EVALUATION AND TREATMENT OF VISUAL DYSFUNCTION FOLLOWING CONCUSSION

CONCEPTS FOR THE VESTIBULAR PHYSICAL THERAPIST

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LEARNING OBJECTIVES:
- Identify the most common visual system impairments occurring after mild traumatic brain injury.
- Describe the anatomy and physiology of the ocular motor, vergence, and accommodative system; and elucidate how visual system pathology is coupled with vestibular dysfunction.
- Demonstrate screening and assessment techniques for identifying visual system impairment for the physical therapist.
- Identify potential intervention for managing visual deficits following concussion.

EPIDEMIOLOGY OF CONCUSSION/mTBI:
- Difficult to accurately report incidence, as concussion is grossly underestimated
- General Population: Approx 1.4 million incidents of TBI reported each year; w/ 75-90% classified as mild (CDC 2004)
  - WHO estimates >600 per 100,000 incidence (Cassidy 2004)
  - Falls, MVC’s, Work-related accidents, Falls, Assaults, Other accidents.
- Military: 194,561 mTBI cases between 2000-2012
  - OIF, OEF, OND
- Sports: 2 million sports and recreation concussive injuries occur annually in US
  - CDC Toolkit for Physicians (2008), estimates up to 3.8 million
  - 20-30 % of high school football players have experienced at least 1 concussion (Powell 1999; McCrea 2004)

Commonly Reported Symptoms - within 3 days of injury

<table>
<thead>
<tr>
<th>SYMPTOM</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td># 1 Headache</td>
<td>71 %</td>
</tr>
<tr>
<td># 2 Feeling slowed down</td>
<td>58 %</td>
</tr>
<tr>
<td># 3 Difficulty concentrating</td>
<td>57 %</td>
</tr>
<tr>
<td># 4 Dizziness</td>
<td>55 %</td>
</tr>
<tr>
<td># 5 Fogginess</td>
<td>53 %</td>
</tr>
<tr>
<td># 6 Fatigue</td>
<td>50 %</td>
</tr>
<tr>
<td># 7 Visual Blurring/double vision</td>
<td>49 %</td>
</tr>
<tr>
<td># 8 Light sensitivity</td>
<td>47 %</td>
</tr>
<tr>
<td># 9 Memory dysfunction</td>
<td>43 %</td>
</tr>
<tr>
<td># 10 Balance problems</td>
<td>43 %</td>
</tr>
</tbody>
</table>

Lovell et al., 2004; N = 215

OCULAR MOTOR SYMPTOMS FOLLOWING CONCUSSION USING THE VOMS (n=85)

<table>
<thead>
<tr>
<th>VOMS Sub-test</th>
<th>Symptomatic (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth Pursuits</td>
<td>33% (28)</td>
</tr>
<tr>
<td>Horizontal Saccades</td>
<td>42% (36)</td>
</tr>
<tr>
<td>Vertical Saccades</td>
<td>38% (32)</td>
</tr>
<tr>
<td>Convergence</td>
<td>34% (29)</td>
</tr>
<tr>
<td>VOR</td>
<td>58% (49)</td>
</tr>
<tr>
<td>Visual Motion Sensitivity</td>
<td>49% (42)</td>
</tr>
</tbody>
</table>

Mucha et al, AJSM 2014.

CONCUSSED PATIENTS: OCULAR MOTOR AND VESTIBULAR FINDINGS (n=85)

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Concussed</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth Pursuits</td>
<td>2.9*</td>
<td>0.1</td>
</tr>
<tr>
<td>Hor. Saccades</td>
<td>2.9*</td>
<td>0.1</td>
</tr>
<tr>
<td>Ver. Saccades</td>
<td>2.6*</td>
<td>0.1</td>
</tr>
<tr>
<td>VOR</td>
<td>4*</td>
<td>0.1</td>
</tr>
<tr>
<td>VMS</td>
<td>4.5*</td>
<td>0.1</td>
</tr>
<tr>
<td>NPC (cm)</td>
<td>6.1*</td>
<td>3.8</td>
</tr>
</tbody>
</table>

*p<.001

OCULAR MOTOR DISTURBANCES FOLLOWING mTBI*

<table>
<thead>
<tr>
<th></th>
<th>% mTBI n = 20</th>
<th>% Controls n = 20</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocular Misalignments (Vertical Phoria)</td>
<td>55%</td>
<td>5%</td>
<td>0.0012*</td>
</tr>
<tr>
<td>Ocular Misalignment (Horizontal Phoria)</td>
<td>45%</td>
<td>5%</td>
<td>0.0084*</td>
</tr>
<tr>
<td>Accommodative Dysfunction</td>
<td>65%</td>
<td>15%</td>
<td>0.0031*</td>
</tr>
<tr>
<td>Convergence Insufficiency</td>
<td>55%</td>
<td>5%</td>
<td>0.0012*</td>
</tr>
<tr>
<td>Saccadic impairment</td>
<td>30%</td>
<td>0%</td>
<td>0.0202*</td>
</tr>
<tr>
<td>Pursuit impairment</td>
<td>60%</td>
<td>0%</td>
<td>&lt;0.0001*</td>
</tr>
</tbody>
</table>

