

Vision Problems in TBI: Impacts on Cognition & Attention

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Disclaimers/Disclosures

- Consultant, RightEye (Bethesda, MD) mTBI/TBI eye tracking metrics and App development
- Consultant, Diopsys (Pine Brook, NJ) VEP biomarker algorithm for mTBI
- Consultant, A.M.P. Systems (St. Louis, MO) concussion protocols.
- Consultant, EyeNext (Turin, Italy) visual aspects of dyslexia/mTBI.

Category of head injury

80-90%

Mild head injury

- GCS = 13-15
- associated with loss of consciousness or amnesia for less than 1 hour

Moderate head injury

- GCS = 9-12
- associated with a loss of consciousness for up to a day

Severe head injury

- GCS less than or equal to 8
- associated with loss of consciousness for more than 24 hours

Why Vision?

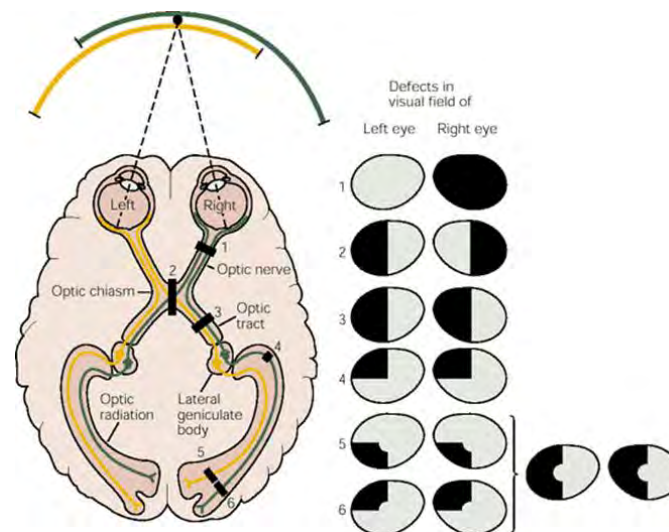
- 80-90% of all information entering the brain is visual
- Over 50% of brain is involved in visual processing (over 30 brain regions and 8 cranial nerves)
- Visual processing alone consumes 45% of brain's energy
- 90% of all concussions will have 1 or more ocular problems
- Hidden vision problems frequently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

TBI Vision Problems: Visual Impairment vs. Visual Dysfunction

- Visual Impairment: Visual acuity is decreased and/or the visual field is constricted; More common in moderate or severe TBI; More obvious and therefore easier to diagnose; Tends to be more “focal”; Relatively more “permanent”. Patient is rarely unaware of it.
- Visual Dysfunction: Any disorder of afferent or efferent function. Common to all types of TBI. Oculomotor (eye alignment, fixation, versions, vergences, accommodation); and Non-oculomotor (visual spatial, visual temporal, perceptual, visual-motor-integration). Symptoms of visual dysfunction are commonly experienced after mTBI despite excellent visual acuity. Patient may or may not be aware of it. Undiagnosed, the visual sequela can affect one’s schoolwork, employment and other activities of daily living. Less obvious and harder to diagnose. Relatively more amenable to “change”.

Common TBI Visual Impairments

- Pre-chiasmal Impairment (monocular vision loss): traumatic optic neuropathy; ischemia; traumatic cataracts, traumatic maculopathy, retinal hemorrhages, globe ruptures, angle recession, hyphema, and corneal injuries (14% of mod/severe TBI).
- Chiasmal/Post-chiasmal Impairment (binocular vision loss): visual field deficits from lesion along the primary visual pathway; trans-synaptic retrograde optic neuropathy (18-30% of mod/severe TBI).



Rehabilitation for Visual Impairments

- Optical Management: prisms, magnifiers, telescopes, reverse telescopes, enlarged fonts, etc.
- Compensatory Strategies: Training scanning (head movement, eye movement), training awareness, and training mobility
- North Dakota Vision Services/School for the Blind

mTBI (concussion)

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

Pathophysiology of Concussion and Clinical Findings

Post-TBI pathophysiology

Ionic flux

Energy crisis

Axonal injury

Impaired Neurotransmission

Protease activation, altered cytoskeletal proteins, cell death

Acute symptom / clinical correlate

Migraine headache, photophobia, phonophobia

Vulnerability to second injury

Impaired cognition, slowed processing, slowed reaction time

Impaired cognition, slowed processing, slowed reaction time

Chronic atrophy, developmental of persistent dysfunctions

mTBI Clinical Trajectories (UPMC)



