THE EYES ARE THE WINDOWS TO THE BRAIN IN CONCUSSION

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The University of Alabama at Birmingham
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Schedule. Friday. April 7, 2017

<table>
<thead>
<tr>
<th>QUESTIONS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:00-1:15 How is concussion currently diagnosed?</td>
</tr>
<tr>
<td>1:15-2:00 Why Vision?</td>
</tr>
<tr>
<td>2:00-3:00 Why Vestibular?</td>
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<tr>
<td>3:00-3:15 Break</td>
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<tr>
<td>3:15-4:00 What clinical tests will best guide PT treatment?</td>
</tr>
<tr>
<td>4:00-5:00 What intervention strategies are effective for athletes with concussion?</td>
</tr>
</tbody>
</table>
HOW IS CONCUSSION DIAGNOSED?

Concussion: A Difficult Diagnosis

- Lack of consistent objective findings in the identification of concussion
- This can impact initial diagnosis, development of a treatment plan, and tracking of recovery
- This makes it difficult to distinguish pre-existing or co-morbid conditions from those attributable to concussion
A Difficult Diagnosis

- Objective evidence to support the identification of concussion could:
  - expedite diagnosis
  - facilitate appropriate treatment
  - provide a means to monitor recovery
  - allow more proactive management of pre-existing or co-morbid conditions

PHYSICAL EXAM (Matuszak 2016)

- “Concussion physical examination has not been standardized or supported by evidence”
- Elements of the physical examination appear to have utility for evaluating concussion
  - Screening ocular examination
  - Cervical musculoskeletal examination
  - Static and/or dynamic balance assessment
  - Mental status examination
- Data on validity are lacking
SYMPTOM SCALES (Grubenhoff 2010; Lovell 2003; Schatz 2006; Gioia 2009)

- Graded Symptom Checklist can distinguish concussion from those without concussion within the first 2 days after injury in children ages 6 years and older.
- Post-concussion Symptom Scale can distinguish concussion from those without TBI within the first 4 days after injury in high school athletes.
- Other validated symptom scales have shown reliability in diagnosis of concussion and have demonstrated validity at ages younger than high school.

NEUROIMAGING (Koerte 2016)

- Routine head CT for diagnostic purposes not recommended
- Brain MRI is not recommended
- Specialized MRI imaging sequences show promise in research settings:
  - functional MRI
  - diffusion tensor imaging
  - gradient recalled echo imaging
  - others
- Single Photon Emission Computed Tomography (SPECT) may demonstrate hypoperfusion or hypometabolism but the qualitative nature results in significant variability.
NEUROCOGNITIVE ASSESSMENT (Schatz 2006; nelson 2016; Schmidt 2012)

- ImPACT cognitive testing probably distinguishes high school athletes with and without concussion in the first 4 days post-injury
- Other validated computerized cognitive tests are also accurate in the diagnosis of concussion in adults and children
- Insufficient evidence to determine whether baseline testing in children better identifies concussion post-injury

EEG (McCarthy 2015)

- EEG recordings can be used to classify head injuries and can detect structural and functional brain injuries
- Quantitative EEG or limited montage EEG may provide a quick, safe biomarker that can reliably help diagnose, characterize, and monitor individuals following concussion
- Still under investigation and not recommended in routine diagnosis of concussion
SERUM BIOMARKERS (McCarthy 2015)

- S100β most frequently studied
- Neuron-specific enolase
- Plasma tau
- Further investigation of the circulating biomarkers needed
  - temporal profile of the biomarkers
  - correlation with the clinical course
- Other laboratory studies
  - CSF
  - Saliva, urine, and tears

PHYSICAL EXAM (Matuszak 2016)

- Elements of the physical examination appear to have utility for evaluating concussion
  - Screening ocular examination
  - Cervical musculoskeletal examination
  - Static and/or dynamic balance assessment
  - Mental status examination
- Objective Testing of Vision, Balance, and Vestibular Function
WHY VISION & VESTIBULAR? (Ciuffreda 2014)

- 30 areas of the brain and 7 of 12 cranial nerves deal with vision
- Balance is derived from multiple sensory inputs from vestibular end-organs, the visual system, and the somatosensory and proprioceptive systems

**Postural control**

- Vision
- Vestibular info
- Proprioception

- Motor command
- Volition, Feed forward control

- Joint mechanics, external constraints
- Movements

WHY VISION?
Concussion and Vision – Literature 2012-2013

- Reduced near-point of convergence (Szymanowicz, 2012)
- Consistent accommodative fatigue effects (Thiagarajan, 2013)
- Perceived limited depth perception (Ciuffreda, 2012)
- Photosensitivity (Capo-Aponte, 2012)

9 year old: charged on basketball court and hit back of head on concrete floor (2013)

- 9 months later
  - Unable to attend school for more than 2 hours at a time for a maximum of 3 days a week.
  - Has a teacher come to his house 4 days a week
  - Neuropsychologist suggests brain rest
    - Hold off on everything else including eye exercises until he can attend school for 10 hours a week.
UAB/COA VORClinic 2014

UAB/COA VORClinic
2015-2016
Why The Eye?
It is built from the brain
It is built like the brain
It courses through the brain

\[ mTBI = mTBEye \]
Why The Eye in Concussion?  
It's built from the brain.  
Week 3 – 10 of pregnancy

Diencephalon (forebrain)
Mechanism of Diffuse Axonal Injury

Axon Shear (Post Concussion Syndrome)

A. Trauma causes the axon to twist and tear
B. The result is permanent death of the brain cell

Why The Eye in Concussion?
It's built Like the brain.
Why the Eye in Concussion?
It courses Through the brain.

- Cranial Nerves
  - I - Olfactory
  - II - Optic
  - III - Oculomotor
  - IV - Trochlear
  - V - Trigeminal
  - VI - Abducens
  - VII - Facial
  - VIII - Vestibulocochlear
  - IX - Glossopharyngeal
  - X - Vagus
  - XI - Accessory
  - XII - Hypoglossal
Why The Eye in Concussion?

- The Eye
  - is built from the brain,
  - is built like the brain,
  - courses through the brain.

Concussion and Vision

"Is Vision Part of the Puzzle?"

- Ventura RE, Jancuska JM, Balcer LJ, Galetta SL
- Pubmed review of last 5 years +
- Concussion:
  - abnormal
    - Saccades, pursuit eye movements
    - Convergence and accommodation
    - VOR
Concussion and Vision - Prevalence Literature

<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>Convergence Insufficiency</th>
<th>Accommodative Insufficiency</th>
<th>Eye Mov’t</th>
<th>Visual Field</th>
</tr>
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<tbody>
<tr>
<td>Master 2015</td>
<td>100</td>
<td>49%</td>
<td>51%</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td>Stelmack 2009</td>
<td>103</td>
<td>28%</td>
<td>47%</td>
<td>6%</td>
<td>14%</td>
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<tr>
<td>Brahm 2009</td>
<td>191</td>
<td>42%</td>
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<td>33%</td>
<td>32%</td>
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<tr>
<td>Goodrich 2007</td>
<td>50</td>
<td>30%</td>
<td>22%</td>
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<td>Suchoff 1999</td>
<td>62</td>
<td>42%</td>
<td>10%</td>
<td>40%</td>
<td>32%</td>
</tr>
<tr>
<td>Normal population</td>
<td></td>
<td>5%</td>
<td>3%</td>
<td>2%</td>
<td></td>
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</table>

Concussion and Vision Problems

COA Database:
- Reduced NPC: 44%
- Convergence Insufficiency: 20%

Vision rarely mentioned in Return to Learn Protocols (Halstead 2010, McCrory 2013, Harmon 2013)
CHANGING RECOMMENDATIONS REGARDING VISION

- **2014 National Athletic Trainers’ Position statement (Broglio 2014)**
  - Consider: smooth pursuits, nystagmus, pupil reflex; (CN testing)
  - No convergence, accommodation, eye tracking recommended

- **2015: Current and emerging rehabilitation for concussion: a review of the evidence (Broglio 2015)**
  - RECOMMEND screening of eye movements and vision in concussion