* Blast-related mTBI

Capo-Aponte et al. Military Medicine 2012

THE ROLE OF THE VESTIBULAR PHYSICAL THERAPIST IN VISION ASSESSMENT AFTER CONCUSSION:

- Provide screening and/or assessment of visual function in conjunction with vestibular assessment
- Identify areas of visual impairment common to concussion
- Act as gatekeeper
- Manage simple issues; refer more complicated problems

Vision evaluation and treatment is NOT part of entry level curriculum!!

ANATOMY AND PHYSIOLOGY OF THE VISUAL SYSTEM & COMMON VISUAL DYSFUNCTION FOLLOWING CONCUSSION

NATHAN W. STEINHAFEL, M.S., O.D., F.A.A.O.

OTHER VISION/TBI RESEARCH...

Ciuffreda, et al. K. 2007: Accommodative and vergence deficits were most common in the mTBI subgroup, whereas strabismus and CN palsy were most common in the CVA subgroup.

Brahm et. al. 2009: Visual dysfunctions (convergence, accommodative, and oculomotor dysfunction) were common inpatient and out populations who suffered blast and non-blast related concussion. Visual field defects were more often associated with blast than non-blast events.
**CRANIAL NERVE NUCLEI**

**CRANIAL NERVES THAT CONTROL EYE MOVEMENT**

**4 GENERAL AREAS OF BINOCULAR FUNCTION**

**VISUAL SYMPTOMS**

- Similar to vestibular symptoms
- Blurred vision
- Double vision
- Photophobia vs. photopsia
- Illusions of movement
- Poor eye tracking
- Eye fatigue
- Vertigo

**OCULOMOTOR PATHWAY**

- Responsible for:
  - Saccades – redirects the fovea with large (gross) or small (fine) conjugate eye movement jumps from point A to point B.
  - Pursuits – tracks a moving target and stabilizes images on fovea
  - Redirected the eye position toward the oncoming visual scene (i.e. Fast phases).
  - Keeping an image on the fovea when the head is moving. Tied into the vestibular system (i.e. Slow phases).
  - Fixation – Keeping a stationary target on the fovea in primary gaze or when gaze holding in other fields of gaze.


**SACCADIC PATHWAY**

- Front cortex – Frontal eye field (FEF)
- Dorsal lateral prefrontal cortex
- Superior colliculus (SC)
- Brain stem
- Posterior parietal cortex (PPC)
SACCADIC PATHWAY

- Horizontal saccades – FEF, PPC, SC, cerebral vermis
  
  ![Horizontal saccades](http://www.neuroanatomy.wisc.edu/HTML/brain/images/13K.jpg)

- Vertical saccades – FEF, SC, riMLF, dorsal midbrain
  
  ![Vertical saccades](http://www.eyecalc.com/DWAN/graphics/figs/wrtd/0100/002f.jpg)

PURSUIT PATHWAY

- Pursuits –
  - Overlap w/ saccadic movt.
  - FEF
  - PPC
  - Cerebral structures
  - Medial temporal and medial superior temporal cortex

VERGENCE PATHWAY

- Responsible for:
  - Vergence Eye Movements:
    - Moves the eyes in opposite direction to align both foveas on the same object in space.
    - **NEAR to FAR** bilateral disconjugate eye movements
      - i.e. Turning the eyes **IN** and **OUT**, respectively.

  - Stimulus for a vergence response: Double vision or different positions of image on the retina. Which creates a "Fusional Vergence Movement".

VERGENCE SYSTEM

- Convergence
- Divergence

**Property of Nathan Steinhafel and Anne Mucha. Do not use without permission.**
VERGENCE PATHWAY

- Stimulus: Double vision or different positions of image on the retina → fusional vergence.
- Visual signal from occipital cortex → vergence premotor neurons in midbrain reticular formation → Midbrain CNIII → Triad:
  - 1. convergence leads to:
  - 2. accommodation leads:
  - 3. miosis of the pupil

TYPES OF VERGENCE

- Tonic convergence
  - Resting state
  - Maintaining a converged position at a particular working distance.
- Proximal convergence
  - Something up close
- Accommodative convergence (AC/A)
  - Amount of convergence induced by accommodation
  - Partly responsible for gross alignment of eyes from distance to near.
- Fusional – Double vision or different positions of image on the retina cause either convergence (positive fusional vergence [PFV]) and divergence (negative fusional vergence [NFV]).
- Voluntary convergence
  - Voluntary without a target (i.e. crossing your eyes)

TAKE AWAY

- TEAM EFFORT!
- Conjugate movement (EOM movement, SACCADIES and PURSUITS), disconjugate movements (CONVERGENCE and DIVERGENCE), the FIXATION system, accommodation and VOR control the position of an image on the fovea.