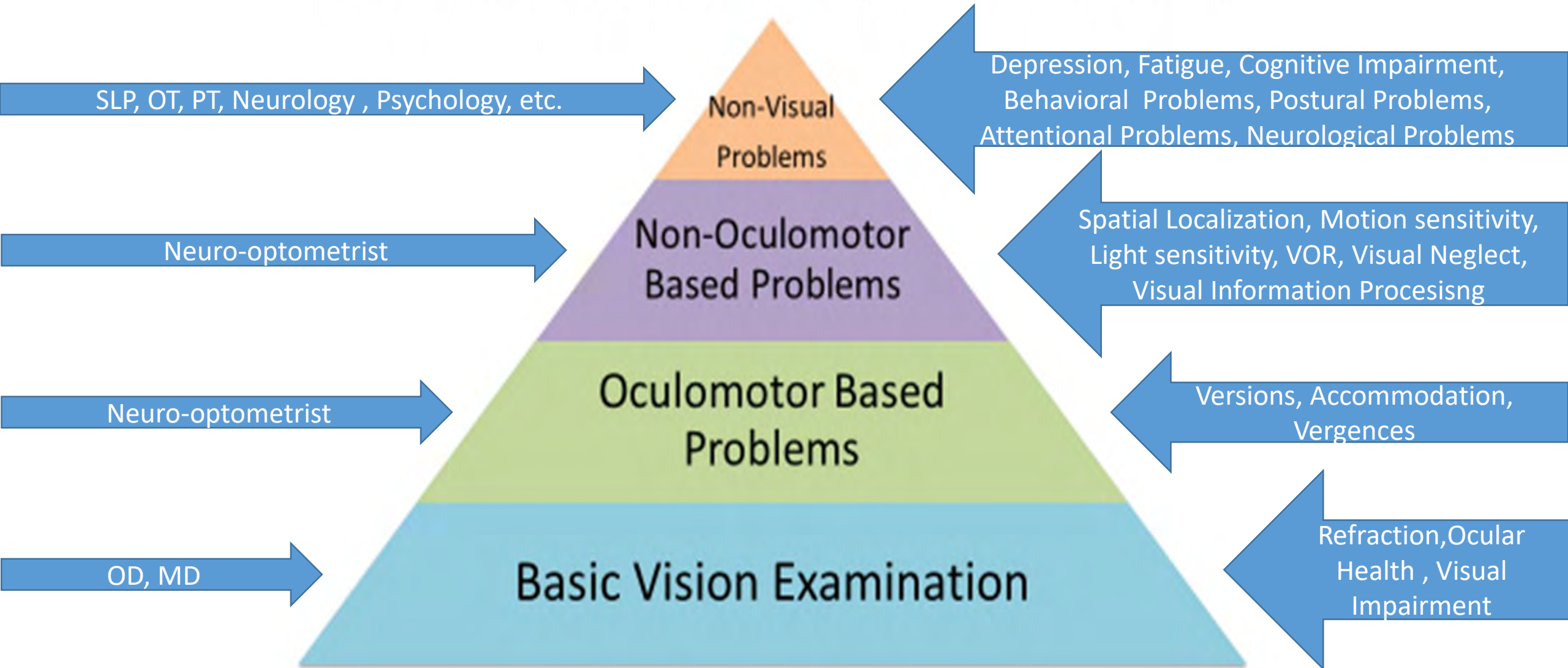
Visual Dysfunctions may contribute to a myriad of mTBI symptoms

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

Typical Visual Dysfunctions Associated with mTBI

- Eyes drift outward (exophoria/exotropia)
- Fusional Vergence Dysfunction/Convergence Insufficiency
- Eye Tracking Difficulties (saccades/pursuits)
- Blurred Vision (Accommodative Dysfunction)
- Visual Discomfort/Eyestrain
- Light Sensitivity
- Motion Sensitivity
- Concentration Difficulties
- Reading Problems
- Poor Visual Judgment/depth perception
- Shifted egocentric localization (sense of one's midline)

