Vision Problems in TBI: Impacts on Cognition & Attention

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Disclaimers/Disclosures

• Consultant, RightEye (Bethesda, MD) mTBI/TBI eye tracking metrics and App development

• Consultant, Diopsys (Pine Brook, NJ) VEP biomarker algorithm for mTBI

• Consultant, A.M.P. Systems (St. Louis, MO) concussion protocols.

• Consultant, EyeNext (Turin, Italy) visual aspects of dyslexia/mTBI.
## Category of head injury

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mild head injury</strong></td>
<td>- GCS = 13-15</td>
</tr>
<tr>
<td></td>
<td>- associated with loss of consciousness or amnesia for less</td>
</tr>
<tr>
<td></td>
<td>- than 1 hour</td>
</tr>
<tr>
<td><strong>Moderate head injury</strong></td>
<td>- GCS = 9-12</td>
</tr>
<tr>
<td></td>
<td>- associated with a loss of consciousness for up to a day</td>
</tr>
<tr>
<td><strong>Severe head injury</strong></td>
<td>- GCS less than or equal to 8</td>
</tr>
<tr>
<td></td>
<td>- associated with loss of consciousness for more than 24 hours</td>
</tr>
</tbody>
</table>
Why Vision?

- 80-90% of all information entering the brain is visual
- Over 50% of brain is involved in visual processing (over 30 brain regions and 8 cranial nerves)
- Visual processing alone consumes 45% of brain’s energy
- 90% of all concussions will have 1 or more ocular problems
- Hidden vision problems frequently persist 6-9 months after a concussion
- Vision problems can undermine the efficacy of other therapies and affect workplace productivity
TBI Vision Problems: Visual Impairment vs. Visual Dysfunction

• Visual Impairment: Visual acuity is decreased and/or the visual field is constricted; More common in moderate or severe TBI; More obvious and therefore easier to diagnose; Tends to be more “focal”; Relatively more “permanent”. Patient is rarely unaware of it.

• Visual Dysfunction: Any disorder of afferent or efferent function. Common to all types of TBI. Oculomotor (eye alignment, fixation, versions, vergences, accommodation); and Non-oculomotor (visual spatial, visual temporal, perceptual, visual-motor-integration). Symptoms of visual dysfunction are commonly experienced after mTBI despite excellent visual acuity. Patient may or may not be aware of it. Undiagnosed, the visual sequela can affect one’s schoolwork, employment and other activities of daily living. Less obvious and harder to diagnose. Relatively more amenable to “change”.
Common TBI Visual Impairments

• Pre-chiasmal Impairment (monocular vision loss): traumatic optic neuropathy; ischemia; traumatic cataracts, traumatic maculopathy, retinal hemorrhages, globe ruptures, angle recession, hyphema, and corneal injuries (14% of mod/severe TBI).

• Chiasmal/Post-chiasmal Impairment (binocular vision loss): visual field deficits from lesion along the primary visual pathway; trans-synaptic retrograde optic neuropathy (18-30% of mod/severe TBI).
Rehabilitation for Visual Impairments

• Optical Management: prisms, magnifiers, telescopes, reverse telescopes, enlarged fonts, etc.

• Compensatory Strategies: Training scanning (head movement, eye movement), training awareness, and training mobility

• North Dakota Vision Services/School for the Blind
mTBI (concussion)

- 2.5 million ER visits per year due to head injury
- 80-90% of TBI are mild, most are never seen medically
- Over 15% of mTBI are symptomatic over one year
- Diffuse micro-environmental changes to axons, vasculature, and blood-brain barrier not diagnosed by traditional methods
- Neurometabolic cascade leading to neuronal dysfunction and cell death
Pathophysiology of Concussion and Clinical Findings

<table>
<thead>
<tr>
<th>Post-TBI pathophysiology</th>
<th>Acute symptom / clinical correlate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionic flux</td>
<td>Migraine headache, photophobia, phonophobia</td>
</tr>
<tr>
<td>Energy crisis</td>
<td>Vulnerability to second injury</td>
</tr>
<tr>
<td>Axonal injury</td>
<td>Impaired cognition, slowed processing, slowed reaction time</td>
</tr>
<tr>
<td>Impaired Neurotransmission</td>
<td>Impaired cognition, slowed processing, slowed reaction time</td>
</tr>
<tr>
<td>Protease activation, altered cytoskeletal proteins, cell death</td>
<td>Chronic atrophy, developmental of persistent dysfunctions</td>
</tr>
</tbody>
</table>
mTBI Clinical Trajectories (UPMC)
Visual Dysfunctions may contribute to a myriad of mTBI symptoms

