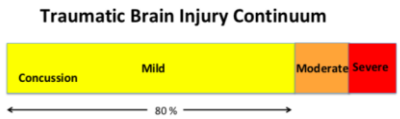
MTBI VS CONCUSSION

- Traumatic Brain Injury Continuum
- All concussions are a mTBI but not all mTBI's are a concussion



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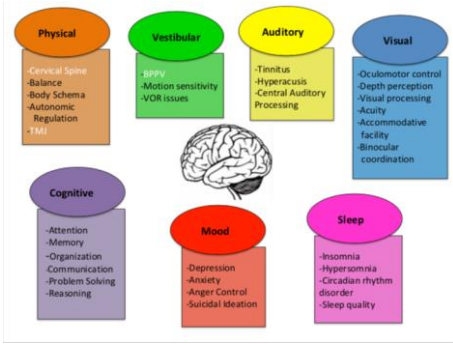
IDENTIFYING THE MTBI SUBGROUPS



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Symptom	Physical	Auditory	Cognition	Sleep	Vision	Mood	Vestibular
Headache	●	○	●	●	●	●	●
Fatigue	●	○	●	●	●	●	●
Dizziness	●	○		●	●		●
Sensory Sensitivity		○		●	●	●	●
Confusion		○	●	●	●	●	●
Exercise Intolerance	●			●	●	●	●
Brain Fog			●	●	●	●	●
Nausea	●				●		●
Trouble Reading			●	●	●		
Social Isolation	●	○	●	●	●	●	●
Screen Intolerance				●	●		
Trouble speaking		○	●	●	●		

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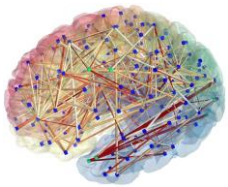
ALTERED NETWORK CONNECTIVITY = INEFFICIENCY

- INEFFICIENCY
  - You can't filter sensory stimulus
  - You can't easily maintain your balance and move through your environment
  - You can't use multiple systems at the same time
  - You get easily fatigued



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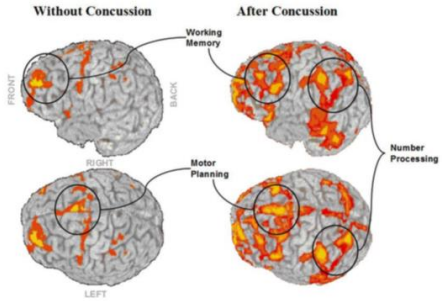
mTBI & Mental Subtraction



http://www.ccs.fau.edu/section_links/HBBLv2/Research/MTBI.html

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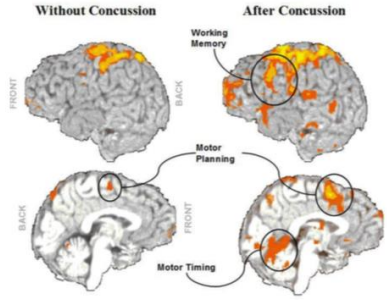
mTBI & Rt finger sequencing task



http://www.ccs.fau.edu/section_links/HBBLv2/Research/MTBI.html

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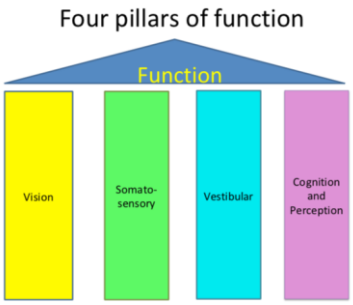
VISION DISORDERS AFTER A BRAIN INJURY



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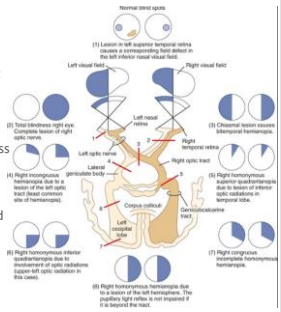
VISUAL FIELD DEFECTS (SENSORY DEFICIT)

- Area of visual field loss WILL BE seen on testing
- Lesions along these pathways— Physical representation of the neurological insult
- Respects neural anatomy
- Patient symptoms:
  - Aware of area involving visual field loss
  - Compensatory mechanisms are in place
  - Erratic eye movements in area of field loss



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OCULOMOTOR DISORDERS

- Accommodative Dysfunctions
- Binocular Vision Dysfunctions
- Saccadic Dysfunctions
- Pursuits Dysfunctions
- Visual-Vestibular Dysfunctions
- Nystagmus

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ACCOMMODATIVE DYSFUNCTION

- Patient symptoms
  - Blurred near vision
  - Fatigue with near work
  - Headaches and asthenopia with near work
  - Slow shift of focus from near to far to near
  - Difficulty with attention and concentration when reading
- Most common diagnosis after TBI
  - Accommodative Insufficiency
  - Prevalence: 41.1% (normal population: ~5%)
- Most common diagnosis after CVA
  - Accommodative Infacility
  - Prevalence: 12.5% (normal population: ~5%)

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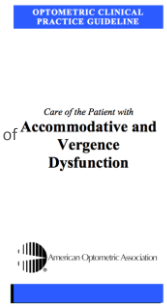
ACCOMMODATIVE DYSFUNCTION

- Accommodative Dysfunction
  - Accommodative Insufficiency
    - Accommodative insufficiency occurs when the amplitude of accommodation (AA) is lower than expected for the patient's age and is not due to sclerosis of the crystalline lens. Patients with accommodative insufficiency usually demonstrate poor accommodative sustaining ability.



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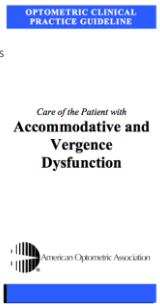
ACCOMMODATIVE DYSFUNCTION

- Accommodative Dysfunction
  - Ill-Sustained Accommodation
    - A condition in which the AA is normal, but fatigue occurs with repeated accommodative stimulation.
  - Accommodative Infacility
    - Accommodative infacility or accommodative inertia occurs when the accommodative system is slow in making a change, or when there is a considerable lag between the stimulus to accommodation and the accommodative response.15 The patient often reports blurred distance vision immediately following sustained near work. Some have considered this infacility to be a precursor to myopia. Accommodative and Vergence Dysfunction



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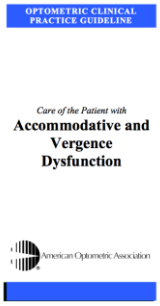
ACCOMMODATIVE DYSFUNCTION

- Accommodative Dysfunction
  - Paralysis of Accommodation
    - A rare condition in which the accommodative system fails to respond to any stimulus. It can be caused by the use of cycloplegic drugs, or by trauma, ocular or systemic disease, toxicity, or poisoning. The condition, which can be unilateral or bilateral, may be associated with a fixed, dilated pupil.
  - Spasm of Accommodation
    - The result of overstimulation of the parasympathetic nervous system, spasm of accommodation may be associated with fatigue. It is sometimes part of a triad (overaccommodation, overconvergence, and miotic pupils) known as spasm of the near reflex (SNR). This condition may also result from other causes, such as the use of either systemic or topical cholinergic drugs, trauma, brain tumor, or myasthenia gravis.