ACCOMMODATION PATHWAY

- Responsible for:
  - Keeping an image CLEAR on the retina.
- Stimulus is:
  - Blurry Vision/Loss of focus
    - Retinal blur → LGN → Visual Cortex
    - Retinal blur → Pretectal nucleus → EW nucleus → CB ganglion → Ciliary body → Lens of the eye
- Accommodation also leads to convergence!

ACCOMMODATIVE – VERGENCE INTERACTION

- AC/A: A change in accommodation causes a change in vergence.
- CA/C: A change in vergence causes a change in accommodation.
- CA/C is pretty constant and less meaningful clinically compared to AC/A.
Brain injury can lead to visual deficits. Vision abnormalities typically reflect functional deficits or occasionally a serious underlying central nervous system condition. Always need to rule out acute or ongoing pathology first.

**Convergence/Miosis/Accommodation**

1. Convergence

**Visual Requirements:**

Visual acuity depends on:
1. Position of image on fovea
2. Ability to hold image steady

- **Position of Image:** “Gaze Shifting”
  - For best vision, object within 0.5º of center of fovea
  - Fovea (eye) must be moved to achieve proper position for vision
  - Saccades, Pursuits, Vergence eye movements

- **Holding Image Steady:** “Gaze Holding”
  - Vision deteriorates when retinal motion ≥ 5º/sec w/ activities requiring high spatial resolution (eg; reading)
  - Optokinetic, Visual Fixation, Vergence and Vestibular eye movements

**Visual Issues Can Influence Vestibular Function:**

- Ex: Patient with decompensated Exophoria performing Horizontal VOR exercises

**Screening for Visual Problems after Concussion:**

- Good binocular function is a prerequisite to normal eye/head movement

Leigh and Zee. The Neurology of Eye Movements. 2006
VESTIBULAR/Ocular Motor Screening (VOMS)

- The VOMS consists of brief assessments in the following domains of Ocular Function:
  1. Smooth Pursuits
  2. Horizontal and Vertical Saccades
  3. Near Point Convergence (NPC)
  4. Horizontal VOR
  5. Vertical VOR
  6. Visual Motion Sensitivity (VMS)

- Following each VOMS assessment, patients rate on a scale of 0 (none) to 10 (severe) changes in:
  - headache, dizziness, nausea and fogginess symptoms
  - Convergence is assessed by both symptom provocation and NPC distance in cm (measured as average of three trials)
  - Normal = <5cm

VOMS: Standardized Assessment of:

- horizontal and vertical pursuits
- horizontal and vertical saccades
- near point convergence
- horizontal and vertical VOR
- Visual Motion Sensitivity

Do Controls Differ From Concussed Patients on the VOMS Items?

<table>
<thead>
<tr>
<th>VOMS Item</th>
<th>Concussed</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth Pursuits*</td>
<td>2.1 +/- 4.8</td>
<td>0.1 +/- 0.3</td>
</tr>
<tr>
<td>Horizontal Saccades*</td>
<td>2.5 +/- 4.8</td>
<td>0.1 +/- 0.3</td>
</tr>
<tr>
<td>Vertical Saccades*</td>
<td>2.1 +/- 4.6</td>
<td>0.1 +/- 0.3</td>
</tr>
<tr>
<td>Horizontal VOR*</td>
<td>3.7 +/- 5.1</td>
<td>0.1 +/- 0.3</td>
</tr>
<tr>
<td>VMS*</td>
<td>3.1 +/- 5.7</td>
<td>0.1 +/- 0.3</td>
</tr>
<tr>
<td>NPC (Sx)*</td>
<td>2.2 +/- 4.0</td>
<td>0.1 +/- 0.3</td>
</tr>
<tr>
<td>NPC Distance (cm)*</td>
<td>5.9 +/- 7.7</td>
<td>1.9 +/- 3.2</td>
</tr>
</tbody>
</table>

*p<.001

• **NO CONTROLS reported a total symptom score >2 following any VOMS individual item**

Interpreting the VOMS:

- Controls report few symptoms following VOMS and have normal NPC distances (< 5 cm)
- VOMS symptom scores >2 and NPC distance >5 cm represent clinically useful cut-off.
- 3 VOMS items (VOR, VMS, NPC distance) resulted in 89% accuracy for identifying patients with concussion.
- The VOMS measures distinct constructs than traditional concussion tools and compliments neurocognitive testing, balance assessment and symptom reports.
- Initial research provides preliminary support for the utility of the VOMS as a brief vestibular/ocular motor screen following SRC.