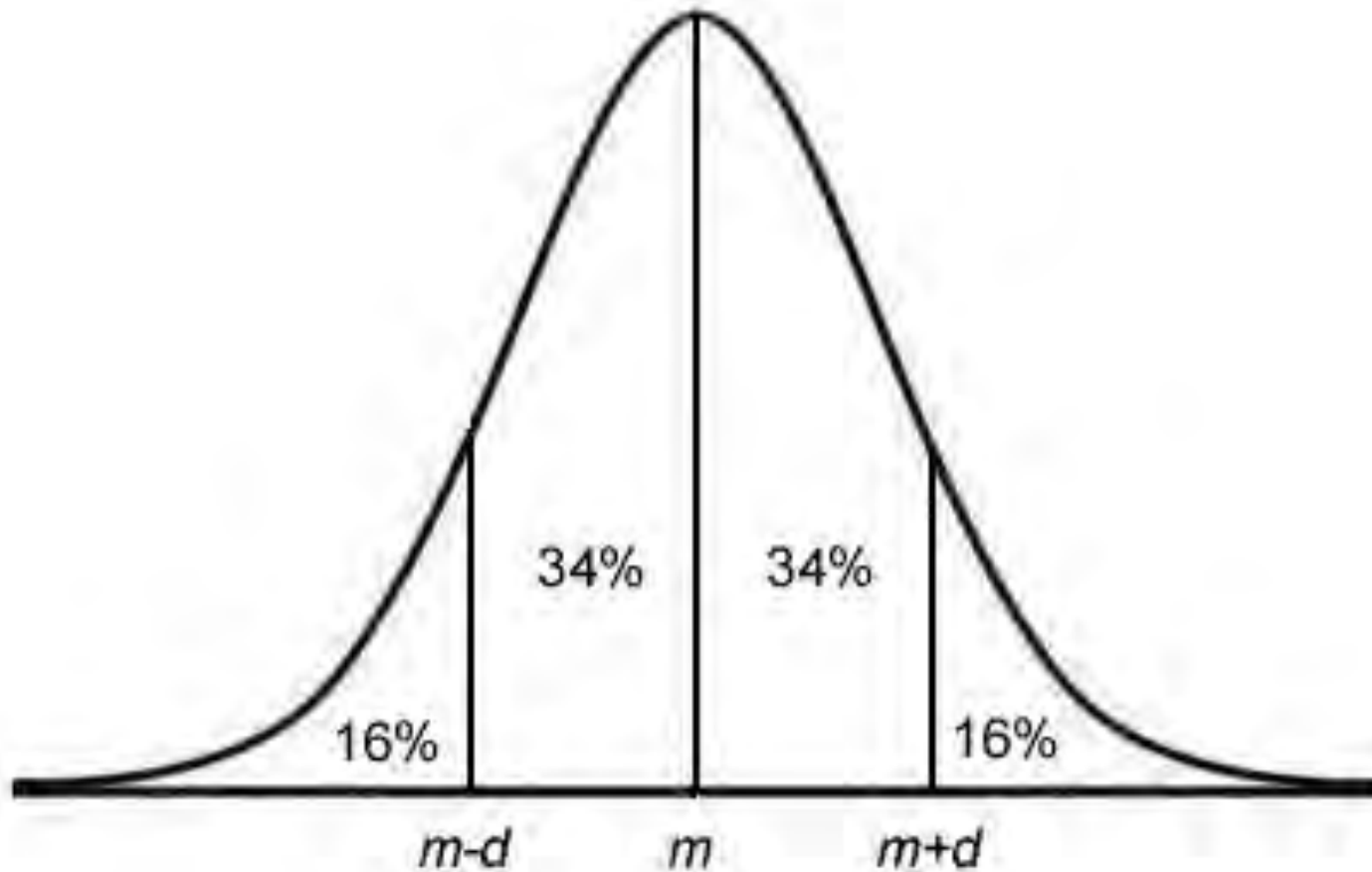
4 Tiered Conceptual Model of Vision Assessment (in mild TBI) *(Ciuffreda et al 2016)*



I. Basic Vision Examination: Refraction, Ocular Health, Visual Impairment (Graded Scale Tests)



Visual Dysfunction Diagnoses Require Norm-Referenced Tests Beyond “Basic Vision Exam”



“Developmental” Vision Problems & Learning

- Vision dysfunctions have been reported to be significant contributors to reading difficulties and ultimately to the need for special education services.
- One study of students (ages 6-16) with IEPs found that 69% who pass visual acuity screenings have undiagnosed and untreated vision problems affecting reading speed and comprehension.
- Undiagnosed vision problems can increase educational costs in the form of Individualized Education Programs (IEPs) and special education services, which would otherwise not be necessary, if the vision problems were treated.