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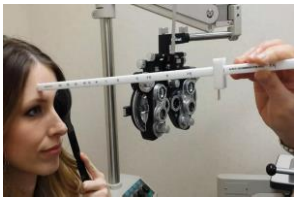
ACCOMMODATIVE DYSFUNCTION - OT SCREENING

- Expectations are age dependent
- Monocular Amplitudes to screen for accommodative insufficiency and ill-sustained accommodation
- **Push Up Method**
- Materials
  - High contrast, black and white near point card with print size 0.6M
  - Patient's habitual glasses
  - Occluder



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ACCOMMODATIVE DYSFUNCTION - OT SCREENING

- "You can now see a recognizable single number before your right eye (40cm), we will slowly bring it closer towards the eye. You should try and keep seeing the figure clear (with no blur). As soon as you reach a point where the number is blurred and stays blurred (sustained blur), tell us. Please note that this does not necessarily mean that you will not recognize the number."
- This is performed four times on each eye, with different numbers and an average is calculated. Monitor for fatigue!
- Goal for **minimum** amplitude is 15-1/4(age). Failure to meet minimum amps or scores that worse with repeated testing indicates a referral to neuro-optometry is warranted.

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BINOCULAR VISION DYSFUNCTIONS

- Patient symptoms
  - Asthenopia and headaches
  - Poor spatial awareness
  - Intermittent diplopia or blur at distance and/or near
  - Symptoms worse at the end of the day
  - Difficulty with reading (vergence dysfunction at near)
- Lead to a loss of one or all levels of stereopsis (depth perception)

Double vision makes it difficult to read and comprehend.

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BINOCULAR VISION DYSFUNCTIONS

- Most common diagnosis after TBI
  - Convergence Insufficiency
  - Prevalence: 56.3%, (normal population: 2-8%)
- Most common diagnosis after CVA
  - Convergence Insufficiency
  - Prevalence: 36.7%, (normal population: 2-8%)

Convergence Insufficiency can make text look double when trying to read

Some people with Convergence Insufficiency experience a 'halo effect' instead of double vision

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BINOCULAR VISION DYSFUNCTIONS

- Strabismus

Box 4: Classification of Strabismus

Age of Onset
- Congenital/infantile (postnatal to 6 months)
- Early Onset (6 months to 36 months)

Constancy
- Constant
- Intermittent
- Accommodative

Location
- Distance
- Near

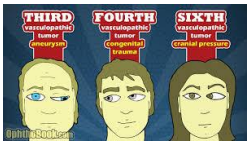
Laterality
- Unilateral
- Alternating

Directionality
- Esotropia/Exotropia
- Hypertropia/Hypotropia
- Incyclotropia/Excyclotropia

Magnitude
- Microtropia (up to 4PD)
- Small-angle strabismus (4 to 9PD)
- Moderate-angle strabismus (10 to 30 PD)
- Large angle strabismus (>30PD)

Correspondence
Comitancy
Organicity (association with disease)

From Press, L. J. Applied concepts in vision therapy. Santa Ana, CA: Optometric Extension Program Foundation; 2008:90.



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BINOCULAR VISION DYSFUNCTION

- Strabismus
- Patient symptoms
  - Double or blurred vision
  - Difficulty navigating through space
- Most common type after a TBI
  - Strabismus at near
  - Prevalence: 25.6%
- Most common type after a CVA
  - Strabismus at far
  - Prevalence: 36.7%
- Most common type of palsy after a TBI
  - CN III Palsy
  - Prevalence: 6.9%
- Most common type of palsy after a CVA
  - CN III Palsy
  - Prevalence: 10%

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BINOCULAR VISION DYSFUNCTIONS

- Non-Strabismic Binocular Dysfunctions
  - Direction = Posture of eyes
    - Esophoria
      - Eyes have an inward tendency
    - Exophoria
      - Eyes have an outward tendency
  - Vertical Heterophoria
    - One eye has a tendency to turn up or down

Table I
Modified Duane Classification System*

Convergence insufficiency	X < X' Low AC/A ratio Receded near point of convergence Reduced fusional convergence
Divergence excess	X > X' High AC/A ratio High tonic exophoria Large exophoria/tropia at distance
Basic esophoria	X = X' Normal AC/A ratio
Convergence excess	E < E' High AC/A ratio
Divergence insufficiency	E > E' Low AC/A ratio High tonic esophoria
Basic esophoria	E = E' Normal AC/A ratio
Vergence insufficiency	Normal AC/A ratio Restricted fusional vergence amplitudes Steep fixation disparity curve
Vertical phorias	Comitant deviations Noncomitant deviations • Old decompensated 4th nerve palsies • Newly acquired 4th nerve palsies

X = exophoria at distance; E = esophoria at distance;
X' = exophoria at near; E' = esophoria at near.

*Modified from Duane A. A new classification of the motor anomalies of the eye, based on physiologic principles. Part 2. Pathology. Ann Ophthalmol Otolaryngol 1897; 6:247-60.