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>🍌 ⛔️ ⛔️ ⛔️ ⛔️ ⛔️ ⛔️</td>
</tr>
<tr>
<td>Fatigue</td>
<td>🍌 ⛔️ ⛔️ ⛔️ ⛔️ ⛔️ ⛔️</td>
</tr>
<tr>
<td>Dizziness</td>
<td>🍌 ⛔️ ⛔️ ⛔️ ⛔️ ⛔️ ⛔️</td>
</tr>
<tr>
<td>Sensory Sensitivity</td>
<td>🍌 ⛔️ ⛔️ ⛔️ ⛔️ ⛔️ ⛔️</td>
</tr>
<tr>
<td>Confusion</td>
<td>🍌 ⛔️ ⛔️ ⛔️ ⛔️ ⛔️ ⛔️</td>
</tr>
<tr>
<td>Exercise Intolerance</td>
<td>🍌 ⛔️ ⛔️ ⛔️ ⛔️ ⛔️ ⛔️</td>
</tr>
<tr>
<td>Brain Fog</td>
<td>🍌 ⛔️ ⛔️ ⛔️ ⛔️ ⛔️ ⛔️</td>
</tr>
<tr>
<td>Nausea</td>
<td>🍌 ⛔️ ⛔️ ⛔️ ⛔️ ⛔️ ⛔️</td>
</tr>
<tr>
<td>Trouble Reading</td>
<td>🍌 ⛔️ ⛔️ ⛔️ ⛔️ ⛔️ ⛔️</td>
</tr>
<tr>
<td>Social Isolation</td>
<td>🍌 ⛔️ ⛔️ ⛔️ ⛔️ ⛔️ ⛔️</td>
</tr>
<tr>
<td>Screen Intolerance</td>
<td>🍌 ⛔️ ⛔️ ⛔️ ⛔️ ⛔️ ⛔️</td>
</tr>
<tr>
<td>Trouble speaking</td>
<td>🍌 ⛔️ ⛔️ ⛔️ ⛔️ ⛔️ ⛔️</td>
</tr>
</tbody>
</table>
Typical Visual Dysfunctions Associated with mTBI

• Eyes drift outward (exophoria/exotropia)
• Fusional Vergence Dysfunction/Convergence Insufficiency
• Eye Tracking Difficulties (saccades/pursuits)
• Blurred Vision (Accommodative Dysfunction)
• Visual Discomfort/Eyestrain
• Light Sensitivity
• Motion Sensitivity
• Concentration Difficulties
• Reading Problems
• Poor Visual Judgment/depth perception
• Shifted egocentric localization (sense of one’s midline)
4 Tiered Conceptual Model of Vision Assessment (in mild TBI) (Ciuffreda et al 2016)

- Basic Vision Examination
- Oculomotor Based Problems
- Non-Oculomotor Based Problems
- Non-Visual Problems

- OD, MD: Refraction, Ocular Health, Visual Impairment
- Neuro-optometrist: Versions, Accommodation, Vergences
- SLP, OT, PT, Neurology, Psychology, etc.: Depression, Fatigue, Cognitive Impairment, Behavioral Problems, Postural Problems, Attentional Problems, Neurological Problems
I. Basic Vision Examination: Refraction, Ocular Health, Visual Impairment (Graded Scale Tests)
Visual Dysfunction Diagnoses Require Norm-Referenced Tests Beyond “Basic Vision Exam”
“Developmental” Vision Problems & Learning

• Vision dysfunctions have been reported to be significant contributors to reading difficulties and ultimately to the need for special education services.

• One study of students (ages 6-16) with IEPs found that 69% who pass visual acuity screenings have undiagnosed and untreated vision problems affecting reading speed and comprehension.

• Undiagnosed vision problems can increase educational costs in the form of Individualized Education Programs (IEPs) and special education services, which would otherwise not be necessary, if the vision problems were treated.
II. Oculomotor Based Vision Problems

A. Versions (saccades & pursuits): Vision rehabilitation
B. Vergences: Vision rehab, near lenses and/or prisms
C. Accommodation: Vision rehab and/or near lenses
## Oculomotor Problems and mTBI

Capo’-Aponte et al. Military Medicine 2012

<table>
<thead>
<tr>
<th>Type of visual Impairment</th>
<th>%mTBI</th>
<th>%controls</th>
<th>p</th>
</tr>
</thead>
<tbody>
<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>0.0001</td>
</tr>
<tr>
<td>Ocular misalignments (vertical phoria)</td>
<td>55%</td>
<td>5%</td>
<td>0.0012</td>
</tr>
<tr>
<td>Ocular misalignments (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>
</tbody>
</table>
RightEye: Versions (saccades/pursuits)
Visagraph: Saccadic Reading Eye Movements

**Good Reader**

- The Greeks were the first to discover sponges growing in the ocean and to supply them to other countries. Sponges are gathered in shallow water by men in glass-bottomed boats.