II. Oculomotor Based Vision Problems

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

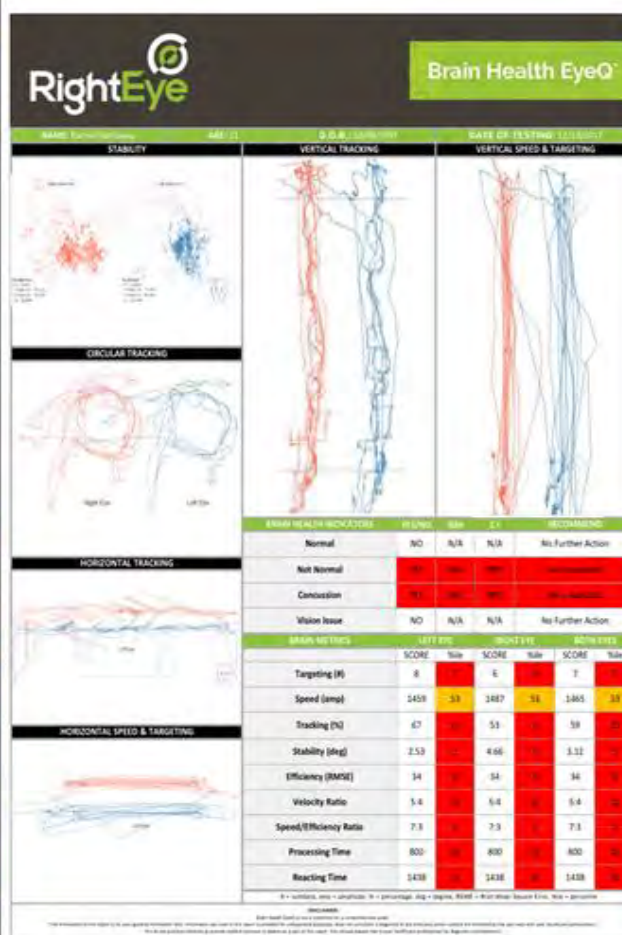
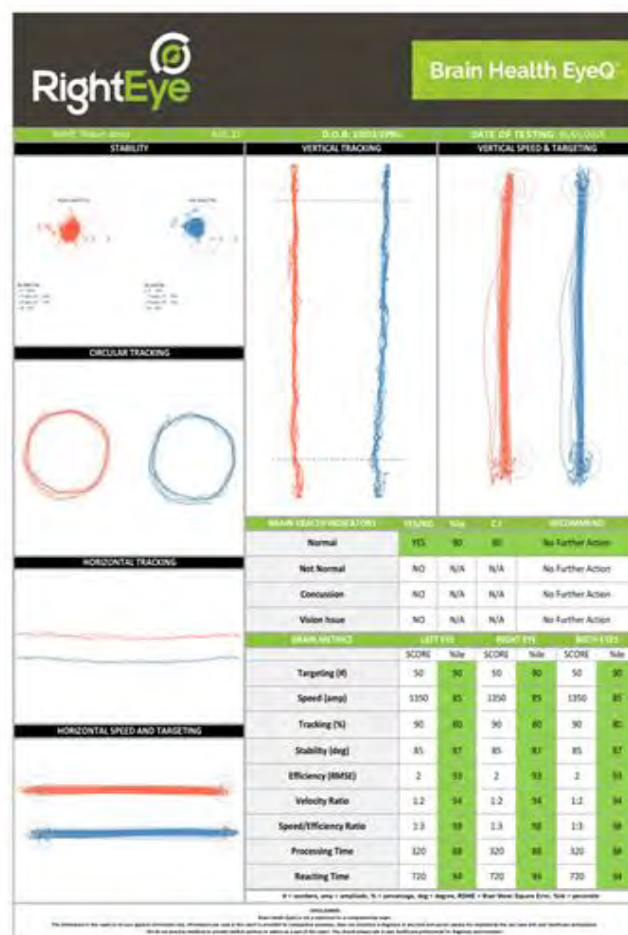