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BINOCULAR VISION DYSFUNCTIONS

- Non-Strabismic Binocular Dysfunctions
  - Can also be classified based on the relationship between the magnitude of the phoria at distance and the magnitude of the phoria at near
  - Distance to Near Relationship
    - Magnitude equal at distance and near:
      - Basic esophoria
      - Basic exophoria
    - Magnitude greater at distance:
      - Divergence excess (exophoria)
      - Divergence insufficiency (esophoria)
    - Magnitude greater at near:
      - Convergence insufficiency (exophoria)
      - Convergence excess (esophoria)

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BINOCULAR VISION DYSFUNCTIONS – OT SCREENING

- Red/Green Near Point of Convergence
- Evaluate the ability of the two eyes to work together, following a light that approaches their nose.
- Materials:
  - Patient's Habitual Near Glasses
  - Pen Light
  - RED/GREEN glasses
- Note the distance when two lights are seen, greater than 4-5 inches suggests Convergence Insufficiency and a referral to neuro-optometrist is warranted

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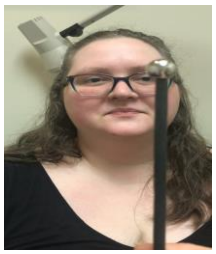
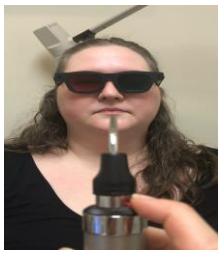
BINOCULAR VISION DYSFUNCTIONS – OT SCREENING





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BINOCULAR VISION DYSFUNCTIONS - OT SCREENING

- Comfort Point of Convergence
- Determine point discomfort for performing near work
- Materials:
  - Patient's Habitual Near Glasses
  - Non-accommodative target
- Note the distance where the patient first reports their eyes are straining, greater than 10 inches and a referral to neuro-optometrist is warranted
- NOTE: During any convergence techniques, blur points occur at the end of focal processing abilities, break points occur at the end of ambient function, and recovery points show the resilience off the system

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BINOCULAR VISION DYSFUNCTIONS - OT SCREENING

- Brock String
  - Patient wears habitual lenses
  - Ask the patient to look at a bead at 16 inches. "What do you notice while looking at the bead" They should report an X. "While looking at the bead and noticing the strings, where the strings cross?"
    - In front of the bead = esophoria
    - Behind the bead = exophoria
  - "Are the strings equal heights?"
    - No= vertical heterophoria
  - Any report of parts of the string, missing, flickering, a Y or an upside down Y indicate a referral to neuro-optometry is warranted. Any overt strabismus, an esophoria, an exophoria or a vertical heterophoria indicate a referral to neuro-optometry is warranted.

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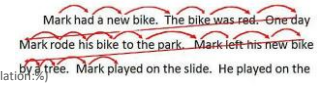
SACCADIC & PURSUIT DYSFUNCTIONS

- Patient symptoms
  - Loss of place and/or omission of words when reading
  - Difficulty visually tracking objects
  - Reduced efficiency and productivity
  - Poor attention span/easy distractibility
  - Dizziness or Motion Sensitivity
- Most common diagnosis after TBI
  - Saccadic Deficiencies
  - Prevalence: 51.3%, (normal population: 2%)
- Most common diagnosis after CVA
  - Saccadic Deficiencies
  - Prevalence: 56.7%, (normal population: 2%)



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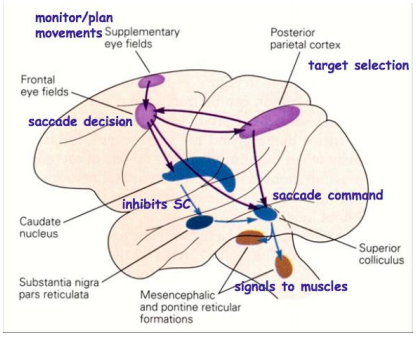
NEURAL NETWORKS OF SACCADIC FUNCTION



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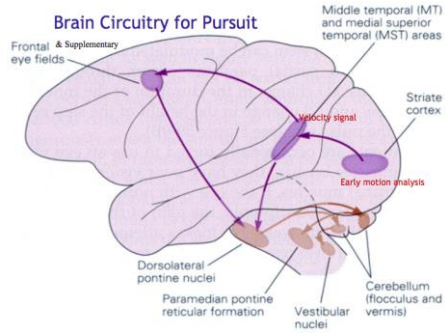
NEURAL NETWORKS OF PURSUIT FUNCTION



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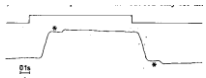
SACCADIC & PURSUIT DYSFUNCTIONS

- Hypometric Saccades



- Hypermetric Saccades

- Saccadic Intrusio

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VISUAL-VESTIBULAR DYSFUNCTION

- In collaboration with a Vestibular PT…
- Dysfunctions between visual skills and the VOR
- Patient symptoms:
  - Dizziness
  - Blurred vision
  - Nausea
  - Difficulty with dynamic environments

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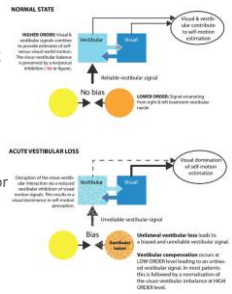
VISUAL-VESTIBULAR DYSFUNCTION

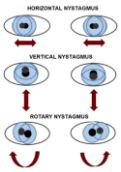
- Vestibular origin?
  - The brain becomes more 'visually dependent' for the sensory monitoring of locomotion and spatial orientation
- Visual origin?
  - **Focal binding**, ambient dysfunction
  - Symptoms triggered in visually-busy environments such as shopping malls or supermarkets
- Both?



139

NYSTAGMUS

- A repetitive movement of the eyeball during which the eye seems to drift off target and then quickly corrects to re-gaze at the target
- Causes considerable reduction of visual clarity as well as a sense of dizziness
- Deficits are likely indicative of brainstem damage or cerebellar damage
- Communicate with Vestibular PT to rule out vestibular nystagmus



140

DISRUPTED SENSORY COHERENCE

- All of these functional visual problems are disorders due to disrupted ambient/focal processing!
- Proactive affect of vision and motor are compromised
- Problems with communication
- Affects memory
- Focal binding compromises preconscious, proactive relationship between ambient and motor
- Movement becomes conscious (top down) and isolates function (lack of automaticity)
- No fluency because the system is unable to anticipate (i.e. reading, etc.)

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DISRUPTED SENSORY COHERENCE

- Focal Binding, Abnormal Ambient vision
  - Causes inability to release detail
  - Environment becomes over stimulating
  - Movement in the environment (busy, crowded) becomes chaos to the visual system
  - Print on page becomes a mass of detail
  - Movement of the eyes is projected into the field causing movement of print or ground being walked on

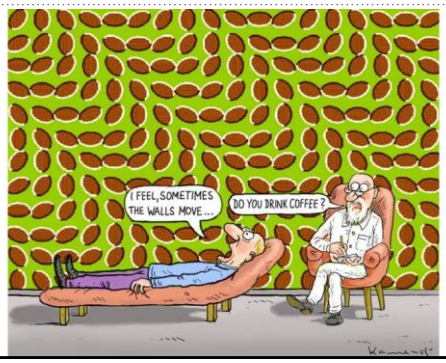
142

DISRUPTED SENSORY COHERENCE

- Affects postural tone!
- An ABI causes a breakdown in the CNS and automatic responses which links with the pre-conscious nature of the visual process (ambient!)
- Stationary objects appear to move
- Attempting to walk on a floor that looks tilted
- Difficulty maneuvering in crowded, moving environments
- Patients are often told that their eyes are healthy and its not their eyes!!
- Anxiety is heightened