### Concussion and Vision - Prevalence Literature

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Prolonged Recovery Characteristics
Corwin DJ, Zonfrillo MR, Master CL; J Pediatr 2014;165:1207-15

- N = 247 patients age 5 to 18 years with concussion
- Median
  - Return to Part-Time School: 12 days
  - Return to School without accommodations: 35 days
  - Symptom Free: 64 days
  - Return to Play (cleared for sports): 75 days
- Prolonged recovery associated with:
  - Depression or anxiety history
  - Initial c/o dizziness
  - Abnormal convergence or symptoms following OM exam
  - h/o prior concussion

Optometry and Vision Science
http://www.optvissci.com

Academic Difficulty and Vision Symptoms in Children with Concussion

Mark W. Swanson, Katherine K. Wine, Laura E. Drey, James Johnson, Richard D. Davis, Drew Ferguson, Matthew Heath Hale, Sara J. Grisham, Jennifer R. Merry, Claudio Bussard, Sarah D. Lee, and Erin Swanson

ABSTRACT
Response Academic difficulty is reported in children with prolonged post-concussive symptoms. Despite growing evidence that vestibular ocular and more specific dizziness are common in children with concussion, these subjects were not systematically assessed in return-to-play protocols. The purposes of this study was to evaluate the influence of children with post-concussive symptoms on academic difficulties. Academic difficulty was assessed in children with prolonged post-concussive symptoms.

Methods: Data were obtained from the Children’s Hospital of Alabama Concussion Initiative (CHACI) database and the hospital’s pediatric chart. Children were included based on the presence of prolonged post-concussive symptoms, including school performance. The demographic and concussion severity were noted as outcomes, and the correlation with reported academic difficulty was assessed.

Results: Of the 100 children, 54 (54%) reported academic difficulty. Children with prolonged post-concussive symptoms were more likely to report academic difficulty (OR 2.16, 95% CI 1.05, 4.46) compared to those without symptoms. Similarly, children with symptoms for more than 21 days were more likely to report academic difficulty (OR 3.35, 95% CI 1.04, 10.95) compared to those with symptoms for less than 21 days. In addition, children with abnormal convergence or symptoms following OM exam were more likely to report academic difficulty (OR 2.90, 95% CI 1.05, 7.98) compared to those without.

Conclusion: Vision problems were commonly reported in children with concussions and were independently associated with those reporting academic difficulty. Comprehensive vision assessment should be considered in children reporting academic difficulty and in the development of return-to-play protocols.

Keywords: concussion, school, education, vision, vestibular traumatic brain injury
# Symptoms of Mild TBI – Children’s of Alabama Concussion Database

M. Swanson, et al. 2017

<table>
<thead>
<tr>
<th>Symptom</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic Difficulty</td>
<td>141</td>
<td>13.7</td>
</tr>
<tr>
<td>Amnesia/Confusion</td>
<td>272</td>
<td>26.4</td>
</tr>
<tr>
<td>Balance</td>
<td>111</td>
<td>10.7</td>
</tr>
<tr>
<td>Concentration Difficulty</td>
<td>231</td>
<td>22.6</td>
</tr>
<tr>
<td>Confusion</td>
<td>811</td>
<td>80.8</td>
</tr>
<tr>
<td>Dizziness</td>
<td>978</td>
<td>95.9</td>
</tr>
<tr>
<td>Fatigue</td>
<td>329</td>
<td>32.9</td>
</tr>
<tr>
<td>Headache</td>
<td>922</td>
<td>90.9</td>
</tr>
<tr>
<td>Hearing Problem</td>
<td>141</td>
<td>14.1</td>
</tr>
<tr>
<td>Initiative</td>
<td>131</td>
<td>13.1</td>
</tr>
<tr>
<td>Nausea</td>
<td>355</td>
<td>34.1</td>
</tr>
<tr>
<td>Sleep Disturbance</td>
<td>137</td>
<td>13.7</td>
</tr>
<tr>
<td>Slurred/Speechless</td>
<td>16</td>
<td>2.7</td>
</tr>
<tr>
<td>Vision</td>
<td>385</td>
<td>38.5</td>
</tr>
<tr>
<td>Vomiting</td>
<td>174</td>
<td>17.4</td>
</tr>
</tbody>
</table>

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COA REDCap Database: 2007-2013

Swanson M, et al, 2017

Swanson M, Weise KK, Dreer LE, Johnston J, Davis RD, Ferguson D, Hale MH, Gould SJ, Swanson E, Christy JC, Busettini C, Lee SD.

- **What factors** correlate with **academic difficulty** in children with **prolonged post-concussive symptoms**?
  - Self-reported concussion symptoms
  - SCAT2 scores
  - Demographics
  - Concussion severity
COA REDCap Database: 2007-2013
Swanson M, Weise KK, Dreer LE, Johnston J, Davis RD, Ferguson D, Hale MH, Gould SJ, Swanson E, Christy JC, Busettini C, Lee SD.

- Cross-sectional study
- N = 1,033 (2007-2013)
  - Cohort of interest (N = 276)
    - 5 to 18 years
    - ≥ 3 symptoms
    - > 10 days of concussion-related symptoms (self-report)

COA REDCap Database: 2007-2013
Swanson M, et al, 2017
Swanson M, Weise KK, Dreer LE, Johnston J, Davis RD, Ferguson D, Hale MH, Gould SJ, Swanson E, Christy JC, Busettini C, Lee SD.

- N = 276 Symptomatic Concussed Children
  - Average age: 13.8
  - Median time since concussive event: 21 days
COA REDCap Database: 2007-2013
N = 1033 kids aged 5-18

- Age
- Days since concussion
- Race
- Gender
- Insurance (Private vs. Public)
- Number of Previous Concussions
- Loss of consciousness
- Event Amnesia
- Imaging
- SCAT
- Balance Difficulty
- Concentration Difficulty
- Confusion
- Dizziness
- Fatigue
- Headache
- Hearing
- Irritable
- Nausea
- Sleep disturbance
- Slurred speech
- Vision
- Vomiting
- Education Difficulty

COA REDCap Database: 2007-2013
N = 276 Concussed, Symptomatic (>3 symptoms > 10 days out)

- 29% reported Academic Difficulty
- 46% reported Vision Abnormalities

- >30 days (33%): Only vision and concentration remained statistically significantly associated with academic difficulty
COA REDCap Database: 2007-2013

• “Vision problems were commonly reported in children with concussions and were independently associated with those reporting academic difficulty.
• **Comprehensive vision assessment** should be considered in children reporting academic difficulty and in the development of return-to-learn protocols.”

Consider referral to eye care professional in concussion and academic difficulty when returning to learn.
Concussion and Vision - Evidence-based Clinical Eye Testing for mTBI (Capo-Aponte JE 2012)

- Near lateral and vertical phorias
  - Eyes pointing to same place on page?
- Positive fusional vergence
  - Eyes work together to stay on same place on page?
- Stereoacuity (Randot Preschool, e.g.)
  - 3D vision
- Near point of convergence
  - Eyes cross to same place on page?
- Amplitude of accommodation
  - Strength of focusing system?
  - Monocular accommodative facility
  - Flexibility switching from desk to chalkboard?
- Saccades and pursuit eye movements
  - Eye tracking
  - King-Devick
  - Also consider
    - CISS
    - Visual Acuity
    - Visual Field
    - Dynamic visual acuity
    - EO-ROM

Receded Near Point of Convergence (NPC)


Symptoms related to CI (CISS) is Increased in concussion (≥16)