Oculomotor Problems and mTBI

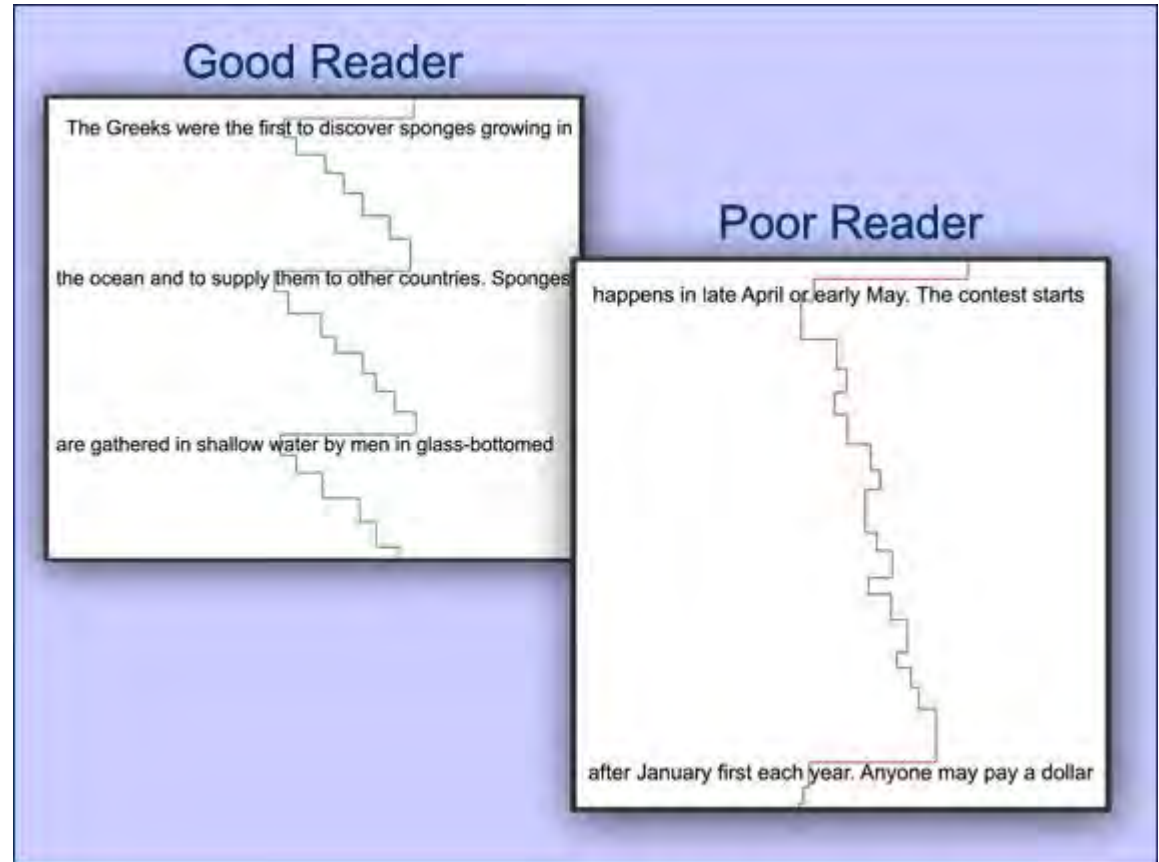
Capo'-Aponte et al. Military Medicine 2012

Type of visual Impairment	%mTBI	%controls	p
Convergence Insufficiency	55%	5%	0.0012
Saccadic Impairment	30%	0%	0.0202
Pursuit impairment	60%	0%	0.0001
Ocular misalignments(vertical phoria)	55%	5%	0.0012
Ocular misalignments(horizontal phoria)	45%	5%	0.0084
Accommodative Dysfunction	65%	15%	0.0031

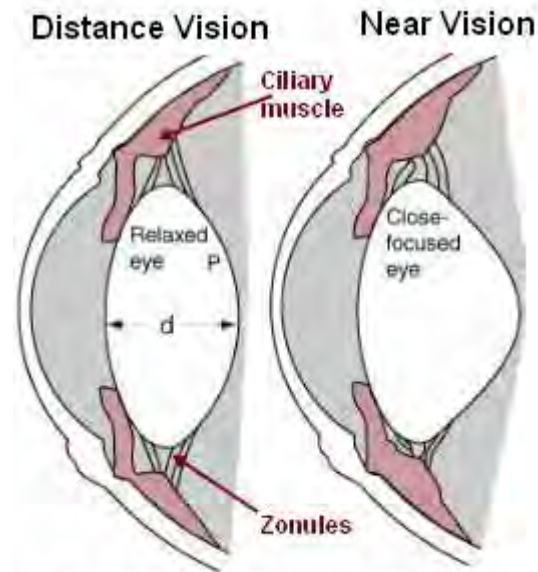
RightEye: Versions (saccades/pursuits)



