Objective Evidence of Visual Improvement from Vision Rehabilitation after Brain Injury

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Hannu Laukkanen, OD MEd FAAO FCOVD-A
Professor Emerita Pacific University

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Overview – what should a savvy rehab professional know about mTBI?

- How common is mTBI? Why is it under-diagnosed & under-reported?
- What is mild-to-moderate TBI? What the heck is going on in the brain?
- Why can't doctors image structural brain lesions from mTBI?
- Why do individuals who have sustained mTBI complain about vision?
- Can the vision problems be successfully treated?
  - What are the most effective treatments that are commonly prescribed?
  - How compelling is the evidence that these treatments actually work?
- Who should you send these clients to with vision complaints?
  - Ophthalmologist, Neuro-ophthalmologist, Optometrist, Neuro-optometrist?

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Brain Injury
Neurodegenerative vs. Acquired

- **Neurodegenerative disease**
  - Progressive loss of structure, function or death of neurons in the brain
  - Examples include Parkinson disease, Alzheimer disease, and other dementias
- **Acquired Brain Injury (because injury acquired after birth)**
  - Damage to the brain either from traumatic or non-traumatic cause
  - Non-traumatic causes include stroke, heart attack, anoxia, toxicity, tumors, encephalitis, meningitis, etc.
  - Traumatic caused by sudden bump, jolt or blow to the head or penetrating injury
    - TBI = Traumatic Brian Injury
    - CHI = Closed Head Injury
    - PHI = Penetrating Head Injury

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Most Frequent Causes of mTBI:

1. Falls (35.2%)

– 50% of children's TBIs (aged 0 to 14 years)

– 61% of adults TBIs (aged ≥ 65 years)

2. Motor vehicle – traffic (17.3%)

– motor vehicle crashes/traffic-related incidents
2nd leading cause of TBI but resulted in the largest percentage of TBI-related deaths (31.8%)

3. Struck by/against events (16.5%)

– Colliding with a moving or stationary object

4. Assaults (10%)

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Mild Traumatic Brain Injury (mTBI)

- **An estimated 1.4 to 3.8 million mild traumatic brain injuries (mTBI) are diagnosed every year in the United States**
  (Ventura, et al. 2015)

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Traumatic Brain Injury (TBI)

5.3 MILLION AMERICANS SUFFER MENTAL OR PHYSICAL DISABILITY DUE TO BRAIN INJURY

NOT AN OVER-ESTIMATION – TRUE PREVALENCE HIGHER

- 5.3 million number based on hospitalization data: U.S. Centers for Disease Control & Prevention
- **Doesn't include ER, MD office pts sent home, or those who sought no hospital treatment**

LOTS OF "HIDDEN" OR UNIDENTIFIED HEAD TRAUMA

"MILD"-"MODERATE" BRAIN-INJURED INDIVIDUALS: APPEAR NORMAL, LOOK LIKE EVERYONE ELSE

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mTBI Numbers are Rising

- Concussion rate has increased more than 4-fold from 1998-2008 (15.5% annual increase)
- Number of reported concussions has doubled in the last ten years, and the number among teens has increased by 200% (Head Case, 2013)
- Boys' sports accounted for 53% of athlete-exposure and 75% of all concussions

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Brain Injury described by "severity" concussion is a "mild" form of traumatic brain injury

Brain injuries categorized as:

- **"mild", "moderate", "severe"**

Categorization based on length of loss of consciousness & amnesia

Severity category DOES NOT equal the expected recovery time, recovery outcome, or eventual functional status of injured person

Even "mild" injuries can result in:

- **Multidimensional long-lasting effects on a person's life**
- **Complete disability**

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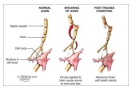
You Don't Have to Hit Your Head to Sustain a mild TBI



acceleration-deceleration whiplash-type injury = mTBI

- Coup contrecoup
- rotational, translational, and screw movements of the brain within the cranium that causes further brain contusion and damage (stretching), especially to the white matter fiber tracts

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Two Categories Tissue Damage with mTBI / Concussion

1. FOCAL TISSUE DAMAGE (DAMAGE THAT CAN BE IMAGED)
   - alteration of brain tissues that can be imaged
2. DIFFUSE TISSUE DAMAGE (DAMAGE CAN'T BE IMAGED)
   - axonal shear (diffuse)
   - axonal stretch (diffuse)
   - cavitation (diffuse)
   - vascular (diffuse)
   - anoxia (mostly diffuse)
   - electrical shock (mostly diffuse)
   - chemical/toxic (mostly diffuse)