### CONVERGENCE INSUFFICIENCY SYMPTOM SURVEY (CISS)

<table>
<thead>
<tr>
<th></th>
<th>Never</th>
<th>(not very often)</th>
<th>Infrequently</th>
<th>Sometimes</th>
<th>Fairly Often</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Do your eyes feel tired when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Do your eyes feel uncomfortable when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Do you have headaches when reading or doing close work?</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>4. Do you feel sleepy when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Do you lose concentration when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>6. Do you have trouble remembering what you have read?</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>7. Do you have double vision when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>8. Do you see the words move, jump, swim or appear to float on the page when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>9. Do you feel like you read slowly?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Do your eyes ever hurt when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Do your eyes ever feel sore when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Do you feel a “pulling” feeling around your eyes when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>13. Do you notice the words blurring or coming in and out of focus when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>14. Do you lose your place while reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Do you have to re-read the same line of words when reading?</td>
<td></td>
<td></td>
<td>X 0</td>
<td>X 1</td>
<td>X 2</td>
<td>X 3</td>
</tr>
</tbody>
</table>

For a score of 16 or greater, vision therapy may be indicated. 1,2,3
CISS is a valid, reliable instrument


Near Point of Convergence After Sport-Related Concussion: Measurement of Reliability and Relationship to Neurocognitive Impairment and Symptoms (Pearce KL, Dec. 2015)

CONCLUSION:
CI was common (~42%) in athletes evaluated within 1 month after SRC. Athletes with CI had worse neurocognitive impairment and higher symptom scores than did those with normal NPC. Clinicians should consider routinely screening for NPC as part of a comprehensive concussion evaluation to help inform treatment recommendations, academic accommodations, and referrals for vision therapy.”
Convergence Insufficiency Treatment Trial

- N = 221
- Age: 9 to 17 years
- RCT:
  - Office-based vision therapy (12 weeks) – 73%
  - Home-based pencil push-ups – 43%
  - Home-based computer therapy – 33%
  - Office-based placebo therapy – 35%
- Improved outcome = lower CISS (p <0.001), improved NPC and PFV (p = or < 0.005)
- [www.clinicaltrials.gov](http://www.clinicaltrials.gov)

Convergence Insufficiency Treatment Trial (non-concussed kids)

- Pennsylvania College of Optometry (25)
  - PI: Mitch Scheiman, OD
- Bascom Palmer Eye Institute (35)
- SUNY College of Optometry (28)
- UAB School of Optometry (28)
- NOVA Southeastern University (27)
- The Ohio State University College of Optometry (24)
- Southern California College of Optometry (23)
- University of CA San Diego: Ratner Children’s Eye Center (17)
- Mayo Clinic (14)

- National Eye Institute, Bethesda, MD: Paivi Miskala, PhD.
- Data and Safety Monitoring Committee
Convergence Insufficiency Treatment Trial (non-concussed kids)


• Most highly accessed article in 2008 for Archives of Ophthalmology

CITT-ART

• Convergence Insufficiency Treatment Trial – Attention and Reading Trial
  • Southern California College of Optometry at Marshall B Ketchum University
  • Pennsylvania College of Optometry at Salus University
  • The Ohio State University College of Optometry
  • NOVA Southeastern University College of Optometry
  • University of Alabama at Birmingham School of Optometry
  • State University of New York College of Optometry
  • Akron Children’s Hospital
  • Bascom Palmer Eye Institute
  • [www.clinicaltrials.gov](http://www.clinicaltrials.gov)
CITT – Concussion (CICON) – UG1 proposal

- Salus University (PCO) and Children’s of Philadelphia
  - M. Scheiman, OD, PhD  C. Master, MD
  - T. Alavarez, PhD

- UAB and Children’s of Alabama
  - K. Weise, OD, MBA  M. Heath Hale, MD
  - C. Busettini, PhD
  - J. Christy, PT/PhD  L. Dreer, PhD

- SCCO and Children’s of Orange County
  - S. Cotter, OD

- Akron Children’s Hospital
  - R. Hertle, MD (ophthalmology)
  - Tawna Roberts, OD, PhD

- Harvard and Boston Children’s

NPC > 6 cm – refer for vision testing
Concussion and Vision:
“Is Vision Part of the Puzzle?”

- Ventura RE, Jancuska JM, Balcer LJ, Galetta SL
- Pubmed review of last 5 years +
- Sideline Testing
  - SCAT3
  - King-Devick
  - Eye tracking devices
  - Pupillary assessment...

King-Devick
Vision Testing Is Additive to the Sideline Assessment of Sports-Related Concussion

*Neurol Clin Pract* July 2014

“Combining K-D and SAC captured abnormalities in 89%; adding the BESS identified 100% of concussions.”
King-Devick: Galetta KM, J Neurol Sci 2011

K-D Time Scores (seconds)

A

B

C

P=0.009 vs. baseline

P=0.0000 vs. baseline

P=0.0001 vs. baseline

Baseline

Concussion

n = 10

Baseline

Post-workout

n = 18

Baseline

Post-season

n = 219

King-Devick and Pre-season Visual Function in Adolescent Athletes
(Weise KK, 2017)

- Weise KK¹, Swanson MW, Penix K, Hale MH, Ferguson D.
- Optom Vis Sci. 2017
- UAB/COA
Weise KK, Swanson M, et al, April 2017
n = 619

Mean, fastest, Error-free time = 43.9 seconds (24s – 120s)
ICC = 0.92

Weise KK, Swanson M, et al, April 2017
n = 619

• KD is NOT associated with
  • Failed NPC (p = 0.63)
  • Modified Thorington (p = 0.55)
• Therefore,
  • Score is not slower because of poor convergence or eye coordination
  • Consider NPC + KD
• If less than 20/30, 4 to 6 seconds slower
• Implications: pre-season with glasses vs. on-field without
King Devick

- Baseline data required
  - Repeat up to 4 times in high school and junior high kids
- Avoid using it as a single sideline test
- Step in the right direction
  - Identifies a need for objective testing!

NeurOptics Pupillometer
UAB/COA Pre-season Sports Physicals Spring 2015 - Pupillometer

• N = 247 in one high school
• Repeatability of Pupillometer
  • ICC (interclass correlation) = 0.57958 for OD
  = 0.57963 for OS
• This is the interclass correlation coefficient for the RIGHT pupillometry and the repeat. This indicates there is Fair agreement between the two measures.
• Note the similarity between Right and Left ICC.

UAB/COA Pre-season Sports Physicals Spring 2015 - Pupillometer

• N = 247 in one high school
• Average NPi (from company)
  • 4.1 ± 0.32
• Average NPi (from UAB/COA)
  • 4.1 ± 0.30
• Bland-Altman Limits of Agreement (UAB/COA)
  • LOA (OD) = 0.49; LOA (OD) = 0.48
• Repeat if two measures differ by 0.50 or more
• A measure that is 0.50 different post concussion is a true difference
UAB/COA Pupillometer under Friday Night Lights

- Average NPI: Pre-Season
  - 4.1 ± 0.30

UAB/COA Pupillometer under Friday Night Lights: RE vs. RE (repeatability)
UAB/COA Pupillometer under Friday Night Lights: LE vs. RE (consistency)

UAB/COA Pupillometer under Friday Night Lights: Pre-season vs. sidelines (RE)
UAB/COA Pupillometer under Friday Night Lights: Pre-season vs. sidelines (LE)

Anne Sereno, PhD
Department of Neurobiology and Anatomy
The University of Texas Medical School at Houston
Detection of Subtle Cognitive Changes after mTBI Using a Novel Tablet-Based Task
Fischer TD, 2016

- Anti-Point RT (0.988)
- Pro-Point RT (0.933)
- SAC (0.849)
- KD (0.536)

True-positive rate (Sensitivity)

False-positive rate (1 − Specificity)

VESTIBULAR AND OCULOMOTOR RESEARCH CLINIC
Knowledge that will change your world

- www.emrl.uab.edu
WHY VESTIBULAR?