**Poor Reader**

- The contest starts in late April or early May. Anyone may pay a dollar after January first each year.
Visagraph Reading Profile

Midway through the Civil War, Lincoln decided that the country needed to be tied together by a railroad. At the time, it took four months to sail from one coast to the other and more than a month to go by stagecoach. Many people thought that the railroad companies should pay for the construction of the railroads themselves. Lincoln felt that it would help the country recover from the war if a railroad were built. After Lincoln died, the government continued the project. Free land and payments for each mile of construction were given to the railroad companies. It took 20,000 workers six years and millions of private dollars to lay the 1,086 miles of track. Many died in the effort. In 1869 in Utah, the last spike driven in was a gold one.
Open Field Autorefractor: Accommodation

For near vision, the ciliary muscles contract and the central lens thickness increases to increase its power.
Receded Near Point of Convergence (NPC) and Receded Near Point of Fixation Disparity (NPFD) : Convergence Insufficiency
III. Non-Oculomotor Based Vision Problems (Ambient Processing)

A. Abnormal egocentric spatial localization: Yoked prisms
B. Photosensitivity: Tints and/or wide brimmed hats
C. Motion sensitivity: Binasal occlusion, tints and/or motion desensitization
D. Vestibular dysfunction: Vision and/or vestibular therapy
E. Visual field defect/neglect: Visual scanning training and/or prisms
F. Visual information processing dysfunction: Visual information processing and perceptual therapy
Atmospheric Experience
- Typically processes through the dorsal stream (Where/Action)
- Affected by Ambient Awareness
- Pre-consciousness
- Vague Emotional Impressions

PERIPHERAL VISION
- Greater than 5 degree retinal eccentricity
- Motion detection
- Low fidelity resolution
- Faster processing
- Color degrades away from fovea
- Typically process to Magno ganglion cells in a >1:1 ratio

Central Vision
- Up to 5 degree radial eccentricity from fovea
- High fidelity resolution
- Slower processing
- Greater color processing
- Cones are densely packed
- Typically process to Parvo ganglion cells in a 1:1 ratio

Intellectual Experience
- Typically processes through the Ventral Stream (what something is)
- Affected by Focal Modes of Attention
- Directed toward a goal
- Consciousness
- Judgement and Decision based
VEP: Ambient Processing Latency Delay

Slow, small, high contrast stimuli

Fast, large, low contrast stimuli

Focal Processing

Ambient Processing
Motion Sensitivity/Visual Vertigo
Coherent Motion Threshold: Elevated with Motion Sensitive Individuals
Critical Flicker Frequency Threshold: Elevated with Light Sensitive Individuals
Egocentric Spatial Localization Tests
Hx of concussion & attention allocation


• The sensitivity of EEG to history of concussion was explored in 81 asymptomatic youth athletes (18 with a history of concussion, ages 13–18) during visual-motor activities that vary in working memory, processing speed demands and motor output requirements.

• The history of concussion group showed a reduction in the theta to gamma power spectral density (PSD) ratio, indicating the persistence of altered attentional processing in athletes with history of concussion.
Neuro-Optometric Vision Rehabilitation
Neuro-Optometric Vision Rehabilitation: A.K.A Vision Therapy, Orthoptics, Oculomotor Training

• Vision therapy is a sequence of activities individually prescribed and monitored by an optometrist to develop efficient visual skills and processing. It is prescribed after a comprehensive eye examination has been performed and has indicated that vision therapy is an appropriate treatment option. The vision therapy program is based on the results of standardized tests, the needs of the patient, and the patient's signs and symptoms. The use of lenses, prisms, filters, occluders, specialized instruments, and computer programs is an integral part of vision therapy. Most effective vision therapy programs in the U.S. are provided by a Certified Optometric Vision Therapist (COVT) under the direction and supervision of a Fellow of the College of Optometrists in Vision Development (FCOVD). Specialized training in TBI diagnosis and therapy is also provided by the Neuro-Optometric Rehabilitation Association (NORA).
5 Components of Effective Neuro-Optometric Vision Rehabilitation

1. Motivation
2. Feedback
3. Repetition
4. Sensory-motor mismatch
5. Intermodal integration
IV. Non-Vision Based Problems

A. Depression: Counseling and/or medications
B. Fatigue: Nutritional counseling, exercise and/or adaptive strategies
C. Cognitive impairment: Cognitive therapy
D. Behavioral problems: Counseling and/or medications
E. Postural problems: Yoked prisms, PT, OT, Chiropractic care
F. Attentional problems: Cognitive/attentional therapy and/or medications
G. Neurological problems: Referral to a neurologist
Brain Injury Vision Symptom Survey (BIVSS)

A 28-item self-administered questionnaire for vision symptoms related to TBI. Score of 32 and above is significant for TBI.

- eyesight clarity
- visual comfort
- diplopia (double vision)
- depth perception
- dry eye
- light sensitivity
- reading

Thank You!

How many fingers am I holding up?

https://noravisionrehab.org/