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mTBI is an "Invisible Injury"

CHRONIC DEFICITS ASSOCIATED WITH MILD–TO–MODERATE TBI ARE UNDER-RECOGNIZED BY PROVIDERS IN THE MEDICAL COMMUNITY

- **Unable to "see" mTBI/concussion tissue damage with past imaging technology**
  - Diffuse Axonal Injury damage to micro-architecture not visible
  - mTBI damages white matter intra-brain communication network
  - DTI-MRI in the future may better reveal damage to white matter tracts
- **Medical providers dismiss problems that can't be imaged**
  - **mTBI / concussion problems often under-recognized & under-treated**

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Neuro-metabolic Cascade Summary

- ✓ Release of neurotransmitters - Glutamate
- ✓ Massive neuron firing creates large cellular demand
- ✓ Calcium influx into neurons blocks oxygen perfusion, preventing normal cellular respiration
- ✓ K+ efflux cause vasoconstriction
- ✓ This prevents fuel (glucose) from getting to the cells
- ✓ This leads to cellular death and dysfunction

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Concussion Pathophysiology

- Just when brain has high metabolic need post-TBI
  - Energy production is reduced
  - Blood flow is decreased
- This mismatch results in cellular damage
- As severely injured cells die, they release cytokines that further drive the inflammatory process
- The inflammatory response produces secondary injury

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"Second Impact Syndrome"

Studies indicate "concussed" brain cells suffer "vulnerability" window for period of time--If 2nd "mild" nonlethal insult occurs during this window: irreversible damage results

Two-concussions within 3-days = severe TBI

Two-concussions ≥ 5-days apart = 2-mild independent TBIs

Repeated concussive or mild TBIs occurring within a short period of time (i.e., hours, days, or weeks) can be catastrophic or fatal

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Personal Consequences of TBI

PATIENT'S "PERCEPTION OF SELF" ALTERED BY EVEN MILD–TO–MODERATE TBI

Survivors w/ persistent problems become a different person

- **Unable work at same level on the job after TBI**
- **Decreased engagement in avocational activities as before**
- **Personality changes often lead to social isolation**
  - Less independent than before injury
  - Changes in family dynamics (much higher divorce rate after TBI)
  - Pre-TBI friends tend to drift away

- **Post-TBI survivor not the same person**

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Societal Consequences of TBI/concussion

RESPONSIBLE FOR LOTS OF "SOCIAL ILLS"

(BI RESEARCH CENTER: MT. SINAI MEDICAL SCHOOL)

– Learning disabilities

- 20% LD children with BI
  - (Kansas State Neurologic-Disabilty Project)
- 50% of children in LD program in NY had suffered "hard blow to head"
  - (study funded by US Dept Education)

– After BI: 2X rate of alcoholism & drug abuse

- sharply elevated rates of depression, OCD, and panic disorder

– chronic homelessness

- 82% in NY shelter had prior blow to head before homelessness
- usually from parental abuse in childhood

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Visual Consequences: mTBI/concussion

- 90% of individuals that have a concussion will demonstrate ≥1 ocular difficulties
- If not addressed, these ocular difficulties can result in a delayed recovery
- 40% of individuals will have ocular difficulties longer than 3 months
- Intervention is helpful in ensuring resolution of ocular complaints and meeting the other trajectories as well

Suter, Penelope S., et al. "Vision Rehabilitation: Multidisciplinary Care of the Patient Following Brain Injury." *By Penelope S. Suter, Lisa H. Harvey (9781439836552)*, Routledge, 2 Feb. 2011, www.allbookstores.com/Vision-Rehabilitation-Multidisciplinary-Care-Patient/9781439836552.

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What visual functions are commonly disrupted by mTBI/concussion?