143

DORSAL & VENTRAL PROCESSING (DEMO)



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VISUAL-SPATIAL PROCESSING DEVICE

- http://fnrejournal.com/index.php/FNRE/article/view/31/25?fbclid=I

CASE STUDY

The Brain Is Primarily A Visual-Spatial Processing Device: Altering Visual-Spatial Cognitive Processing Via Retinal Stimulation Can Treat Movement Disorders

Clark Elliott

Abstract

This paper presents portions of a ten-year self-reporting case study relative to movement, based on my book, "The Ghost In My Brain." As an artificial intelligence and cognitive science professor I took 1200 pages of detailed notes over the course of eight years, of the effects of mTBI, with no expectation of recovery. Symptoms included many deficits in movement: significant and varied balance difficulties; loss of where the body ends yielding, e.g., difficulty passing through doorways; loss of spatial relationships; catatonia, including progressive inability to initiate motion under brain stress; ability to it hard, e.g., to put keys in locks; inability to turn right; the "dolly zoom effect" when walking toward a distant goal; and so on. A clear pattern arises: when the mind cannot conceive spatial relationships, the body will not move. During eight years that included MRI, CT scan, neurocognitive testing, etc., medical science was consistent in the opinion that I would never improve and should learn to live with my symptoms. After neuro-developmental optometric treatment via retinal stimulation and cognitive restructuring using visual puzzles, all cognitive and movement abnormalities were

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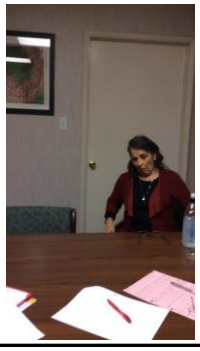
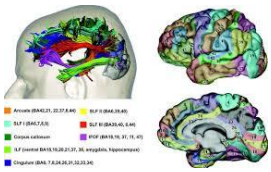
VISUAL-SPATIAL PROCESSING DEVICE



146

PERCEPTUAL DEFICITS

- Visual Neglect
- Visual Midline Shift Syndrome
- Visual Information Processing Dysfunctions
- Agnosias



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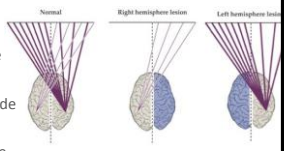
VISUAL NEGLECT

- Area of visual field loss will NOT BE seen on visual field testing
- Usually due to CVA of the right inferior posterior parietal lobe
- Epidemiology:
  - Occurs in 25-30% of all stroke affected individuals
  - ~3-5 million per year worldwide
  - **~90%** of patients with visual neglect have right hemisphere injury



148

VISUAL NEGLECT

- Several synonyms for neglect: unilateral spatial inattention, spatial neglect
- Lack of awareness for sensory events located toward the contralesional side of space
- Behave as if half their world does not exist
- Patient symptoms:
  - Can affects personal, peri-personal, and/or extra-personal space
- NO COMPENSATORY MECHANISMS in place

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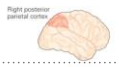
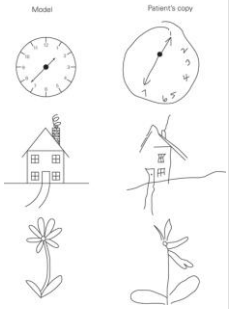
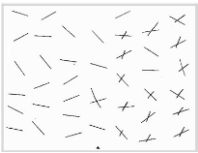
VISUAL NEGLECT



- Paired with a visual field test….
- Line Bisection Test— the patient is asked to mark the centre of a line
- Copy Forms — ask the patient to make their images look like your images

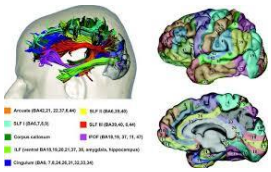




150

PERCEPTUAL DEFICITS

- Visual Neglect
- Visual Midline Shift Syndrome
- Visual Information Processing Dysfunctions
- Agnosias



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VISUAL MIDLINE SHIFT SYNDROME

- Patient Symptoms
  - Floor or walls may appear tilted and appear to shift and move
  - Veering during mobility
  - Person may lean away from the affected side
  - Feelings of imbalance or disorientation similar to vertigo… a sense of being "out of sync" with the environment

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VISUAL MIDLINE SHIFT SYNDROME

- Mismatch between the perceived peripheral vision processing and the actual neuro-motor midline
- Causes an expansion on one side and a contraction on the opposite side
- May be caused by:
  - Dysfunction of ambient visual processing due to lack of sensory coherence at the level of the midbrain
  - Oculomotor imbalance
  - Spatial shifts caused by unilateral hemispheric damage

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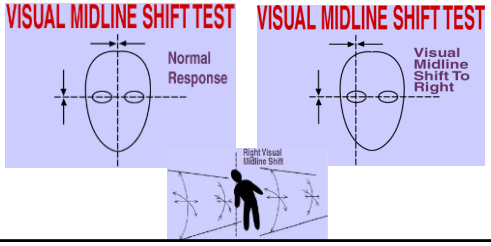
VISUAL MIDLINE SHIFT SYNDROME

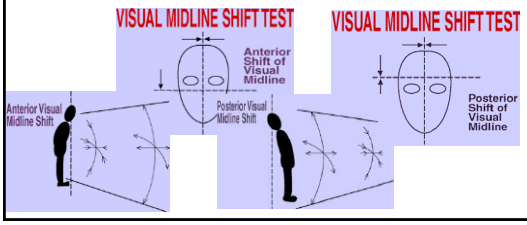
- Screening: Head straight, turn eyes to look at pen, follow pen as it move from left to right or right to left and note where patient reports pen is directly in front of nose. Repeat from both sides.