Impairments from sport related mTBI:

- Poor Static and Dynamic Balance
- Gaze Instability
  - Convergence insufficiency vs. VOR dysfunction
- Poor perception of vertical
- Symptoms
  - Vertigo (head mov’t induced vs. visual vertigo)
  - Off-balance
  - Motion sensitivity
  - Exacerbated with aerobic activity
- Headache - Migraine

Zhou 2015; Corwin 2015; Ellis 2015; Heinmiller 2016; Leddy 2016
LE MS Injury After Return to Play

- Higher incidence of acute LE MS injury compared to controls.
- Odds were 2.48 X’s higher in concussed athletes than controls during 90 days after return to play.
- Why?
  - Vision? Balance? Vestibular?
VESTIBULO-OCULAR REFLEX (VOR)

head

medial rectus

lateral rectus

left

right

vestibular nuc.
College Football Player

- Aged 18 years
- Quarterback, tight end
  - 9 years playing football
- 1st known concussion during practice
- Baseline and post concussion data
BASELINE: HORIZONTAL SACCADES

![Image of experimental setup and data graphs]

The images display various graphs and data charts related to horizontal saccades in an experimental setting. The charts include metrics such as peak velocity, latency, and accuracy, along with corresponding experimental data and visualizations for left and right eye movements over time.
POST-mTBI: HORIZONTAL SACCADIES

Horizontal Saccade Latency

C-S: p=0.004  
C-A: p=0.006  
S-A: p=0.941
BASELINE: VERTICAL SACCADES

POST mTBI: VERTICAL SACCADES
### BASELINE: HORIZONTAL SMOOTH PURSUIT

#### Smooth Pursuit Horizontal 0.10 Hz

- **Plot Description:**
  - Time (sec) vs. Position
  - Data points for different conditions

#### Smooth Pursuit Horizontal 0.20 Hz

- **Plot Description:**
  - Time (sec) vs. Position
  - Data points for different conditions

#### Smooth Pursuit Horizontal 0.40 Hz

- **Plot Description:**
  - Time (sec) vs. Position
  - Data points for different conditions

### Vertical Saccade Latency

- **Graph:**
  - CONTROL: p<0.001
  - ASYMP: p=0.013
  - SYMP: p=0.458
POST mTBI: SMOOTH PURSUIT HORIZONTAL

Baseline and POST-mTBI SMOOTH PURSUIT AT 1.00 Hz
BASELINE & POST mTBI: OKN

VORC EXPERIMENTAL TESTS:

• Predictive Saccades
  - BASELINE: 27% predicted (n=4)
  - POST mTBI: 14% predicted (n=1)
  - “Moving too fast to follow”

• Anti-Saccades
  - Mean latency and % accuracy much worse than baseline.
  - Error rate not different.

• Predictive Saccades
  - Norm Athletes (n=30)
    - On average, female soccer players predicted 10/12;
    - Male football players predicted 5/12.

• Anti-Saccades
  - Error rate (n=30) was 60% (SD=20%)
VORC: EXPERIMENTAL TESTS

- Saccades and Reaction Times
  - DIFFERENCE B/T SACCade AND MOTOR RESPONSE
  - SIMILAR TO SEEING A LIGHT CHANGE AND PUSHING THE BRAKE.
    - BASELINE: 0.33 SEC (18.75% ERROR)
      - Similar to norm
    - POST: 0.99 SEC (57.14% ERROR)
Slower Sinusoid (0.04 Hz)

1.28 Hz sinusoid
BASELINE

mTBI

Chair Sine (SHA)

Gain

Frequency (Hz)

Phase

Chair Sine (SHA)

Gain

Frequency (Hz)

Phase

STEP test @ 100 deg/sec
BASELINE STEP TEST

Peak Eye Velocity

Eye Velocity Time Constant

Asymmetry

BASELINE: crHIT

Mean Gain per Impulse

Leftward Rotation

Rightward Rotation

VOR Gain

Do not copy or distribute without permission from Jennifer Christy
VIDEO HEAD IMPULSE TEST:
MICROMEDICAL: EyeSeeCam (15K)
NATUS: ICS Impulse (15K)

VOR ENHANCEMENT AND SUPPRESSION

Visual Enhancement (VVOR) and Visual Suppression (VFx) graphs are shown with data plotted on frequency (Hz) and gain axes.
VESTIBULAR EVOKED MYOGENIC POTENTIAL

- C-VEMP examines integrity of the saccule and inferior vestibular nerve.
- Measure EMG inhibitory response of the SCM as the stimulus is introduced into the ear canal (107dB NHL tone burst @ 500Hz).
- Can also measure O-VEMP (utricle)

Baseline: 14.5%
Post-Concussion: 6.6%

No significant difference between concussed and controls
WHAT CLINICAL TESTS WILL BEST GUIDE PT INTERVENTIONS?
PUBMED 03.25.2017: “CONCUSSION AND VESTIBULAR”

- N=179 articles
- Peripheral vestibular function typically not tested using gold standard
- Many retrospective (uncontrolled) studies
- Measures focused on symptoms (VOMS), balance (SOT/BESS) and gaze stability (DVA or GST)
- No single test can be used

SYMPTOMS

- SCAT-III (Sport Concussion Assessment Tool)
- VOMS (Vestibular Ocular Motor Screening)
- CISS (Convergence Insufficiency Symptom Survey)
- V-VAS (Visual Vertigo Analog Scale)
SCAT-III SYMPTOM SCORE

ADOLESCENT 13 AND OLDER:

- “Symptomatic” if symptom severity score > 12
- Mean + 2 SD of normative sample in our lab

CHILD VERSION (5-12 YRS)
SYMPTOMATIC IF PARENT SCORE > 18 (Porter et al. 2015)
Vestibular/Ocular Motor Screening (VOMS)

A change from baseline of > 2 is considered abnormal

Mucha, 2014

VOMS Evidence

- VOMS had good internal consistency ($r_s = 0.25-0.66, p<0.02$) and did not correlate with BESS or K-D (Yorke, 2017)
- Good internal consistency (Cronbach $\alpha = 0.97$) and 89% of athletes without concussion scored below cut-off levels (Kontos, 2016)
- Did not provoke symptoms in healthy adolescents
- Symptoms in all but NPC and ACCOM is associated with delayed recovery after concussion (Anzalone, 2017)
- Females with concussion had higher VOMS scores than males (Sufrinko, 2017)
### Convergence Insufficiency Symptom Survey (CISS)

<table>
<thead>
<tr>
<th>Question</th>
<th>Never</th>
<th>(not very frequently)</th>
<th>Sometimes</th>
<th>Fairly Often</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Do your eyes feel tired when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Do your eyes feel uncomfortable when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Do you have headaches when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4. Do you feel sleepy when reading or doing close work?</td>
<td></td>
<td></td>
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<tr>
<td>5. Do you lose concentration when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>6. Do you have trouble remembering what you have read?</td>
<td></td>
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<tr>
<td>7. Do you have double vision when reading or doing close work?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>8. Do you see the words move, jump, or appear to float on the page when reading or doing close work?</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>9. Do you feel like you read slowly?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Do your eyes ever hurt when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Do your eyes ever feel sore when reading or doing close work?</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>12. Do you feel a &quot;pulling&quot; feeling around your eyes when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Do you notice the words blurring or coming in and out of focus when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Do you lose your place while reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Do you have to reread the same line of words when reading?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For a score of 16 or greater, vision therapy may be indicated.\(^1\)\(^,\)\(^2\)\(^,\)\(^3\)

---

### Visual Vertigo Analogue Scale

(Adapted from Longidge et al., 2002)

Indicate the amount of dizziness you experience in the following situations by marking off the scales below. 0 represents no dizziness and 10 represents the most dizziness.