What if VOMS is Abnormal?

- The VOMS may guide referral and treatment following concussion:
  - In conjunction with other measures, helps to identify presence of concussion
  - May indicate a vestibular and/or ocular motor issue. Further evaluation and treatment indicated when issues persist beyond acute stage
  - For Convergence Insufficiency, Pursuit and Saccade abnormalities, refer to either a Vestibular PT (if mild) or Vision specialist (if moderate to severe) to evaluate and treat
**WHEN TO REFER FOR A VISION EVALUATION?**

- 4 weeks post injury
  - Time is part of the healing process!
- Neuro Optometry or Ophthalmology, Pediatric Optometry or Pediatric Ophthalmology.
  - Binocular vision
  - Neuro-optometric rehabilitation
  - Vision therapy
  - Low Vision
- 45 min to 2 hour assessment

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**VISION EXAM**

- **Fusion**
  - Stereopsis
  - Worth 4 dot
  - Fixation Disparity
- **VOR – rotational head movement**
- **Head Thrust**
- **Refraction**
  - Must be best corrected for all binocular vision testing

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**OPTOMETRIC/OPHTHALMOLOGY EXAM**

**Visual Acuity**
- Distance and Near
- Dynamic visual acuity

**Pupil testing**

**Cranial nerve testing**

**Vergence testing**
- Objective: Cover test
- Subjective: Maddox Rod
- BI/BO vergence ranges at distance and near
- Vergence Facility
- NPC (break and recovery)
- NRA/PRA (relative accommodation–indirect vergence testing)

**Accommodative testing**
- Amplitude of Accommodation
- MEM Dynamic Retinoscopy (accuracy/stability) for younger patients
- Monocular/Binocular accommodative facility (+/- 2.00)
- NRA/PRA

**Ocular motor**
- Fixation
- Pursuits
- Saccades
- DEM
- King-Devick

**OPTOMETRIC/OPHTHALMOLOGY EXAM**

**Visual Field Testing**
- 30-2 Threshold
- Goldman
- Tangent screen

**Ocular health**

**Dilation**

**Cognitive ability**
- DTVP-A (Developmental test of visual perception for adolescence and adults)
  - visual memory, visual motor integration.

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**VISION EXAM FOR THERAPISTS – BEYOND THE VOMS:**

- Ocular Alignment
- Convergence
- Accommodation
- Pursuits
- Saccades
- Gaze Holding
- VOR

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**4 GENERAL AREAS OF BINOCULAR FUNCTION**

- **ACCOMMODATIVE SYSTEM**
- **VERGENCE SYSTEM**
- **OCULOMOTOR SYSTEM**
- **VESTIBULAR OCULAR REFLEX SYSTEM**
- **OCULAR ALIGNMENT**
OVERVIEW OF COMMON BINOCULAR CONDITIONS SECONDARY TO (M)TBI

- Pre-existing ocular conditions worsen as a result of decompensation of an uninterrupted binocular state.

Ocular Alignment:
- Ocular alignment decompensates
- Worsening of Non-strabismic binocular vision conditions
  - Exophoria
  - Esophoria
  - Hyperphoria
- Strabismus
  - Exotropia
  - Exotropia
  - Hypertropia
- Palsy
  - 4\textsuperscript{th} nerve – superior oblique (trochlear nerve)
  - 6\textsuperscript{th} nerve – lateral rectus (abducens nerve)

OCULAR MALIGNMENT

- Tropia – overt deviation of the eye
  - Exo – outward (laterally)
  - Eso – inward (medially)
  - Hyper – upward
  - Hypo - downward

- Phoria – Ocular deviation occurs when dissociation occurs.

OCULAR MISALIGNMENT - SYMPTOMS

If Severe:
- Diplopia
- Head tilt (vertical misalignment)
- Noticeable eye turn

If Subtle:
- Difficulty maintaining focus
- Cosmetically normal
- Ocular soreness
- Headaches
- Mental dullness

EXO DEVIATIONS (XP)

*Must be best corrected wearing glasses if prescribed.

- Cover test: fast, objective, quantitative, quantifiable, repeatable, and can be used for comitancy testing.
- Maddox rod: fast, subjective, quantitative, quantifiable, and can be used for comitancy testing.
- Double Maddox rod: fast, subjective, quantitative, quantifiable, comitancy testing. Doesn’t dissociate as good as other subjective methods.
- Modified Thorington: subjective, in instrument.
- Von Graefe: subjective, in instrument.
OCULAR ALIGNMENT TESTING:

Ocular Misalignment = Strabismus vs. Phoria

Tropia:
- Deviation of visual axes during **binocular** viewing of a single target
- **Manifest** deviation: usually observable; present in most circumstances.
- Distance or near
- Intermittent or Constant
- Right, Left, or Alternating
- Diagnosed with cover-uncover.