154

VISUAL MIDLINE SHIFT SYNDROME

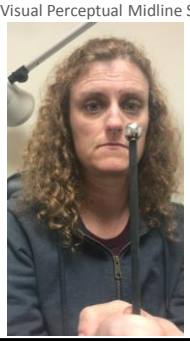
- Repeat from top to bottom of face, noting when pen is directly in front of eyes and note whether the pen is below eyes or above eyes = Anterior/Posterior VMLS
- Presence of visual midline shift indicates a referral to neuro-optometry is warranted



155

VISUAL MIDLINE SHIFT SYNDROME

- Focal and Ambient Visual Perceptual Midline Shift video



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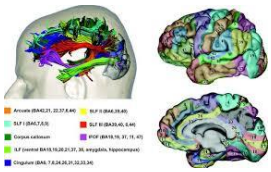
PERCEPTUAL DEFICITS

- Visual Neglect
- Visual Midline Shift Syndrome
- Visual Information Processing Dysfunctions
- Agnosias



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VISUAL INFORMATION PROCESSING DEFICITS & AGNOSIA

- After ruling out functional vision issues…
- Slower information processing speed
- Visuo-spatial deficits
  - Figure-ground discrimination
  - Visual closure
  - Form perception
  - Spatial orientation
  - Right-left discrimination
  - Spatial manipulation
  - Analysis of visual information
  - Visualization

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VISUAL INFORMATION PROCESSING DEFICITS & AGNOSIA

- Deficits in divided attention
- Impairment of focused attention
- Inconsistency of performance Working memory
  - Inability to hold information over short periods of time
  - Needed to remember new information, follow directions, for complex reasoning

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VISUAL INFORMATION PROCESSING DEFICITS & AGNOSIA

- Agnosias
  - Prosopagnosia (inability to recognize faces)
  - Color agnosia (difficulty associating colors with objects)
  - Color Anomia (inability to name colors)
  - Visual Spatial agnosia (difficulty with stereoscopic vision & topography)
  - Akinetopsia (difficulty with motion perception)

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PHOTOPHOBIA (MOTOR, SENSORY & PERCEPTUAL DEFICIT?)

- Photophobia is most severe 7-19 days after an injury but can last up to 6 months after a concussion (or more)
- Fluorescent lights can be especially problematic due to the invisible flicker given off by fluorescent bulbs which is indiscernible to the eye but picked up the brain
- Blue light (UV) can cause of worsen ABI-related symptoms
- Research teams hypothesize that anomalous cortical or subcortical regulation responses to changes in illumination (ipRGCs?) and visual-spatial patterns, possibly mediated by the dorsal visual pathway, may be contributing to the perception of photosensitivity

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PHOTOPHOBIA (MOTOR, SENSORY & PERCEPTUAL DEFICIT?)

- Another theory posed research teams is based on the concept of "visual stress", which results from the visual symptoms after an ABI
- The hypothesis is that the underlying the visual stress from the associated visual perceptual distortions occur in response to a spread of cortical hyperexcitability, which may result in inappropriate firing of neurons related to visual processing and perception
- **Prevalence: 57.8% (normal population: 10%)**

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MANAGEMENT OPTIONS

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STARTING ANY THERAPY….

- The patient needs an anchor—or grounding—"I do not know where it is in space—I do not know where I am in space"
- Without technology
  - Bi-nasal occlusion/sector patching
  - Compression—vest/beans bags on shoulder
  - Tight t-shirt
  - Thera band
- With technology
  - Low plus (+0.50)/micro prism (BI/BO)
  - Yoked prism
  - Tints/filters

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STARTING ANY THERAPY….

- The neck is an important structure that can be overlooked
- Neck stabilizes the chin which allows eyes to have a stable platform
- Visual scanning must be supported by head and neck rotation
- Triad: Vestibulospinal reflex (VSR), Vestibulocolic reflex (CVR), vestibuloocular reflex (VOR)
- Refer to PT to clear or treat cervical spine dysfunction

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NON VISUAL TREATMENT STRATEGIES

- Sleep
  - Sleep hygiene, melatonin, MagCalm
- Pacing and planning (OTs)
  - Subsymptomatic graded activity, ideas for non provoking activities (audiobooks, podcasts)
- Headaches
  - Medication, acupuncture, craniosacral therapy, cervical spine treatment
- Noise sensitivity
  - Musician filter ear plugs, graded exposure, Integrated Listening Program
- Anxiety
  - Mindfulness, craniosacral, Tai Chi

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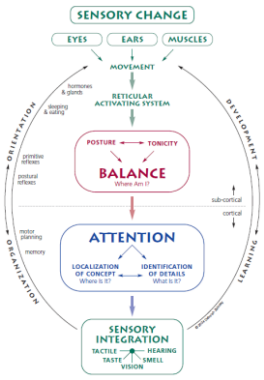

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RESTORING SENSORY COHERENCE

- Objective Versus Subjective
  - Right eye versus left eye
  - Visual versus auditory input
  - Visual versus vestibular input
- Conscious effort must be used for activities that are normally subconscious
  - Have to think about where you're going, how to maneuver, how far away something is and make a calculated motion
  - Lowers efficiency

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NEURO-OPTOMETRIC TREATMENT/MANAGEMENT

- IN CLOSE COLLABORATION WITH OTHER DISCIPLINES
- Modifying the visual input
  - Lenses
  - Prisms
  - Filters
- Vision Rehabilitation
  - Binocularity
  - Ocular Motility
  - Spatial Awareness
  - Visual Information Processing

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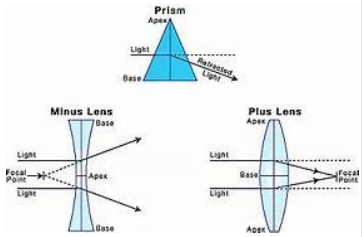
MODIFYING THE VISUAL INPUT: LENS AND PRISMS

- Diagnostic
- Compensatory
- Task Specific
- Therapeutic
  - Developmental
  - Stress-Relieving
  - Performance



170

MODIFYING THE VISUAL INPUT: LENS AND PRISMS

- The role of the lens— Compensatory and/or Task Specific
  - Refractive correction (Distance, Near, Computer, PAL)
  - Fresnel Prism
  - Tints

171

MODIFYING THE VISUAL INPUT: LENS AND PRISMS

- The role of the lens— Compensatory and/or Task Specific
  - Tints
    - Blue
      - Shorter wavelength—calming
      - Increases parasympathetic and increases accommodation
  - Yellow
    - Longer wavelength—stimulating
    - Increasing sympathetic and decreases accommodation

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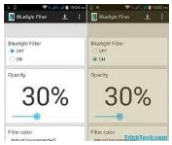
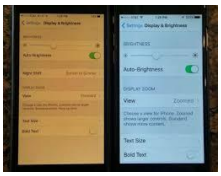
OTHER COMPENSATORY METHODS

- Strategies to reduce visual noise
  - **COLORED OVERLAYS**
    - https://irlen.com/colored-overlays/
- F.lux – blue light filter for computer
- Night Shift –iOS only
- Android blue light filter