- **Walking through a supermarket aisle**: 0 — 10
- **Being a passenger in a car**: 0 — 10
- **Being under fluorescent lights**: 0 — 10
- **Watching traffic at a busy intersection**: 0 — 10
• Static Visual Acuity
• Near Point of Convergence
• Saccades (King-Devick)
• Smooth Pursuit and Ocular Range of Motion
• Ocular Alignment
  • Cover/Cross-Cover Test
  • Modified Thorington

from: J. Vestib Res. 2011;21(3):153
Visual Acuity

Static Visual Acuity

- Wear corrective lenses if usually worn.
- Place the child at whatever distance required of the chart you are using (our chart is for testing at 3 meters or 9.84 feet). Print charts from [http://www.i-see.org/eyecharts.html](http://www.i-see.org/eyecharts.html)
- The child should read the symbols until they begin to miss
- The line above this (or the line where all are correct) is considered their visual acuity.
- **Snellen notation**: 20/40 is interpreted as: the child can read it from 20’ but most people could read it from 40’ (so vision is worse than normal)
- **logMAR notation**: allows for use in statistics since each line differs by 0.1 logMAR. It is calculated by taking the log\(_{10}\) of the fraction. For example, 20/20=1 and the log of this is 0.
NPC > 6 cm – refer to optometry

NEAR POINT OF CONVERGENCE:

1. Ask the child to focus on a small picture (5cm sticker).

2. Ask the child to “keep it as 1 sticker” as you move it toward the bridge of the nose.

3. Ask the child to say “now” when he/she sees the picture as two.

4. Measure the distance between bridge of the nose and point at which the picture becomes double.

Clinical Testing of Saccades

- Hold your finger approx. 15 degrees to one side of your nose. Ask the patient to look at your nose, then quickly shift the eyes to look at your finger, repeating several times. Do this from the left, right, up and down. You are looking for the number of eye mov’t it takes for the patient’s eyes to reach the target.
King-Devick: https://kingdevicktest.com/
Clinical Smooth Pursuit

- Hold the patient’s head or chin stationary.
- Have the patient follow your slowly moving finger horizontally (from center 30 degrees right and then to 30 degrees left), and then vertically (center to 30 degrees up to 30 degrees down).
- You may need to hold the eyelids up in order to see the downward eye movement clearly. Hold the pen or finger at least 12” away from the patient’s eyes.
Clinical Smooth Pursuit

- **Normal response**: Smooth, conjugate eye movement. The key is to move your finger at the correct speed (about 20 deg/sec). If you move your finger too fast, the eye movement will become jerky. Also, do not move the finger past 30 degrees.
- **Abnormal response**: Saccadic or jerky eye movement. Note the direction of pursuit when it occurred. Normal vertical eye pursuit is often interrupted by a saccade.
- **Document the response**: e.g. normal; slow; jerky
- **Ocular Range of Motion** can examined at the same time

Eye Alignment

- The ability to look straight forward is the job of intact cranial nerves and ocular musculature.
- **Tropia** is deviation of one eye from forward gaze when both eyes are open.
- **Phoria** is deviation from forward gaze, apparent when only when the person is looking forward with one eye (the other eye is covered).
- To test eye alignment, do the cover test (for tropia) and the alternating cover test (for phoria).
Alignment Testing ("Modified Thorington")
> 6 = refer to optometry
### A clinical test of dynamic visual acuity for children

Rose Marie Rine*, Jennifer Braswell¹

- Do a static vision test & record the line of all correct
- Rotate the head at 2 Hz (to the beat of a metronome set at 240 bpm). Turn the head at least 30 degrees to each side. Tell the child to “relax and let me move you”
- Stop when the child starts to miss optotypes
- A three or more line decrement between static and dynamic acuity may indicate poor use of vestibular information.


Christy 2014
Computerized DVA & Gaze Stabilization Test

DVA: Looks at the difference in visual acuity during head movement versus stationary

GST: measures the most rapid head movement velocity at which the patient can maintain visual acuity

COMPANIES:
BERTEC
NATUS
MICROMEDICAL
**Computerized DVA and GST - Evidence**

- McDevitt 2016
  - Gaze Stabilization Test + OKN stimulation symptoms + NPC discriminated concussed from healthy controls (94.4%; AUC=0.95)
- Patterson 2017
  - DVA was not affected by physical exertion
  - Natus DVA had fair to good test-retest reliability (ICC=0.40-0.74)

**BUCKET TEST OF SVV**

- Have the patient close the eyes and put the bucket over the patient’s face, turn the line a random direction
- Tell patient to say “now” when the line is straight up and down
- Do 10 trials (5 to each side in random order)
- Record the degrees off for each trial and direction, then average and record the direction that the patient most often perceived.
<table>
<thead>
<tr>
<th>Trial</th>
<th>Report degrees off zero and direction (in relation to patient) the top of the line was tilted when vertical was perceived.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial line position:</td>
</tr>
<tr>
<td></td>
<td>top of line to patient's left</td>
</tr>
<tr>
<td></td>
<td>Initial line position:</td>
</tr>
<tr>
<td></td>
<td>top of line to patient's right</td>
</tr>
<tr>
<td></td>
<td>Degrees off zero</td>
</tr>
<tr>
<td></td>
<td>Direction tilted R/L/S</td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Mean/Mode</td>
<td>Mean:</td>
</tr>
<tr>
<td></td>
<td># Right:</td>
</tr>
<tr>
<td></td>
<td># Left:</td>
</tr>
<tr>
<td></td>
<td># Straight:</td>
</tr>
<tr>
<td>Totals</td>
<td>Total # off to Right:</td>
</tr>
<tr>
<td></td>
<td>Left:</td>
</tr>
<tr>
<td></td>
<td>Straight:</td>
</tr>
</tbody>
</table>

**RELIABILITY**

**ICC= 0.74**
- Kids 6-12

**ICC=0.92**
- adults

**ALL SCORES**

< 2 DEGREES OFF

Christy 2014; Zwergal 2009
Balance Error Scoring System (BESS)

- Shoes off & hands on iliac crests for all tests
- Use Airex Foam
- Establish leg dominance
  - The leg with which they kick a ball
- Double leg stance: Feet together
- Single leg stance
  - Stand on non-dominant leg
  - 20 deg hip flexion, 45 deg knee flexion, neutral frontal plane
- Tandem stance
  - Non-dominant leg in back
  - Back of anterior foot must touch front of posterior foot
- Each trial is 20 seconds

Errors:
- Moving the hands off the hips
- Opening the eyes
- Step, stumble or fall
- Abduction or flexion of the hip beyond 30°
- Lifting the forefoot or heel off of the testing surface
- Remaining out of the proper testing position for greater than 5 seconds

The maximum total number of errors for any single condition is 10.

If a subject commits multiple errors simultaneously, only one error is recorded.
Hansen, 2016:
N=373 healthy children aged 5-14 yrs
Interrater ICC = 0.93
Intrarater ICC=0.96
Test-retest ICC=0.90
MDCs = 9.6, 4.6, 7.3
based on ICC

Alsahaleen, 2015:
N=36 (aged 15.9 +/- 1.5 yrs)
ICC for instrumented or clinical test was 0.74
Functional Gait Assessment (see appendix)

- 2 standard shoe boxes taped together.
- Stopwatch.
- Standard staircase.
- During testing, walk slightly behind the participant while performing the item (for safety). Do not pace the participant. Demonstrate each item after reading the instructions.

FGA (score sheet in appendix)

- 10 items (max score=30)
- Concussion seems to affect the following items:
  - Walking with horizontal and vertical head turns
  - Walking tandem
  - Walking with eyes closed
  - Total score does not seem to be sensitive to concussion
    - Similar scores between concussed symptomatic, asymptomatic and controls in our lab
- Moore 2016 found improvement in FGA following a 6 month VR program in athletes with concussion
CERVICAL JOINT POSITION SENSE ERROR

Review of literature and methods:
Rehab Measures Database
Skill Works (Rob Landel)
http://www.skillworks.biz/news/520810

BENIGN PAROXYSMAL POSITIONAL VERTIGO

- A blow to the head may cause otoconia to become dislodged from the otoliths and fall into the semicircular canals
- Most often the posterior canal
- Will cause vertigo (spinning) with changes in head position
Dix-Hallpike Test

• Watch for nystagmus and symptoms (use goggles if you have them)
• Posterior Canal BPPV:
  • Upbeating
  • Torsional
  • Canolithiasis: <60 seconds
  • Cupulolithiasis: >60 seconds
• Test both sides

BPPV Treatment: Epley Maneuver. Canalith Repositioning Technique

In each position, WAIT until the nystagmus subsides + 30 seconds before going to the next position.
WHAT INTERVENTIONS ARE EFFECTIVE FOR ATHLETES WITH CONCUSSION?