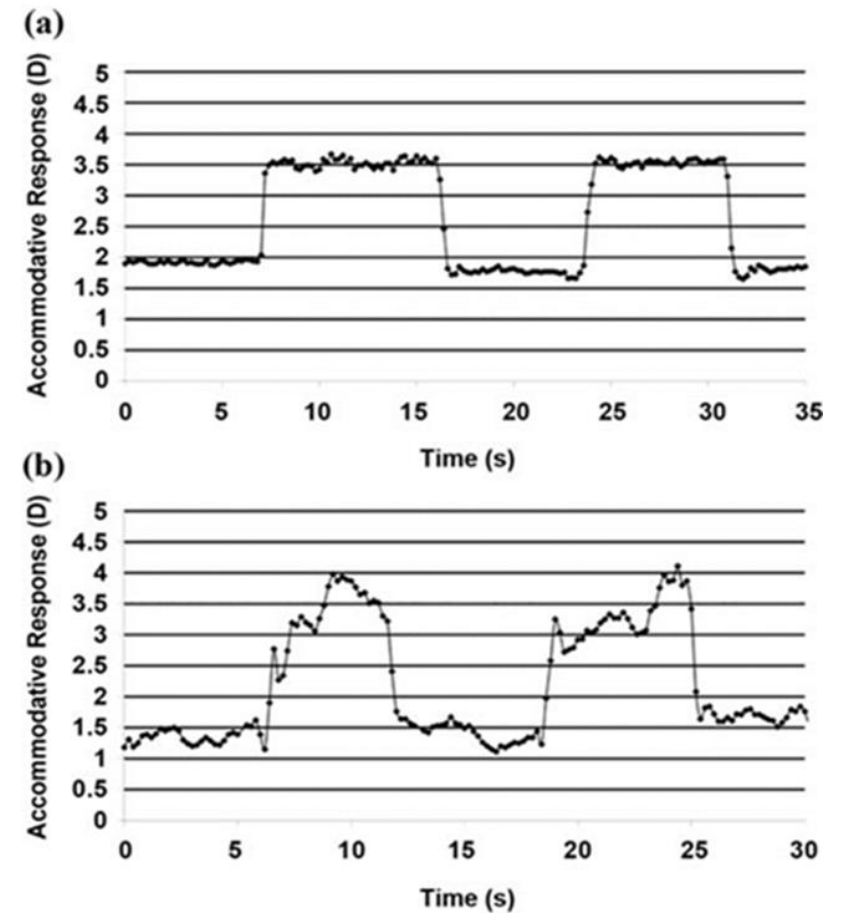
Visagraph: Saccadic Reading Eye Movements



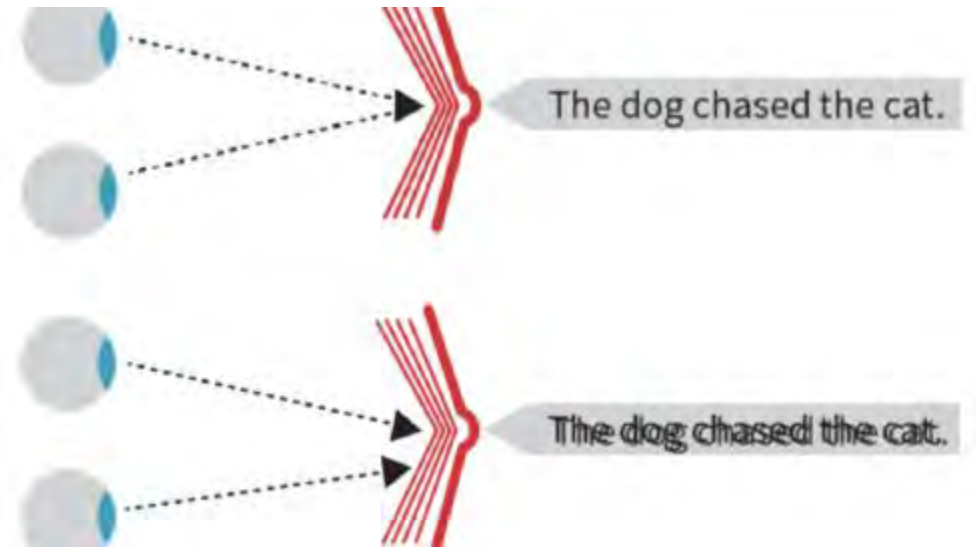
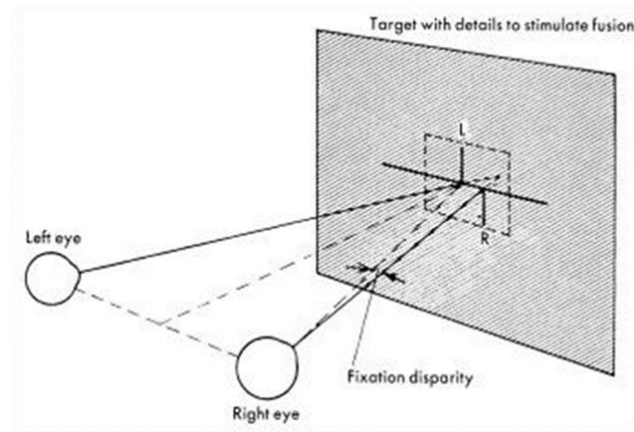
Open Field Autorefractor: Accommodation



For near vision, the ciliary muscles contracts and the central lens thickness increases to increase its power.