Phoria:
- These patients are binocular.
- Latent deviation: deviation is not always apparent. Need to break fusion of eyes to test.
- Diagnosed with alternate cover test.

**OCULAR ALIGNMENT TESTS**

- **Cover-Uncover Test** (Unilateral): Test for tropia. Perform cover test first on each eye; if no movement of uncovered eye tropia is not present.
- **Alternate Cover Test** (Cross Cover Test):
  - Test for phoria or measures the magnitude of phoria or tropia.

Assessing Ocular Alignment:

**Cover Test**
- While focusing on target, one eye is covered
- Look for “movement of redress” of uncovered eye
- Identifies tropia of uncovered eye (eso/exo/hyper/hypo)

**Uncover Test**
- Observe for movement of occluded eye when cover is removed
- In practice, cover and uncover tests are done together (“Cover-Uncover” Test)
- It can indicate phoria, however phorias a BEST observed by alternative cover test.

COVER/UNCOVER: TROPIA

COVER/UNCOVER: PHORIA

ASSESSING OCULAR ALIGNMENT:

Alternate (Cross) Cover Test
- Occluder quickly transferred from eye to eye
- Prevents binocular viewing and allows proper fixation for each eye.
- Do multiple times – deviations can grow with further dissociation because of decompensation in binocularity.

Courtesy Suzanne Wickum, OD
MADDOX ROD
Testing Horizontal Alignment:
1. Hold Maddox Rod over RIGHT eye w/ slats (cylinders) in horizontal direction
2. Direct light toward bridge of nose at distance approx. 3ft
3. Ask if red line is to right, left or through the light

What the patient sees
Interpretation

DOUBLE MADDOX ROD

SO WHAT IF THERE IS A MISALIGNMENT??
- MAY need referral to vision specialist –
  - ALWAYS refer any VERTICAL Misalignment
- MAY need additional visual exercises prescribed as part of rehab
- MAY need additional time for recovery

4 GENERAL AREAS OF BINOCULAR FUNCTION

VERGENCE DYSFUNCTION
- General Symptoms
  - Asthenopia when reading
  - Frontal headaches
  - Intermittent or constant double vision
  - Squints, closes one eye.
  - Letters will appear to float or move around the page
  - Lack of symptoms but findings persist
  - Suppression, avoidance, or occlusion (pre-existing?)
- Common Vergence Problems
  - Convergence Insufficiency
  - Convergence Excess
  - Convergence Spasm

CONVERGENCE INSUFFICIENCY
- Symptoms:
  - “Double” (or blurred) vision at a reading distance
  - Eye strain while reading.
  - Frontal headaches.
  - Pulling around the eyes.
- Definition: Sensory and neuromuscular anomaly of the binocular vision system, characterized by an inability of the eyes to turn towards each other or sustain convergence. Also, when there is a tendency of the eyes to deviate outward (exophoria). Not age dependent.
- Non-TBI Cohort: prevalence up to 6% in general population. Much greater in mTBI cases.

CONVERGENCE INSUFFICIENCY

• Common Direct findings
  1. Decrease near point of convergence (>6cm)
  2. Crossed diplopia (Right eye sees left image and left eye sees right image).
  3. Exophoria greater at near than distance
     - Normal: orthophoria to 4 XP (±2)
     - Abnormal: >6XP
  4. Abnormal: Poor compensating fusional convergence skills
     - i.e. 6 XP with BO X II
  Sheard’s Criterion: Compensating fusional convergence skills should be double the amount of the exophoria.

• Indirect findings
  • Decreased binocular accommodative facility (plus difficult)
  • Decreased negative relative accommodation (NRA)
  • Low A/C/A ratio

CONVERGENCE INSUFFICIENCY

Testing

• 1. Using a single target 3 sizes above threshold near visual acuity.
  - i.e. if they are capable of seeing 20/20 print use a 20/40 single target – newspaper sized print.
• 2. Start at ~50cm and slowly bring it to the tip of their nose.
• 3. "I’m going to move this target toward you. Tell me when it’s double." Regardless if it’s blurry.
• 4. NPC= “Double” or when one eye deviates = NPC (break)
• 5. RECOVERY: “I’m going to pull it back away from you. Tell me when you regain a single image.” (recovery).
• Difference between break/recovery: 3-4 cm.

CONVERGENCE INSUFFICIENCY

• Alternatively
  • a. Red lens test (no maddox)
    - Over one eye
    - More repeatable
    - Pen light
    - NPC= “Two lights: red and white”
  • b. Near point fixation disparity card
EXO DEVIATIONS (IRXT)

- Unit of measure – Diopters (D)
- Bends light toward base.
- Bends image towards apex.
- Used to measure the magnitude of a phoria or tropia
- Base in is used to measure exo deviations.
- Base out prism is used to measure eso deviations.
- Base down prism to measure hyper deviations.
- Base up prism to measure hypo deviation.