PUBMED SEARCH 03/25/2017:

• “CONCUSSION AND PHYSICAL THERAPY”
  • 292 ARTICLES

• “CONCUSSION AND PHYSICAL THERAPY EXERCISE”
  • 40 ARTICLES
• **Leddy 2016**: “Absolute rest beyond the 1st few days after concussion may be detrimental to recovery.” Do sub-symptom threshold exercise

• **Chrisman 2017**: Sub-symptom Threshold Exercise Program (n=83)

• **Grabowski 2017**: Multimodal impairment based PT (n=25), retrospective (included VR)

• **Moore 2016**: VR and Aerobic Training Program (n=14)

• **Gagnon 2016**: Active rehabilitation intervention (n=10)

• Retrospective reviews include balance training and vestibular rehabilitation (Alsalaleen 2016)

---

**VESTIBULAR REHABILITATION AND CONCUSSION AND BALANCE THERAPY FOR ATHLETES WITH CONCUSSION**

• **Hoffer, Schubert and Balaban, 2015**:  
  • Review article with conclusions drawn from the literature on the military and clinical experience

• **Alsalaleen et al. 2010**:  
  • Retrospective Chart Review  
  • VR improves outcomes and shortens disability times in patients with mTBI that did not improve with rest
Schneider et al. 2014:

- Randomized Controlled Trial
- 31 individuals with concussion aged 12-30 years
  - Treatment group (standard care + Vestibular PT and cervical spine PT)
  - Control group (standard care: rest until symptom free, followed by graded exertion)
- The treatment group returned to sport significantly faster than the control group (within 8 weeks of initiating treatment).
**Gottshall et al. 2010**

- Pre-test/Post-test design
- N=82 military participants with mTBI who received vestibular therapy
  - SOT and Motor Control Test.
  - Dynamic Gait Index.
  - Neurocom inVision Tunnel Standardized Test:
    - SVA. DVA. Perception Time. Target acquisition. Target Following. GST.
- **Vestibular therapy** was provided 2X/week for 1 hour, 4-8 weeks, home program.
- Most outcomes returned to normal after 4 weeks

**Broglio et al. 2015:**

- INVITED REVIEW ARTICLE
- Concussion rehab: consensus based
- Controlled exercise and cognitive activity may stimulate recovery
- Vestibular, oculomotor and pharmacological therapies are promising if delivered by a trained professional
VESTIBULAR REHABILITATION IS BASED ON FUNDAMENTAL THEORIES OF RECOVERY

- **Adaptation:**
  - Retinal slip drives VOR adaptation at the level of the vestibular nuclei
- **Substitution:**
  - Promote centrally pre-programmed saccades to help with gaze stability (Schubert et al.)
  - Promote use of all available sensory systems for balance
- **Habituation:**
  - To decrease symptoms

Mechanisms of recovery: ADAPTATION

- The capability of the vestibular system to make long term (plastic) changes in the neuronal response to head movement
  - **Goals:**
    - Decrease retinal slip
    - Improve postural stability
  - Rebalancing of neural activity
  - VOR adaptation
  - To get adaptation, must have retinal slip
    - Vestibular exercises
    - Adequate head mov’t
Schubert 2008

- Showed that adults with unilateral vestibular loss improved aVOR gain following vestibular rehabilitation exercises
- DVA also improved
- Measured with bite block and scleral coil contacts

Mechanisms of recovery: SUBSTITUTION

- The substitution of alternative strategies to replace the lost or compromised function
- Cervico-Ocular Reflex
- **Central preprogramming of Saccades**
- Suppression of perception of oscillopsia

Shelhamer, 2000; Schubert, 2008

IT IS PROBABLY NOT:

- Cervico Ocular Reflex
  - Gain: 0.07-0.2 (Schubert 2004)
  - Dynamic range: <0.1 Hz
- Smooth pursuit
  - Pts with BVL showed gain at the upper end of normal range
  - Did not exceed normal peak velocity (100 DEG/SEC)
  - Unable to train above this velocity

WE THINK THAT IT IS:

- Central pre-programming of saccades:
  - High velocity slow phase eye mov’t
  - Minimizes gaze error in predictable situations
  - Adult patients with UVL and BVL increased the # of pre-programmed saccades following VR.
  - Dynamic visual acuity improved
  - Measured with bite block and scleral coil contacts
Mechanism of Dynamic Visual Acuity Recovery With Vestibular Rehabilitation

Michael C. Schubert, PT, PhD, Americo A. Migliaccio, PhD, Richard A. Clendaniel, PT, PhD, Amir Allak, BS, John P. Carey, MD

Arch Phys Med Rehabil Vol 89, March 2008

A

Pre Recovery UVHr

aVOR Gain = 0.68 ± 0.04
CS Ratio = 2.7

Post Recovery UVHr

aVOR Gain = 1.02 ± 0.13
CS Ratio = 0.64
Mechanisms of recovery: HABITUATION

- Long term reduction of a response to a noxious stimulus (specific mov’t) brought about by repeated exposure to the provocative stimulus
- Vestibular asymmetry leads to sensory mismatch (symptoms)
  - Poor tolerance of mov’t or afferent input
  - Examples: optokinetic stimulation for someone with visual vertigo; swinging or spinning a kid to get them “used to” the movement

HABITUATION

- Non-permanent decrease in response to a repeated benign stimulus
  - Synaptic activity decreases
  - # of connections decrease
  - Develop exercises that provoke mild to moderate symptoms and do them several times a day.
  - Should produce symptoms but not too much
Experiment on aplysia (sea slug)

Decrease in # of transmitter vesicles released from presynaptic terminals (less glutamate released)

Enhancement of synaptic inhibition is another mechanism.

The effect (memory) depends on how long the stimulus lasts, and how the stimulus is delivered: massed vs spaced training

Vestibular and Balance Therapy

- Goal: improve gaze stability with head movement
  - Gaze Stabilization Exercises
- Reduce Symptoms of dizziness/motion sensitivity
  - Habituation Exercises
- Improve balance
  - Static and Dynamic Balance Exercises
- VBT: do several times/day at home
- 1-2X/week clinic visits to progress
- Symptoms typically resolve in 6-12 weeks

GAZE STABILIZATION EXERCISES

1. Repetition (3X/day minimum for 6-12 weeks)
2. Error signal (ADAPTATION)
3. Voluntary head movement
   - Yaw and Pitch
   - Small Amplitude
   - Neck soreness
   - Exercises might make them dizzier
4. Active participation
5. Goal oriented and specific
   Hall 2016
Gaze Stabilization Exercises

- X1 viewing
- X2 viewing
- Gaze Shifting
- Remembered Targets

- IMPORTANT: These exercises should not induce a headache. If headache occurs during the exercise, the PT should adjust so that the exercise can be completed without inducing headache.

Equipment for GSE:

- Two business cards, index cards or post-it notes with a single small letter or number written on them in black ink (referred to as “target” in the instructions). **NOTE**: the target letter or number should be small enough that keeping it in focus during head movement will be a challenge. Therefore, target size will vary between participants depending on their abilities. The goal is to make the exercise challenging without inducing headache.
- Blank wall or busier background (depending on level)
- Chair (if doing the exercises in sitting)
- A method of timing the exercises (e.g. timer, song, stopwatch)
**X1 Viewing, Distant Target:**

- Assess symptoms of dizziness on a scale of 0 (no dizziness) to 10 (extremely dizzy). This will become the baseline symptom score.
- Place the card with the target onto a blank wall at eye level while the participant is standing with feet shoulder distance apart, 6-10 feet from the wall.
- The participant should be instructed to move their head in yaw (i.e. saying “no”) as quickly as possible while keeping the target in focus. The head movement does not have to be very large. Cue the participant to move the head faster and faster until they feel that the target is "just about to go out of focus."
- Continue for 1 minute without stopping
- Rest for 1 minute or until symptoms of dizziness return to no more than 2 over baseline.
- Repeat using pitch head movements (i.e. saying “yes”)
- Can also do while holding the card in front of them (simple background)