I. Visual clarity
   - Blurry vision / double vision / fluctuation of vision

II. Refraction / need for optical correction

III. Visual comfort
   - Photosensitivity (indoors, outdoors, especially fluorescent lighting
   - Headaches/fatigue/dizziness related to use of vision
   - Visual Motion Sensitivity / perceived peripheral motion

IV. Ocular Motilities
   - Accommodation (focusing)
   - Vergence (2-eyed teaming)
   - Binocularity (2-eyed depth perception)
   - Eye Movement stability/accuracy/precision
     - Reading eye movement skills

V. Visual-Perception Skills
   - Visual Memory
   - Figure Ground
   - Form Constancy,
   - Visual Neglect, etc., etc.

Photo retrieved from http://www.lvpei.org/EyeTopics/EyeHealth/Diplopia/Double_Vision.php

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Tool used worldwide for symptoms

- **Brain Injury Vision Symptom Survey = BIVSS**
- The BIVSS is a 28-item scaled questionnaire designed to query vision behaviors related to mild-to-moderate brain injury

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What is the Purpose of BIVSS

- **Document the many different visual complaints of TBIs**
- **Establish a complaint scale for comparison to test results**
- **Explore if complaint patterns predicted different types of TBI**
- **Understand the natural progression of symptoms after TBI**
- **Serve as a yardstick to compare before and after treatment**
- **Help allied health professionals identify which TBI patients were MOST in need of vision examination referral**

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mTBI soldiers vs. controls
BIVSS symptom results by category

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Validation Study Results for BIVSS

- 27/28 questions completed by 93.5% of TBI subjects, all 28 items were completed by all 157 reference subjects.
- TBI results significantly differed from non-TBIs.
- BIVSS sensitivity was 82.2% for correctly predicting TBI and 90.4% for correctly predicting non-TBI
- A raw **BIVSS score of >31 was determined as discriminative** of a significant visual problem for the survey.

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Conclusions

- The BIVSS has **good test-retest reliability**
- No significant bias in BIVSS scores between test administrations (with either TBI or non-TBIs)

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Longitudinally stable: no significance variance in test-retest results 2-wks to 2-mo. apart

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Conclusions from BIVSS studies

- BIVSS detected symptoms of PCS (post-concussive syndrome) with athletes better than the Rivermead Post-Concussive Survey Questionnaire (Island, H_Concussed athlete study, 2017)
- **BIVSS is a valuable tool for assessing & quantifying vision symptoms associated with mTBI**

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How common are vision function problems after concussion?

- 69% had <u>at least one</u> vision problem
  - –Accommodative problems: 50%
  - –Convergence insufficiency: 49%
  - –Saccadic dysfunction: 29%

Master CL, Scheiman M, Gallaway MF, et al. Vision Diagnoses are Common after Concussion in Adolescents. Clin Pediatr 2016 Mar;55(3):260-7.

slide courtesy of Dr. Mitchell Scheiman 26

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JRRD Volume 47, Number 3, 2010 Pages 183–200 Journal of Rehabilitation Research & Development

Accommodation in mild traumatic brain injury

Wesley Green, MS;[1] Kenneth J. Ciuffreda, OD, PhD;[1]* Preethi Thiagarajan, BS Optom, MS;[1] Dora Szymanowicz, BS;[1] Diana P. Ludlam, BS, COVT;[1] Neera Kapoor, OD, MS[2]
Departments of [1]Vision Sciences and [2]Clinical Sciences, The State University of New York/State College of Optometry, New York, NY

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Post-mTBI Ocular Motor deficits common

90% TBI's with ''visual symptoms'' in mTBI clinic population manifested >1 oculomotor deficits*

- 50% had abnormal versional eye movements*
  - Saccadic intrusions
- 55% had abnormal vergence function*
  - 43% convergence insufficiency
- 41% incidence of accommodative dysfunction
- 25% strabismus
  - 7% Cranial Nerve IV and III palsies

*Ciuffreda, et al. Occurrence of oculomotor dysfunctions in acquired brain injury: a retrospective analysis. Optometry 2007;78:155–61

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Diagram of proposed neural mechanism

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Post-concussion Ocular Motor deficits common

- Approximately 30% of those with concussion experience abnormalities in saccadic functioning (Ventura et al, 2015; Mucha et al, 2014; Capo-Aponte et al, 2012;)
- 60% of the concussed experience smooth pursuit dysfunctions (Capo-Aponte et al, 2012)
- Smooth pursuit is commonly used to assess the higher cognitive functions of memory and attention. (Ventura et al, 2016)

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Video of circular tracking by non-TBI

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Video of circular tracking by mTBI

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Common mTBI Problem: **Visual Motion Sensitivity**

- Inability to tolerate complex visual environments
  - Coping difficulties with grocery store aisles and highly patterned floors
- Causes the individual to feel unstable, fear of falling & bumping into objects, frequently accompanied by nausea
  - Movement seen in peripheral environment standing still
  - Problems walking down busy streets
- complex social situation visual coping difficulty
  - Often results in minimal eye contact when socializing in groups