173

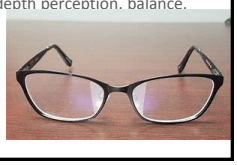
OTHER COMPENSATORY METHODS: OCCLUSION

- Total Occlusion
  - If possible, total occlusion should be avoided!!
  - Only an appropriate treatment if no other strategy is successful (lenses, prisms, partial occlusion, etc)
- Partial Occlusion
  - Utilized with intermittent diplopia

174

OTHER COMPENSATORY METHODS: BINASAL OCCLUSION

- Reduces visual "noise"
- Can treat visual midline shift syndrome
- Diplopia management
- Emphasize peripheral awareness and facilitate central peripheral integration
- Can cause immediate improvement in depth perception, balance, eyesight, etc
- Reduces car sickness, imbalance, etc



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OTHER COMPENSATORY METHODS: BINASAL OCCLUSION

- Treatment of visual midline shift syndrome (must integrate perceptual midline with active therapy)
- Before and after medial occlusion
- Spatial Localization in Vision Rehabilitation

176

OTHER COMPENSATORY METHODS

- Strategies to reduce visual noise
  - Reduce clutter in workspace
  - Solid, non-print background (and clothes)
  - Visors or hats while shopping
- Natural or incandescent lights
- Eliminate glaring surfaces

177

TREATING NYSTAGMUS

- Starts with an assessment of whether or not there is a particular position of gaze where the nystagmus reduces
- If this is seen, specialized lenses may be prescribed incorporating yoked prism, allowing for improved head/body posturing and ultimately improved balance
- Binasal occlusion are can be effective in reducing symptoms
- Referral to Vestibular PT to look for vestibular dysfunctions
- Vision rehabilitation therapy to improve eye movement control and to teach compensatory strategies

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MODIFYING THE VISUAL INPUT: LENS AND PRISMS

- The role of the lens— Therapeutic
  - Improve visual regulation or reduce visual stress
  - Aid accommodation
  - Aid spatial awareness
  - Aid peripheral awareness
  - Aid central-peripheral integration

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MODIFYING THE VISUAL INPUT: LENS AND PRISMS

- Change light energy entering the eyes and brain.
- Change the way the brain processes visual input (Influence visual motor to guide visual sensory)
- Effects a change in the output of vision and other sensory/motor systems.
- Creates a change in perception… Guide projection to equal perception
- Improve visual grasp, release and manipulation
- Allows for improved attention and awareness.
- Alter gait or movement
- Influence symmetrical posture
- Increase reading speed
- Change can be immediate…and profound.

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MODIFYING THE VISUAL INPUT: YOKED PRISMS

- Yoked prism is used to modify environmental awareness by causing an image shift toward the apex (ventral or focal processing)
- Base down causes the perception of an image shift further, bigger, uphill
- Base up causes the perception of an image shift closer, smaller, downhill
- Base right causes the perception of an image shift expanding of space right and contraction of space left
- Base left causes the perception of an expansion of space left and a contraction of space right

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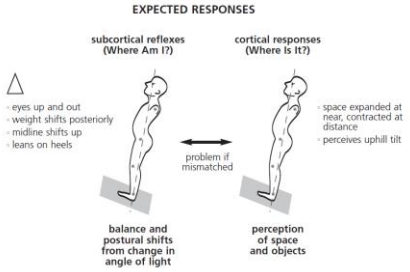
MODIFYING THE VISUAL INPUT: YOKED PRISMS

- Yoked prism is used to affect motor by causing a shift of the center of mass toward the base (dorsal or ambient processing)
- Base right, eyes look left, rotates the body left
- Base left, eyes look right, rotates the body right

182

BASE DOWN

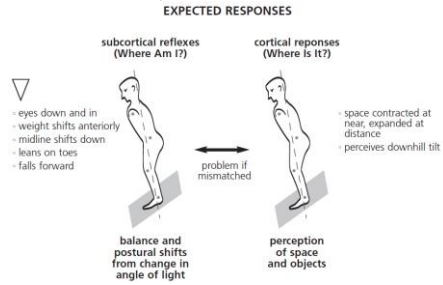
- Base down causes the eyes to look up and out, reciprocal motor reaction will cause the person to lean back on the heels



183

BASE UP

- Base up causes the eyes to look down and inward, reciprocal motor reaction will cause the person to lean forward on their toes



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MODIFYING THE VISUAL INPUT: NON-YOKED PRISMS

- Base In prism will cause objects appear further and bigger, shoulders shift back
- Base Out prism will cause objects appear closer and smaller, shoulders shift forward
- When objects appear closer to a person, the eyes pull inward inducing shoulder movement via the spinal accessory nerve, vice versa

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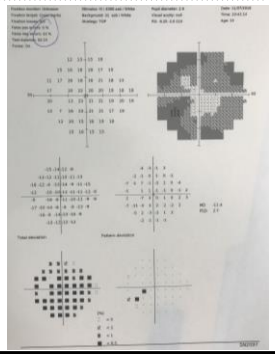
MODIFYING THE VISUAL INPUT

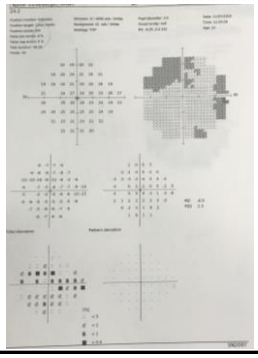
- Yoked prism



186

MODIFYING THE VISUAL INPUT

- Yoked prism



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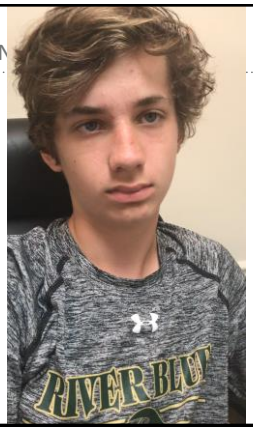
MODIFYING THE VISUAL IN

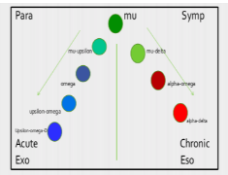
- Plus lenses



188

OPTOMETRIC PHOTOTHERAPY

- Syntonics
  - Using light to balance the Parasympathetic and Sympathetic systems



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TREATMENT OPTIONS

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TREATING PHOTOPHOBIA

- Compensatory strategies?
- Syntonics (Optometric Phototherapy)
- Dynamic therapy
  - Multi-systems therapy, vestibular, cerebellum, parietal, frontal—with saccades and eye hand coordination
- Dry eye management