**X2 Viewing (only after X1 with no symptoms)**

- While sitting or standing, hold the target at arm’s length.
- Instruct the participant to move the head and target in yaw (i.e. saying “no”) in opposite directions, keeping the target in focus. As with X1, the head and target movement does not have to be very large. Cue the participant to move the head and target faster and faster until they feel that the target is "just about to go out of focus."
- Continue for 1 minute without stopping
- Rest for 1 minute or until symptoms of dizziness return to no more than 2 over baseline.
- Repeat using pitch head movements (i.e. saying “yes”)
**PROGRESSION**

<table>
<thead>
<tr>
<th>Levels</th>
<th>Background</th>
<th>Balance Challenges</th>
<th>Target Size</th>
<th>Speed of head movement</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy</td>
<td>Plain/White</td>
<td>Sitting or standing with feet shoulder width apart</td>
<td>Large (e.g. 2.5cm or larger)</td>
<td>Slow (1Hz)</td>
<td>1 minute</td>
</tr>
<tr>
<td>Medium</td>
<td>Busy (checkerboard or wallpaper)</td>
<td>Standing with feet together or in tandem Standing on foam pad Standing on 1 foot</td>
<td>Medium (e.g. 2cm)</td>
<td>Medium (1.5 Hz)</td>
<td>1.5 minutes</td>
</tr>
<tr>
<td>Difficult</td>
<td>Moving background (e.g. TV; window in front of traffic; holding card in crowded area)</td>
<td>Walking forward/back; jumping; standing on 1 foot on foam pad; treadmill</td>
<td>Small (e.g. 1 cm or smaller)</td>
<td>Fast (2 Hz)</td>
<td>2 minutes</td>
</tr>
</tbody>
</table>

**GAZE SHIFTING**
Gaze Shifting

- The participant should sit or stand 2 feet from a blank wall.
- Place 2 targets (e.g. X and Z) on the blank wall at eye level, side by side. To achieve the correct distance between targets, place 1 target slightly to the participant’s left at eye level. The participant should then turn the head to point the nose at the target. Place the 2nd letter to the participant’s right so that the participant can see the target using peripheral vision. In most cases, the letters will be about 2 feet apart.
- Instruct the participant to point the nose and eyes to the X (i.e. target on the left).
- Instruct the participant to “turn the eyes to the Z” (i.e. make a saccade to the target on the right), then quickly “point the nose at the Z” (i.e. make a quick head movement while keeping the letter in focus).
- Repeat, going to the opposite side (i.e. Eyes, then Head)
- Continue for 1 minute without stopping
- Rest for 1 minute or until symptoms of dizziness return to no more than 2 over baseline.
- Repeat using pitch head movements (i.e. saying “yes”)

Progression

<table>
<thead>
<tr>
<th>Levels</th>
<th>Background</th>
<th>Balance Challenges</th>
<th>Speed of head mov’t</th>
<th>Target placement</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy</td>
<td>Plain/White</td>
<td>Sitting or standing with feet shoulder width apart</td>
<td>Slow</td>
<td>2 targets placed side by side or up/down</td>
<td>1 minute</td>
</tr>
<tr>
<td>Medium</td>
<td>Busy (checkerboard or wallpaper)</td>
<td>Standing with feet together or in tandem; Standing on foam pad; Standing on 1 foot</td>
<td>Medium</td>
<td>Several targets placed diagonally</td>
<td>2 minutes</td>
</tr>
<tr>
<td>Difficult</td>
<td>Moving: e.g. window with traffic or TV</td>
<td>Walking forward/back; standing on 1 foot on foam pad; treadmill</td>
<td>Fast</td>
<td>Several targets placed in functional places (e.g. simulate driving)</td>
<td>3 minutes</td>
</tr>
</tbody>
</table>
Remembered Targets

- Place a single target on the wall (note: do not let the participant hold the target)
- Instruct the participant to focus on the target then close the eyes, imagine that they are still looking at the target and turn the head to the side while continuing to imagine that they are looking at the target, then open the eyes to focus on the target.
- Repeat in the opposite direction
- Try to move the head as fast as possible, while being accurate
- Continue for 1 minute without stopping
- Rest for 1 minute or until dizziness symptoms return to no more than 2 over baseline
- Repeat using pitch or diagonal head movements.

Progression

<table>
<thead>
<tr>
<th>Levels</th>
<th>Background</th>
<th>Balance Challenges</th>
<th>Speed of head mov’t</th>
<th># of head mov’ts</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy</td>
<td>Plain/White</td>
<td>Sitting or standing with feet shoulder width apart</td>
<td>Slow</td>
<td>1</td>
<td>1 minute</td>
</tr>
<tr>
<td>Medium</td>
<td>Busy (checkerboard or wallpaper)</td>
<td>Standing with feet together or in tandem, Standing on foam pad, Standing on 1 foot on floor</td>
<td>Medium</td>
<td>2-3</td>
<td>2 minutes</td>
</tr>
<tr>
<td>Difficult</td>
<td>Moving: e.g. window with traffic or TV</td>
<td>Standing tandem or on 1 foot on foam pad</td>
<td>Fast</td>
<td>3 or more (e.g. head shake and stop)</td>
<td>3 minutes</td>
</tr>
</tbody>
</table>
Habituation

1) Determine the stimulus that causes the participant to become symptomatic using an appropriate outcome measure (e.g. MSQ, VOMS, VAS, VVAS)

2) Identify 2-3 specific stimuli (head movement, body movement or visual stimulus) that mildly or moderately provoke symptoms. These will be the exercises to prescribe.

3) If habituation of head or body movement is the goal, instruct the participant to complete the exacerbating movement 3-5 repetitions, 3 times per day, resting between repetitions so that the symptoms return to baseline. For example, if going from supine to sitting is moderately provoking, the participant should first rate symptoms on a scale of 0 (no symptoms) to 10 (severe symptoms), go from supine to sit, then let the symptoms return to baseline, then lie back down and repeat 3-5 times.

4) Do this 2-3 times per day with the goal of being able to go 3 days in a row without motion related symptoms.

• If habituation of visual stimuli is the goal, find a video on you tube that mildly provokes symptoms (note: if you search for “urban walking” there are many videos to choose. You can also search for “Emory Dizziness and Balance”). Instruct the patient to watch the video ONLY UNTIL SYMPTOMS BEGIN. The participant should then document the # of seconds, let the symptoms return to baseline, and repeat (i.e. 2 repetitions total).

• Do this 2-3 times per day with the goal of increasing the time of viewing the video to 2 minutes without symptoms.

• NOTE: the goal is to bring on symptoms, but they should not get sick. Following the exercises, symptoms should return to baseline within 15 minutes or you did too much. If you give them too much, you can make them worse.

• These exercises should not induce a headache. If headache occurs during the exercise, the PT should adjust so that the exercises do not induce headache.

• X1 and X2 viewing can be used as habituation. For example, if yaw and pitch head movements are symptom provoking, you can use these as habituation exercises.
### Balance Exercises

<table>
<thead>
<tr>
<th>Difficulty</th>
<th>Deficient System for Balance</th>
<th>Potential Exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing with eyes closed on a stable floor</td>
<td>Somatosensory</td>
<td>Work on stable floor with eyes closed or vision challenge (e.g. dark glasses, Vaseline goggles, busy visual environment, tossing ball on Bosu – be careful of neck)</td>
</tr>
<tr>
<td>Standing with eyes opened on a compliant surface</td>
<td>Vision</td>
<td>Work on compliant surfaces getting the participant to focus on a stable object in the visual field.</td>
</tr>
<tr>
<td>Standing on a compliant surface with eyes closed</td>
<td>Vestibular</td>
<td>Work on a compliant surface or single leg/tandem while moving the head, closing the eyes, or in front of a busy visual environment, tossing ball while on Bosu (be careful of neck)</td>
</tr>
</tbody>
</table>

### HOME EXERCISE PROGRAM PRINCIPLES

- The VBT Home Exercise Program (HEP) should be custom designed for each participant
- The HEP session should be able to be completed in under 10 minutes so that it is not too overwhelming for participants to complete 2-3 times per day.
- The PT should specifically write out the home program for the participant and require that participants keep a log of activities completed, and symptoms.
- The PT should stress that the exercises should not induce headache.
  - If headache increases with exercise, the participant should contact the PT so that exercises can be adjusted (e.g. increasing target size, slowing down head movement, sitting, decreasing time).
HEP for a patient in week 1 of VBT who has poor dynamic visual acuity, static balance problems and visual vertigo.