Image: *Grocery Store*, retrieved from https://www.flickr.com/photos/1flatworld/26378466616/in/photolist-526DU5-bxmM5X-bxuJhF-bxnOax-9NYCfb-bxnML2-bxnQH6-7PNzhY-8WQus-cxn6Sz-cxnEA9-9q2kwA-uSRHE-vchao-5i6Drb-bjPTXr-xngqrK-9Ufa83-gDpuA3-aiVQnhH-oOxdTp-5qJ7kc-oCxCYt-bx9qTF-4Gs8rv-61mvwS-qbetgb-5dCVBk-q4FH68-7Gzz7U-5dHDAv-dvME1Np-5eEn2-4adggd-o6CrZ5-9FdcTr-nGZtyA-BzpCL-bgdKwe-7usMLc-9FghWG-LNmyD-4NgGz5-4P65a1-pkwdt-6ubJS3-pKTuDQ-8v5dhA

Ciuffreda, Kenneth J., et al. "Traumatic Brain Injury." *Advances in Ophthalmology and Optometry*, vol. 1, no. 1, 2016, pp. 307–333.

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Visual Motion Sensitivity (VMS)

- Estimated to be present in at least 40% of TBI
- VMS is a sensory-perceptual "hypersensitivity"
- Refers to visual motion hypersensitivity, especially in the retinal periphery
  - We are normally habituated to peripheral "Gibsonian optic flow"
  - TBI can disrupt habituation to peripheral retinal optic flow
  - When TBIs with VMS traverse a complex visual environment, the dynamic stream of retinal-image motion reduces their stability.

Ciuffreda, Kenneth J., et al. "Traumatic Brain Injury." *Advances in Ophthalmology and Optometry*, vol. 1, no. 1, 2016, pp. 307–333.

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- Photos of provocative targets for VMS

Good VMS screening test: BDT Bihemispheric Dissonance Test

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Binasal tape can significantly improve symptoms of VMS

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tandem walk with/without binasal tape

tandem walk with hab (-) dist Rx
- Patient video 1

tandem walk with binasal tape
- Patient video 2

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VEP amplitudes with binasal occlusion

Binasals decr non-TBI VEP amps
Binasals increased VEP amps of TBIs

Ciuffreda K, et al. Effect of binasal occlusion (BNO) on the visual-evoked potential\ (VEP) in mild traumatic brain injury (mTBI). Brain Injury 2012

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Vision *Critical* for Balance & Localization Commonly Disrupted with mTBI

The body maintains balance INTEGRATING sensory information from 3-systems:

1. Vision
2. Vestibular system
3. Proprioception

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mTBI / concussion regularly results in loss of sensory integration between vision, proprioception, and the vestibular sense

– Standing demo

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"Abnormal Egocentric Localization"
AEL also called VMSS or Visual Midline Shift Syndrome

Chapter #6 by Ciuffreda/Ludlam in
Vision Rehabilitation by Suter/Harvey

- Alteration in "sense of straight ahead"
  - Objective body coordinates ≠ subjective perception of what is straight ahead
- Other professions use different names for same phenomenon:
  - "Disturbed egocentric space representation"
  - "Anomalous midline projection"

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mTBI patients trying to point "straight-ahead with eyes closed = AEL

Patient egocentric localization photos

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with and without small yoked prisms

negligible RE

- Patient video 3

2ΔBL yoked prism

- Patient video 4

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Risk of fall (RoF) intervention by affecting visual egocenter through gait analysis and yoked prisms

William V. Padula, Prem Subramanianb, April Spurlinga and Jonathan Jennessa

NeuroRehabilitation 37 (2015) 305–314

BACKGROUND: Following traumatic brain injury (TBI) a shift of egocenter can directly affect posture, balance and spatial orientation. As a consequence, this increases the risk of fall (RoF)

OBJECTIVE: To determine if significant change in balance with the intervention of yoked prisms to reduce the risk of fall.

METHODS: Ambulation of 36-subjects evaluated on a pressure sensitive mat before and after intervention with yoked prisms. Changes in gait and balance analyzed in the anterior-posterior (AP) and medial-lateral (ML) axes during ambulation.