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TREATING OCULOMOTOR DYSFUNCTIONS

- Standard of Care for Non-Strabismic Binocular Dysfunctions

Box 3: The AOA Clinical Guideline for Management of Non-Strabismic Binocular Dysfunctions

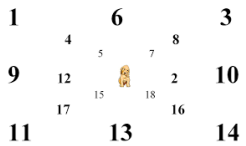
Convergence Insufficiency:
In office vision therapy along with home therapy activities is the treatment of choice
Divergence Excess:
In office vision therapy focusing on diplopia awareness with operant conditioning technique to reinforce alignment.
Occlusion, over-minus lenses, base in prism for distance
Convergence Excess:
Plus lenses for near
In office vision therapy focusing on peripheral awareness and divergence at near
Divergence Insufficiency:
Base out prism for distance
In office vision therapy focusing on peripheral awareness and divergence at distance
Binocular Vision Dysfunction:
Lenses and prism generally ineffective
In office vision therapy focusing on both convergence and divergence ranges
Vertical Heterophorias:
Base down/Base up prism
In office vision therapy focusing on increasing horizontal vergence ranges

From Cooper, J., Burns, C., Cotter, S., Daum, K., Griffin, J., & Scheiman, M. *Clinical Practice Guidelines. Care of the Patient with Accommodative and Vergence Dysfunction* (18th ed.). St. Louis, MO: American Optometric Association; 2011:50-57.

192

VISION THERAPY

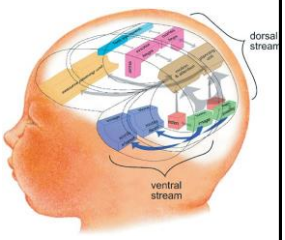
- **Structure evaluation of the eyes does not provide a complete screening or diagnostic assessment for a comprehensive understanding of the visual system!**
- **Vision is a skill. Vision learning and relearning have hierarchies that are fundamental to the development and re- establishment of visual pathways in visual perception and visual behavior**
- **Vision techniques are designed to develop specific visual skills based on individualized, objective data and are evidence based!**



193

VISION THERAPY

- We should not put focal vision exercises on a system that has had a potential brain injury.
- Building on an already challenged peripheral vision and/or vestibular/ proprioception system may cause the patient to get worse
- Start with exercises that start in the peripheral/ambient vision with vestibular components



194

VISION THERAPY

- The majority of ABI patients are "hyper" focal or focally bound
- If we start vision rehab with fixation, pursuits, saccades, accommodation and vergences, the patient will become more locked up and the symptoms may get worse
- This is why vision retraining can have mixed results with healthcare providers who do not understand that the ambient (dorsal) system is the basis for starting therapy!!

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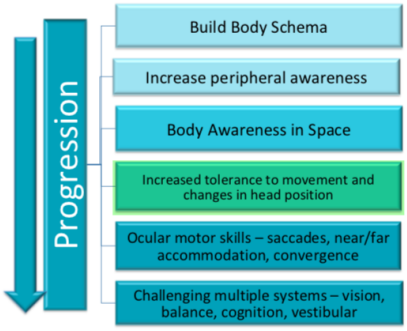
TREATING OCULOMOTOR DISORDERS



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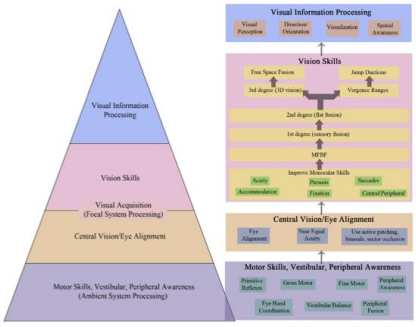
TREATMENT HIERARCHY



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OPTOMETRIC VISION THERAPY SEQUENCING

- **START with Peripheral activities with gross motor and vestibular**
- Monocular skills (acuity, fixation, pursuits, saccades, accommodation)
  - Stick/Straw
  - Flippers
  - Marsden Ball
  - Hart charts
  - Prism jumps (emphasize JND)
  - Lens sorting
  - Ann Arbor Tracking
  - Split bifocal rock
  - Rotating pegboard
  - Eye stretches - Close & Closed Eye Movements

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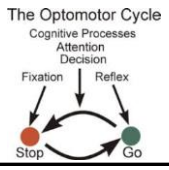
MONOCULAR PURSUITS OR SACCADES

- Start at a slower velocity and lower number of repetitions of saccades and pursues while seated facing a background with minimal stimulation
- Systematically and gradually increase velocity of eye movements and number of targets in the background
- Build motor, ie marching in place, while performing these tasks in front of a stimulating background
- Refer for fusional training and higher level of visual retraining



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PERIPHERAL AWARENESS TECHNIQUE

- Peripheral Ball Toss
- Try to keep soft **gaze forward**
- **Attention** on ball/bean bag
- Can do this while walking
- Same idea bouncing ball on floor

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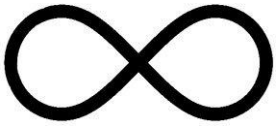
VISUAL/VESTIBULAR INTEGRATION TECHNIQUE

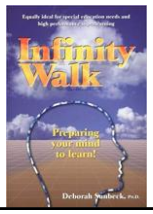
- Rainbow Bean Bag Toss
  - Step 1: Keep head still and eyes on the bean bag. Keep the bean bag in line with the centre of your body and gently toss the bean bag up in the air and catch it. Follow the path of the bean bag with your eyes.
  - Step 2: Keeping head still and eyes on the bean bag. Lightly throw the bean bag from one hand to the other in the shape of a rainbow. Your eyes should follow the path of the bean bag.
  - Step 3: Move head and eyes together to follow bean bag

201

VISUAL/VESTIBULAR INTEGRATION TECHNIQUE

- Infinity Walk
  - Walk at a comfortable but continuous pace. Look at visual target on the wall. Walk in a sideways figure of 8 or infinity symbol while maintaining visual target. When you are turning around bring head and eyes back to the target as quickly as possible.
  - Repeat several times as symptoms allow





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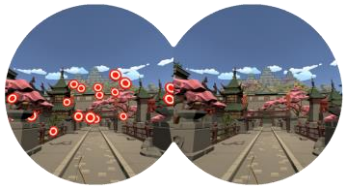
OPTOMETRIC VISION THERAPY SEQUENCING

- Monocular Fixation in a Binocular Field
  - Sanet Vision Integrator with R/B glasses
  - DynaVision with R/G glasses
  - Dissociated prisms
  - Bar Reader/TV Trainer activities
- Integration with other sensory systems (ie metronome to train timing and anticipation)