PRISM

MEASURING DEVIATION

- For EXO deviations
  - To MEASURE amount of DEVIATION: Use BI^.
  - To MEASURE amount of compensating fusion convergence: Use BO^.
- For ESO deviations
  - To MEASURE amount of DEVIATION: Use BO^.
  - To MEASURE amount of compensating fusion convergence: Use BI^.

MEASURING DEVIATION VS. COMPENSATION

Example (TO LEFT)
Exophoria: Measured 3^XP
Vergence Bar: BO X|4|2 = abnormal

Example (NOT SHOWN): Exophoria 7^XP
Vergence Bar: BO X|18|14 = normal

PRISM CAN BE USED IN THERAPY

MEASURING COMPENSATING FUSION CONVERGENCE
**CONVERGENCE INSUFFICIENCY**

- **Treatment options**
  - CI:
    - Vision therapy
    - Prism
  - XP
    - Vision therapy
    - Prism, if the magnitude of the exophoria is larger
    - Strabismus surgery if exo deviation is significant >20°

**CONVERGENCE EXCESS**

- **Symptoms**
  - Asthenopia and headaches, especially after near work
  - Blurred vision near
  - Double vision at near
  - Difficulty concentration
  - Words appear to move on a page

- **Common Direct finding**
  - Orthophoria far
  - More eso at near (~10°)

- **Indirect findings**
  - Decreased NFV (PRA – adding minus lenses)
  - Decreased binocular accommodative facility (minus difficult).

**CONVERGENCE EXCESS**

- **Driven by accommodation**
  - High AC/A (>8)
  - **EXAMPLE:**
    - D: orthophoria
    - N: 10°/EP
    - If a +1.00 Reader changes causes a change in the alignment to ortho the AC/A = 10/1
    - A 1°0 change for every 1.00D of accommodation change.

- **Treatment**
  - Prescribe for hyperopia first
  - Prescribe a bifocal for near if still ESO. Must trial frame first.
  - **Classic convergence excess will become orthophoria at near with plus lenses.**

**CONVERGENCE SPASM**

- **Symptoms**
  - Blurred vision distance and near
  - Double vision distance and near
  - Frontal headaches
  - Binocular fusion easily broken

- **Direct findings**
  - Initially cover testing may indicate orthophoria @ distance and near and eventually result in spontaneous esotropia
  - Uncrossed diplopia (Right eye sees right image and left eye sees left image).
  - Break binocular fusion from testing procedures:
    - Pursuit or saccadic Movement
    - Near point targets
    - Cover testing
    - Stereo glasses, R/G glasses
CONVERGENCE SPASM

Treatment
- Treat the underlying cause
- Prism
  - Base in! You want to decrease the convergence demand. Convergence is less.
- Bi-nasal occlusion
- Cycloplegia typically does not affect convergence spasm because it is independent of accommodation.
- Botox
- MUST rule out accommodative spasm first

TESTING FOR VERGENCE AND/OR MOTOR ALIGNMENT

PT
- NPC
  - Minimum Expected Values/Expected Norms:
    - (<6cm)
  - Screening for ocular alignment.
  - Minimum Expected Values/Expected Norms:
    - Distance: 1 Exo (+/-2°), No Eso
    - Near: 3 Exo (+/-3°), No Eso
- Data falling below these and other ocular expectations are correlated with SYMPTOMS. Referral for treatment is not automatically made because one or more of these criteria for failing are met; professional judgment/further testing is required.

4 GENERAL AREAS OF BINOCULAR FUNCTION

ACCOMMODATIVE SYSTEM
- Monocular test!
- Use newspaper sized print if they can see 20/20 at near.
- Measured in cm, convert to D.
- Bring towards patient until they report sustained “blur”.
- Compared to age related normative values.
- Must be wearing glasses if they have them.

ACCOMMODATIVE INSUFFICIENCY
TESTING FOR ACCOMMODATIVE DISORDERS

- **PT:**
  - Test from the bridge of nose or forehead (or part of face closest to the plane of the cornea)
  - Amplitude of accommodation: <30 years old should be able to achieve at least 15cm.
  - Must be best corrected.
  - i.e. A 16 year old not wearing near sighted correction may cause a false negative
  - i.e. A 16 year old not wearing a hyperopic correction may cause a false positive.

### Table: Minimum Distance (Cm) & Minimum AMP (D)

<table>
<thead>
<tr>
<th>Age</th>
<th>Minimum distance (Cm)</th>
<th>Minimum AMP (D)</th>
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</thead>
<tbody>
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<tr>
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<td>12</td>
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<td>46</td>
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<td>2.5</td>
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</tbody>
</table>

ACCOMMODATIVE DISORDERS

- **General symptoms**
  - Blurry vision at near
  - Blurry vision at near with spasm of accommodation or after periods of reading
  - Excessive blinking
  - Eye fatigue after reading

- **Non-TBI Cohort Studies:** Prevalence: 8-17% in the of general population <15 years of age (school screenings).