RESULTS: T-tests for each measure comparing the difference-of-differences to a zero change at baseline returned statistically significant reductions in both AP ($p < 0.0001$; 95% CI: 1.368–2.976) and ML ($p = 0.0002$; 95% CI: 1.472–4.173) imbalances using specifically directed yoked prisms to correct the visual midline deviation.

CONCLUSION: **yoked prisms have the potential to provide a cost-effective means to restore normal visual midline (egocenter) improving balance, reducing RoF with subsequent injury**.

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Neuro-Optometric Treatment options

- Specific Prism Lens Prescriptions
- Tints and Coatings
- Specific Occlusion Techniques
- Vision Therapy/Orthoptics – restoration of Binocular Function
- Visual Motor Guidance Rehabilitation
- Visual Processing Rehabilitation

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Specific Prism Lens Prescriptions

- Correcting prism for eye turns
- Yoked prism –knowledge base limited to Neuro-optometry
  - Alter perception of visual space
  - Shift perception of midline to actual midline position
  - Eliminate abnormal head turn and position

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Peripheral Visual Field Loss

- Labeled a "field loss" in medical-speak, should be termed a "reduction in sensitivity"
- Generally permanent
- Often irregular – not typical with a loss of visual field due to medical issues
- Patient/Client needs to be made aware of reduced visual field sensitivity and given accommodation techniques – Occupational Therapy plays a major role in this arena

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Tints & lens coatings: valuable treatment for photo-hypersensitivity

- Primarily used to provide relief from abnormal light sensitivity (Photophobia or photo-hypersensitivity)
- Many special tints and coatings available – a part of the Neuro-optometry knowledge base
- Special tints on contact lenses can also be prescribed

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Reading with/without tint

- Patient video 5

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Oculography

A-DEM

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Can eye movements reveal mTBI vs non-TBI?
which one is non-TBI which one is mTBI?

10/28/19 51

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Vision Therapy(VT) / Orthoptics

- VT based upon neuroplasticity
  - Neuroplasticity is flexibility of the brain to restore / regain normal function to best possible extent
    - Neural re-routing around / through damaged areas
    - Establishing new pathways for function restoration
  - Physical evidence of neuroplasticity
    - Collateral sprouting from adjacent intact cells to damaged area

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neuroplasticity fundamental:

1. **Rehabilitation of Binocular Vision**
2. **Rehabilitation of Visual-Motor Guidance**
3. **Rehabilitation of Visual Processing Ability**
   - Frequency & repetition essential for neuroplasticity
   - Successful VT based upon biofeedback mechanisms and enhanced by lenses, prisms, filters

- Physical Therapy and Occupational Therapy share very similar areas of rehabilitation with Neuro-Optometry
- Cognitive Therapy, Neuropsychology, Recreational Therapy and Occupational Therapy share very similar areas rehabilitation with Neuro-Optometry

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Describing the post-VT experience

- Patient video 6

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OBJECTIVE EVIDENCE DEMONSTRATING IMPROVED VISUAL FUNCTION AFTER mTBI FOLLOWING NEURO-OPTOMETRIC REHABILITATIVE VT

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RESULTS: Following the OMT, over **80% of the abnormal parameters significantly improved**. Reading rate, along with the amplitudes of vergence and accommodation, improved markedly. Saccadic eye movements demonstrated enhanced rhythmicity and accuracy. The improved reading-related oculomotor behavior was reflected in reduced symptoms and increased visual attention. None of the parameters changed with ST. **CONCLUSIONS: OBVR had a strong positive effect on oculomotor control, reading rate, and overall reading ability. This oculomotor learning effect suggests considerable residual neuroplasticity following mTBI**.

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Objective Evidence of Improved mTBI Vergence Function after VT intervention

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Variance of Positional Eye Movement Recordings Before and After Vision Therapy

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Measuring steadiness + accuracy of eye movements with research instrument

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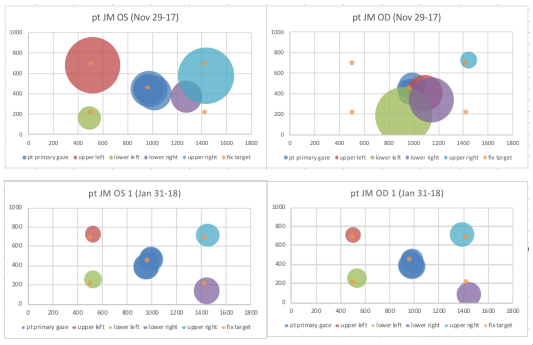
Eye Movement stability & accuracy improved