AM SESSION:
- Standing: X1 viewing to a far target on a blank wall in yaw (1 minute) and pitch (1 minute)
- Sitting: Gaze shifting to 2 targets on a blank wall in yaw (1 minute) and pitch (1 minute)
- Single legged stance with eyes closed (2 minutes total)

NOON SESSION
- Watch a prescribed you-tube video to tolerance twice (allow symptoms to return to baseline and document seconds)
- Remembered targets in yaw (1 minute) and pitch (1 minute)

PM SESSION:
- Take a 5 minute walk outside if weather allows, turn head to look around (dynamic balance)
- X1 viewing in yaw (1 minute) and pitch (1 minute) to hand held target
- Standing: Gaze shifting to 2 targets on a blank wall in yaw (1 minute) and pitch (1 minute)

*Please contact your PT if exercises induce headache. Symptoms of dizziness should return to baseline no more than 15 minutes following each session.

Return to Sports Guidelines

- Athletes should not return to play on the day of their injury
- When returning athletes to play, they should be medically cleared and then follow a stepwise supervised program, with stages of progression.
- There should be at least 24 hours (or longer) for each stage and if symptoms recur the athlete should rest until they resolve once again and then resume the program at the previous asymptomatic stage.
- If the athlete is symptomatic for more than 10 days, the athlete should be referred back to the treating concussion MD.
- Medical clearance should be given before return to play.
<table>
<thead>
<tr>
<th>Rehabilitation Stage</th>
<th>Functional Exercise Focus</th>
<th>Overall Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1: Minimal activity</td>
<td>Physical and cognitive rest</td>
<td>Recovery</td>
</tr>
<tr>
<td>Stage 2: Light Activity</td>
<td>Non-impact exercise keeping intensity BORG 11-13 and sub-symptom threshold</td>
<td>Low intensity aerobic exercise</td>
</tr>
<tr>
<td>Stage 3: Moderate Activity</td>
<td>Impact/non-impact exercise keeping intensity &lt;13 BORG scale and sub-symptom threshold</td>
<td>Higher intensity aerobic exercise; may begin sport specific activity with no head impact</td>
</tr>
<tr>
<td>Stage 4: Non-Contact Sports-Specific Activity</td>
<td>Impact/non-impact exercise with intervals up to BORG 16; may include sport-specific drills with no head impact</td>
<td>Anaerobic intervals &amp; continue sport specific activity with no head impact</td>
</tr>
<tr>
<td>Stage 5: Full Contact Practice</td>
<td>Gradually participate in normal training activities</td>
<td>Restore confidence and assess functional skills by coaching staff.</td>
</tr>
<tr>
<td>Stage 6: Full Contact Play</td>
<td>Full participation in games</td>
<td>Return to sport</td>
</tr>
</tbody>
</table>

**EACH STAGE INCLUDES VARYING DEGREES OF:**

- Cardiovascular conditioning
- Strength and Balance Training
- Flexibility
- Manual Therapy
- Stage 4 will also include sport specific activity and training
  - Team active warm up and conditioning
  - Agility drills
  - Plyometric activity
- Stage 5 will also include return to full contact practice
CONCUSSION CASE:

• Pt is a 18 yo female.

• Freshman on the University soccer team and sustained a concussion from colliding with another player while practicing with the team about 1 month prior to her initial visit at Outpatient PT.

• Thanks to Brian King, MSPT for this case!

• Initial symptoms included nausea and headache following the blow to her head.

• Symptoms at time of eval include ongoing headaches, mild nausea at times, and some dizziness. Pt reports triggers for symptoms include bright lights, loud noises, and the stress of doing school work. She is currently having difficulty attending classes and doing school work and is also having trouble sleeping.

• Previous history of concussion about 8 months prior to this current event and also had a concussion when she was in the 7th grade with loss of consciousness.
Headache

- Current – 6/10 (Headache)
- Highest in past week – 7/10 (Headache)
- Lowest in past week – 4/10 (Headache)

- What tests/measures do you want to do?

BESS

- **BESS**: TOTAL SCORE = 24/60 (# ERRORS IN 20 SEC)

<table>
<thead>
<tr>
<th></th>
<th>STABLE FLOOR</th>
<th>FOAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEET TOGETHER</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TANDEM</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>SLS</td>
<td>7</td>
<td>10</td>
</tr>
</tbody>
</table>
Visual Vertigo Analogue Scale
(Adapted from Longridge et al., 2002)

Indicate the amount of dizziness you experience in the following situations by marking off the scales below.

0 represents no dizziness and 10 represents the most dizziness.

- Walking through a supermarket aisle
- Being a passenger in a car
- Being under fluorescent lights
- Watching traffic at a busy intersection
- Walking through a shopping mall
VVAS

- Visual Vertigo Analogue Scale:
  - Indicated 7/9 items as positive for causing dizziness as follows:
    - through a supermarket aisle - 3 cm
    - Being passenger in car - 0 cm
    - Being under fluorescent lights - 2.5 cm
    - Watching traffic at busy intersection - 4 cm
    - Walking through shopping mall - 2 cm
    - Going down an escalator - not rated
    - Watching movie at movie theater - not rated
    - Walking over a patterned floor - 1 cm
    - Watching action television - 6.5 cm
• Functional Gait Assessment – 27/30
• Convergence Insufficiency Symptom Scale – 29/60
• DVA – 3 lines of difference
  • Symptom VAS score – dizziness following DVA – 2.1 cm

• Balke Treadmill Test (protocol for females):
  • 3.0 mph, increasing incline by approximately 2.5% every 3 minutes
  • On treadmill in the clinic, used 0%, 3%, 5%, 8%, 10%.
• Pt tolerated all the way to 15 minutes without signs or symptoms (HA or dizziness). HR at 15 minutes was 144: 15 min
• Patient’s Physical Therapy consisted of therapy 1x a week. She was instructed on weekly gaze stability exercises at each visit (in standing).
• She was also instructed on video habituation exercises to help work on her visual vertigo issues.
• For balance, pt was instructed to work on standing with eyes closed in both single leg stance and tandem stance (firm ground and foam/compliant).

• Week 1 – X1 exercise far and near in pitch and yaw planes
• Week 2 – As above, plus Eyes/Head exercise (about 10 feet back)
• Week 3 – All above, plus X1 with full visual field in yaw plane, and Remembered target in yaw plane
• Week 4 – X1 with full visual field, X2, Eyes/Head exercise, Remembered target, and gait with head turns (all exercises in pitch & yaw plane)
• Week 5 & 6 – exercises as noted above with time frames adjusted
• For cardiovascular endurance: worked on pushing patient up 5 minutes of activity per session by use of treadmill and LE bike.

• Because pt was asymptomatic during the Balke Treadmill test we used a training zone of 70% based on her HR max from age (141 beats/min).

• Pt was able to get to 30 minutes of activity without significant increases in symptoms with this protocol.

• On the day of discharge, pt reported her headaches have not been as frequent, and her symptoms of dizziness have improved when performing exercises in the gym with the team trainer.

• **BESS**: 14/60 (Double leg stance – 0’s; Single leg stance L LE: Firm – 4; Foam – 10; Tandem Firm – 0; Foam 0) (pt reported on this date that she had an old ankle sprain on the L LE and she feels like this may have influenced her score during the Single leg stance part of the test)

• **Functional Gait Assessment** – 30/30

• **DVA** – 1 line of difference
• Also, pt was tested about 1 month prior to discharge on the NeuroCom for the SOT.

• Her SOT composite score was 83 (WNL for age related norms). All 6 conditions were WNL as compared to age related norms.

THANK YOU!

Please come to Jacksonville, FL for the Pediatric Vestibular Competency Course in October, 2017!

• http://www.specialtytherapy.com/