- **ACCOMMODATIVE INSUFFICIENCY**
  - **Definition:** Inability of the eyes to focus properly at a near target. Amplitude of accommodation is lower than expected for the patient's age.
  - This is the most common accommodative disorder.
  - 80% of individuals who have CI will also have AI.
  - **Direct findings:**
    - Decreased monocular amplitude of accommodation
  - **Indirect findings** for optometry:
    - Decreased PRA
    - Decreased binocular accommodative facility (minus)
    - Lag of accommodation (>0.75 lag)

- **Hofstetter's Formula**
  - Normal AMP (D)= (15 – (0.25)Age) – 1

- **General screening rule:** <30 years of age <15cm.

- **Signs**
  - Decreased amplitude of accommodation
  - Age dependent
  - Measured in diopters
  - $D = \frac{1}{M}$
    - i.e. 10cm = 0.10 M
  - $D = 10 \frac{D}{0.10}$
  - **Treatment**
    - Vision therapy
    - Reading glasses or bifocals.

OTHER ACCOMMODATIVE DISORDERS

- **A. ILL-Sustained Accommodation**
  - A form of AI where function deteriorates with sustained near tasks.

- **B. Accommodative Infacility**
  - The accommodative system is slow to make a change from distance to near.
  - This is the second most common accommodative condition.
  - **Symptoms:**
    - Difficulty copying from the board to notes at school.
  - **Direct findings:**
    - Low Monocular accommodative facility
    - Low Binocular accommodative facility
    - Low PRA
  - **Treatment:**
    - Bifocals
    - Vision therapy
### ACCOMMODATIVE SPASM

#### C. Accommodative spasm
- **Definition:** Greater than normal accommodative response for a given stimulus.
- A relation of accommodative spasm and head trauma seems well established and can be persistent for several years despite the prolonged use of cycloplegic drops.
- **Direct findings**
  - Variable visual acuity
  - Decreased distance visual acuity
  - Lead on MEM dynamic retinoscopy
  - Usually orthophoria (or if accommodation is strong it will drive some convergence spasm response and present as an ESO posture).
- **Treatment options**
  - Cycloplegia – Atrpine is preferred choice.
  - Plus lenses (reading glasses)

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### ACCOMMODATIVE SPASM

- The supranuclear control of accommodation is poorly understood.
- In cats, neurons in temporal lobe correlating with accommodation were found in the **lateral suprasylvian area**.
- Also, electrical stimulation on ipsilateral interpositus nuclei and on contralateral interpositus and fastigial nuclei in the **cerebellum** are known to induce accommodation. These nuclei are connected to parasympathetic oculomotor neurons in the mid-brain.


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### 4 GENERAL AREAS OF BINOCULAR FUNCTION

<table>
<thead>
<tr>
<th>ACCOMMODATIVE SYSTEM</th>
<th>VERGENCE SYSTEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCULOMOTOR SYSTEM</td>
<td>OCULAR ALIGNMENT</td>
</tr>
<tr>
<td>VESTIBULAR OCULAR REFLEX SYSTEM</td>
<td></td>
</tr>
</tbody>
</table>

### OCULOMOTOR DYSFUNCTION

- **General symptoms**
  - Moves head excessively when scanning environment or when reading.
  - Frequently loses place when reading.
  - Uses finger or marker to maintain place.
  - Difficulty with eye tracking or making voluntary eye movements.

### OCULOMOTOR DYSFUNCTION

- **Signs**
  - Hypometric or hypermetric saccadic activity
  - Slow or latency with pursuit movement; or may elicit excessive head movement.
- **Testing PT:**
  - Finger saccades
  - Finger pursuits
  - EOM screening for full range of motion
- **Testing optometry/ophthalmology**
  - EOMs
  - Saccades/Pursuits
  - Monocular Ductions
  - Developmental Eye Movement Test (DEM):
    - Controls for automaticity – ability to cognitively rapid number name.
    - <13 yo. age related norms
  - King-Devick
  - At ages
  - Pierce Test

### OCULAR MOTOR APRAXIA

- Impairment of voluntary horizontal eye movements.
- Reflexive saccades and combined eye-head saccades may be relatively spared.
ACQUIRED NYSTAGMUS

- Vestibular: eg:
  - Unilateral Vestibular Hypofunction
  - BPPV

ACQUIRED NYSTAGMUS: GAZE HOLDING/EVOKED NYSTAGMUS

- Ability to maintain eye position without drifting off target

OCULAR EXAM:

Gaze Holding

- Abnormalities seen with peripheral vestibular & CNS pathology

  - Test:
    - Light and Dark
    - Gaze in straight ahead & 9 directions
    - 30° in all directions
    - Assess nystagmus/ inability to hold position
    - Also look for rebound nystagmus w/ return

ABNORMAL VISION EXAM FINDINGS:

Refer to neurology/neuro-ophthalmology when:

- Visual field cuts
- Abnormal pursuits, saccades, VOR cancellation
- Constant frank diplopia
- Pathological nystagmus

Refer to Neuro-optometry or Neuro-ophthalmology:

- Large convergence insufficiency
- Convergence spasm
- Vertical phoria/tropia
- Horizontal phoria/tropia
- Large phoria
- When smaller issues do not resolve with PT intervention

SPECIAL THANKS

- Janet Helminski PT, PhD
- Janet Callahan PT, MS, NCS

INTERVENTION
VISION THERAPY

**Definition:** Also known as orthoptics, vision training, vision rehabilitation, or vision PT, used to improve vision skills:
- Eye movement control
- Eye focusing and coordination
- Eye teaming and improving binocular function

- Evidence based program involving eye exercises:
  - Lenses
  - Prisms
  - Filters
  - Patching/Occluders
  - Free space activities
  - Computer programs

VISION THERAPY:

- Computer Based Programs:
  - HTS
  - VTS
  - CVS

VISION THERAPY FOR VESTIBULAR PT’S

- Vergence therapy
  - Purpose: Increase positive fusional convergence with increasing speed and accuracy, decreasing latency and increasing vergence response.
  - Develop kinesthetic awareness of converging
  - Normalize NPC & recovery

- Gross convergence
  - Pencil pushups
  - Brock string
  - 3-Dot card
  - Lifesaver card

PENCIL PUSHUPS

1. Holding target at arms length
2. Move it slowly toward nose
3. Teach be aware of diplopia and offer a suppression check.
4. Encourage voluntary convergence using proximal stimulus.

BROCK STRING

- Level 1
- Level 2
- Level 3
**LEVEL 1**
- Patient holds one end at tip of nose and tie other end to door knob (angled downward)
- For CI set the near bead just outside the NPC and the other beads 20cm apart.
- Look at the center of the and describe what is seen
- Use kinesthetic feedback (touch the bead) to assist in fusion by touching a proximal object.

**Progressions:**
- 1. Strings seen as extension of the eyes (2 strings coming toward you from middle bead; 2 strings going away from middle bead)
- 2. The other bead appear double – physiological diplopia used as suppression check. If the patient is suppressing have him wear red/green glasses
- 3. Where the strings are crossing is a measure of accuracy – fixation disparity.
- Once patient is able to fuse the beads hold fixation at far → middle → near bead for 10 seconds each, repeat 10 times.
- Move the near bead 3 cm closer and repeat
- Continue moving the near bead closer while leaving others where they are at.

**BROCK STRING: LEVEL 2 & 3**
- **Level 2:** Bug on a string
  - Same set up as described previously, except the bead are removed
  - Fixate the very end of the string and notice two strings crossing at the end of the string.
  - Slowly fixate closer by voluntary converging. Should be able to do slowly and gradually.
  - If difficulty with level two add 1 bead and trombone the bead with finger.
- **Level 3:** Convergence surprise
  - Proximal convergence using 1 bead.
  - Have patient close their eyes and place the bead anywhere.
  - Have them open their eyes and have them converge to that point, repeat 10 times.

**COMBINATION EXERCISES:**
- Other activities to add to brock string
  - Horizontal movement for those who are going to integrate vestibular activities.
  - Or, vertical or rotational head movement with string fixed.
- Problems: Suppression or some areas of central scotomas with long standing CI.

**TROUBLE SHOOTING:**
- **Suppression**
  - As a CI alignment favors the exo position upon convergence. Convergence is difficult and under converging one of the lines may fall within a suppression zone and diplopia behind the object is easier to see.
CONVERGENCE EXERCISES: 3-DOT CARD

- 3 Dot card or 3 barrel card

3-DOT CARD

- Level 1:
  - Instruct patient to hold card against bridge of nose angled downward and to fixate on the dot farthest away.
  - Report one dot that is a mixture (luster) of colors. The other dots should be seen as double (physiological diplopia)
  - Then fixate on the middle dot and hold for 10 sec.
  - Then fixate on the closest dot and hold for 10 sec.
  - Continue to alternate from one dot to another

- Level 2:
  - Alternate between the dots and a distance target, holding it for 10 sec.
  - Feedback is important!

OTHER CONVERGENCE EXERCISES:

3 Dot Line

Lifesaver Card

(Opaque)

REFERENCES


Schelhamer M. Clinical management of Binocular Vision: Heterophoric, Accommodative, and eye movement disorders. 2008