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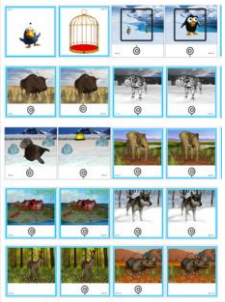
OPTOMETRIC VISION THERAPY SEQUENCING

- 1st degree fusion
  - Dissimilar targets presented
  - Perceived at the same time in the same visual direction
  - Mirror Stereoscopes
- 2nd degree fusion
  - Similar targets with dissimilar components
  - Monocular suppression checks
  - Vectograms/ Tranaglyphs
  - Apeture Rule
- Integration with other sensory systems



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OPTOMETRIC VISION THERAPY SEQUENCING

- 3rd degree fusion
  - 3D Tasks due to disparity, emphas SILO
  - BI/BO tasks
  - VTS4
  - Virtual Reality
- Free space fusion
  - Lifesaver cards
  - Magic Eye
  - Barrel Cards
- Integration with other sensory syste

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OPTOMETRIC VISION THERAPY SEQUENCING

- Vergence Ranges
  - Wheatstone stereoscope
  - Vectograms/Tranaglyphs
  - VTS4
  - Virtual Reality
- Jump Ductions
  - Same as above with added demand
  - Double vectograms
  - Prism Flippers
- Integration with other sensory systems

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OPTOMETRIC VISION THERAPY SEQUENCING

- Visual Information Processing deficits
  - Visual spatial skills
    - Bilateral integration, laterality, directionality
  - Visual analysis skills
    - Visual discrimination, figure ground, visual closure, visual memory, visualization
  - Visual Motor skills
    - General eye-hand coordination, visual-motor ergonomics, fine-motor control

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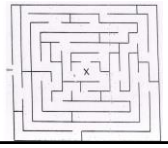
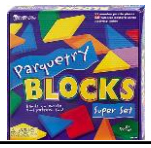
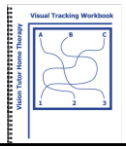
VISUAL INFORMATION PROCESSING TECHNIQUES

- Directional mazes – patient tells you which way to go
- Parquetry blocks – visual discrimination, visual spatial relations, visual closure, can do visual memory, visual sequential memory, visualization
- Michigan tracking – figure-ground, oculomotor, reversals, visual memory
- Where's Waldo – figure-ground







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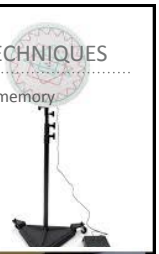
VISUAL INFORMATION PROCESSING TECHNIQUES

- Tachistoscope – visual memory, visual sequential memory
- Wayne saccadic fixator – sports vision
- Rotating peg board
- Sanet Vision Integrator



209

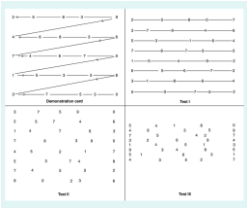
CASE EXAMPLE: A.C.

- 58 year old female
- Suffered a venous subarachnoid hemorrhage after a cerebral thrombosis
- "Sensory overload"
- "So many distractions"
- Headaches, poor depth perception, poor spatial judgments

210

NEURO-OPTOMETRIC FINDINGS: A.C.

- Visual acuity
  - 20/25 OD, OS, OU
- Stereoacuity Normal
- Standardized eye movement assessment, King Devick
  - Too dizzy and nauseated to complete
- Pursuits
  - Appropriate but induces symptoms
- Sensory fusion and convergence
  - Double vision at 16 inches
  - Comfort point of convergence at 20 inches



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NEURO-OPTOMETRIC FINDINGS: A.C.

- Unable to assess vergence ranges
- Visual Midline Shift
  - Positive for dorsal and ventral processing shifts
  - Shifted to the right
- No visual field loss, no visual neglect
- All ocular health structures within normal limits

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NEURO-OPTOMETRIC FINDINGS: A.C.

- Visual acuity
  - 20/20 OD, OS, OU
- Standardized eye movement assessment, King Devick
  - Age appropriate score
- Pursuits
  - Smooth
- Sensory fusion and convergence
  - Fusion at all distances and in all gazes
  - Comfort point of convergence at 4 inches

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CASE EXAMPLE: K.C.

- 9 year old female
- Suffered 3 concussions back to back
- Headaches everyday since her 3rd accident ("during focusing, school work and reading")
- "Eyes get tired very fast"
- Double vision when reading
- Light sensitive

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NEURO-OPTOMETRIC FINDINGS: K.C.

- Visual acuity
  - 20/25 OD, OS, 20/30 OU
- Stereoacuity Normal
- Standardized eye movement assessment, King Devick
  - Unable to score due to amount of errors
- Pursuits
  - Uses head instead of eyes, pain in left gaze

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NEURO-OPTOMETRIC FINDINGS: K.C.

- Visual acuity
  - 20/20 OD, OS, OU
- Standardized eye movement assessment, King Devick
  - 14.0 year old age equivalent
- Pursuits
  - Smooth and accurate, no pain

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ADDITIONAL CASES…

➢

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WHEN TO REFER TO NEURO-OPTOMETRY

- ➢ Is vision helping or hindering recovery?
- ➢ Impaired Visual Acuity: less than 20/40 vision with correction (wearing glasses)
- ➢ Hemianopia
- ➢ Focus Deficiency
- ➢ Binocular Dysfunction
- ➢ Uncoordinated Eye Movements
- ➢ Nystagmus
- ➢ Visual Spatial Disorder
- ➢ Visual Processing and Integration Disorder

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FOR MORE INFORMATION AND DOCTOR LOCATORS…

- ➢ Concussionproject.com
- ➢ https://visionhelp.wordpress.com/
- ➢ Noravisionrehab.com
- ➢ covd.org

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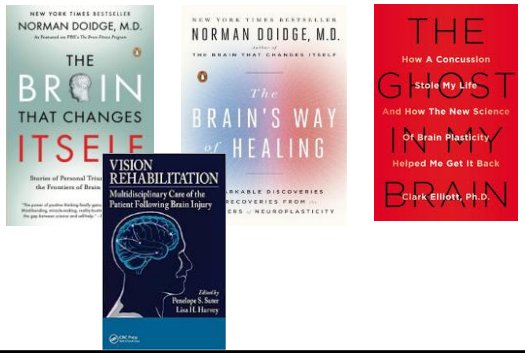
RECOMMENDED READING



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