(left eye results on left/right eye on right)

baseline (top) versus end of vision therapy (bottom)



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mTBI/concussion has negative effect on Neural Synchronization, Neural Recruitment, Functional Connectivity

- Borrowed slide from Dr. Tara Alvarez 1

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- Borrowed slide from Dr. Tara Alvarez 2

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Neural Recruitment with mTBI before and after vision therapy vs non-mTBI

- Borrowed slide from Dr. Tara Alvarez 3

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Functional Connectivity with mTBI before and after vision therapy vs non-mTBI

- Borrowed slide from Dr. Tara Alvarez 4

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Neuro-Optometry vs. Neuro-Ophthalmology

- Kapoor and Ciuffreda, "Vision Problems." In Silver, et. al., Textbook of Traumatic Brain Injury. 2nd Edition, 2011.
  - "…optometry's incorporation of primary eye care, vision therapy, low vision, refraction and visual perception provides the foundation of a sub-specialty referred to as neuro-optometric rehabilitation." (Neuro-Optometry)
  - "neuro-ophthalmology……may be consulted on occasion, depending on the nature and severity of any structural problems such as physical insults to the globe and associated periorbital region."

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When to Refer to Neuro-Optometry

- **Based only upon functional prognosis:**
  - **When is the best time to treat?**
  - **a. Acute phase**
    - **Early intervention better, faster progress**
  - **b. Chronic phase (>35days)**
    - **Late rehab takes longer & costs more**
- **Based upon psych/emotional factors:**
  - **a. When you have a participatory patient**
    - **Emotionally/mentally prepared for rehab**
    - **If too soon, the patient may be experiencing anger, denial, frustration**
    - **If too late, patient may be too accepting & too adapted**
    - **Too accommodated to the handicap**
  - BIVSS score >31

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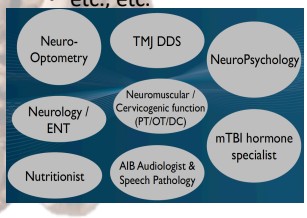
Who Manages Patients with mTBI?

- Physiatrists
- Neuro-Optometrists
- Occupational Therapists
- Speech/Language Pathologists
- Social Workers
- Physical Therapists
- Neuro-Psychologists
- Neuro-Ophthalmologists
- Neurologists
- Chiropractors
- Dietitians
- etc., etc.



Courtesy of Dr. Quaid

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How much does lens treatment cost?

Glasses: 1-3 Rx changes/yr may be needed for rehab

- Single-vision lenses best for vision rehab, so will need separate glasses for near & far seeing activities
  - Spectacle frames
    - Wide range: <$100 to >$500
  - Spectacle lenses (single vision—no bifocal/progressive)
    - <$100 to >$500 Depends upon following lens options:
    - Prism (vertical, horizontal, yoked-prism
    - Lens tints / Photochromatic lenses (darken outdoors)
      - for light hypersensitivity, visual motion sensitivity
    - Anti-reflection coatings (to decrease glare)
  - Yearly costs for rehab glasses can range from $400 to $3000

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How much does **VT treatment** cost?

- Vision Therapy
  - Different VT "care-delivery" models in private practice

  Most common model:
  - weekly office visits (may also be bi-weekly, monthly)
    - in-office VT session ($50-150)
      - Assessment, prescription of home therapy activities
      - 20-30 min home therapy/daily (multiple short activity sessions)
      - 4-6 days/week
    - 20-35-week treatment program length is typical
    - Cost for programs may range from <$1000 to >$4000

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Hannu Laukkanen OD MEd FAAO FCOVD-A

- Emeritus Professor / Optometric Physician
- Course Instructor: VSC 841(PhD-1), 842(PhD-2) OPT 765, BaVS 314, AAVS
- Coordinator MEd – Visual Function in Learning
- Pacific University College of Optometry
- 2043 College Way, Forest Grove, OR 97116
- Voice: 503-352-2751
- FAX: 503-352-3033
- laukkanh@pacificu.edu

I strive to inspire our students to think, care, create, and pursue justice in our world

- President, Brain Injury Connections-Northwest (BIC-NW) Board of Directors
- Neuro-Optometric Rehabilitation Assn (NORA) Advisory Board
- Northwest Congress of Optometry (NWC) Board of Directors

Thank you thank you thank you!

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