Receded Near Point of Convergence (NPC) and Receded Near Point of Fixation Disparity (NPFd) : Convergence Insufficiency



III. Non-Oculomotor Based Vision Problems (Ambient Processing)

- A. Abnormal egocentric spatial localization: Yoked prisms
- B. Photosensitivity: Tints and/or wide brimmed hats
- C. Motion sensitivity: Binasal occlusion, tints and/or motion desensitization
- D. Vestibular dysfunction: Vision and/or vestibular therapy
- E. Visual field defect/neglect: Visual scanning training and/or prisms
- F. Visual information processing dysfunction: Visual information processing and perceptual therapy

Atmospheric Experience

Typically processes through the dorsal stream (Where/Action)

Affected by Ambient Awareness

Pre-consciousness

Vague Emotional Impressions

Intellectual Experience

Typically processes through the Ventral Stream (what something is)

Affected by Focal Modes of Attention

Directed toward a goal

Consciousness

Judgement and Decision based

AWARENESS

AMBIENT

FOCAL ATTENTION

PERIPHERAL VISION

Greater than 5 degree retinal eccentricity

Motion detection

Low fidelity resolution

Faster processing

Color degrades away from fovea

Typically process to Magno ganglion cells in a >1:1 ratio

CENTRAL VISION

Up to 5 degree radial eccentricity from fovea

High fidelity resolution

Slower processing

Greater color processing

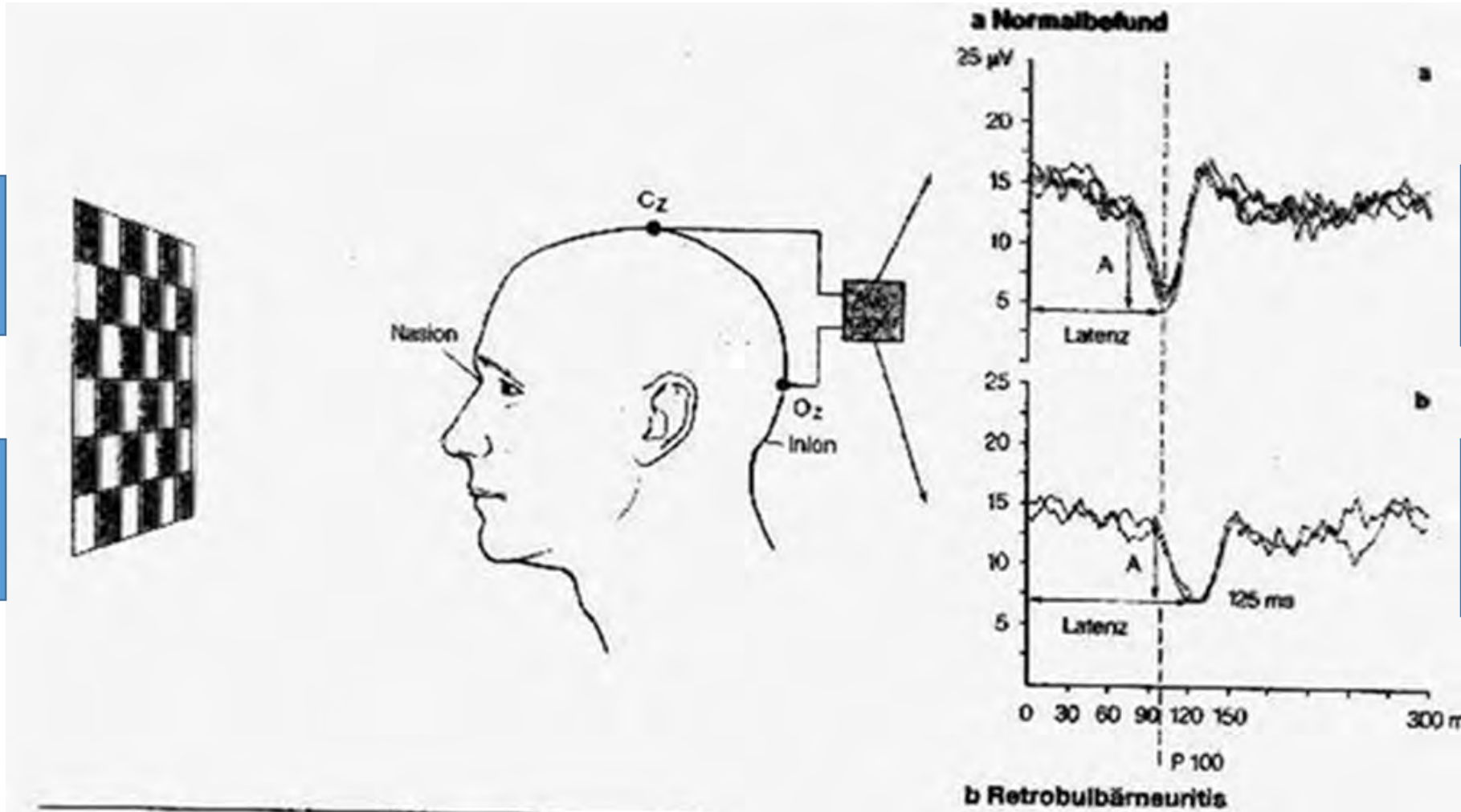
Cones are densely packed

Typically process to Parvo ganglion cells in a 1:1 ratio

VEP: Ambient Processing Latency Delay

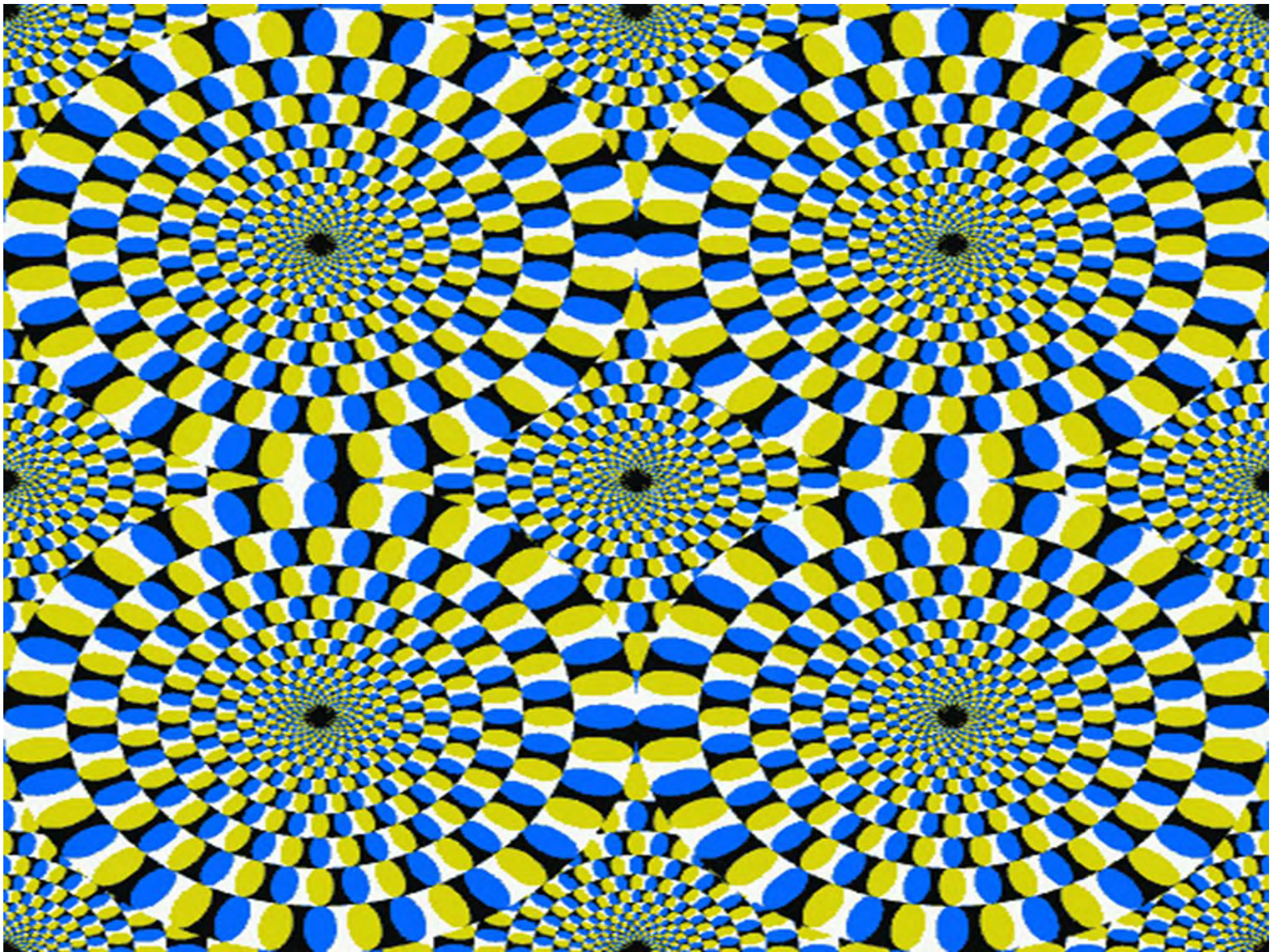
Slow, small,
high contrast
stimuli

Fast, large,
low contrast
stimuli



Focal
Processing

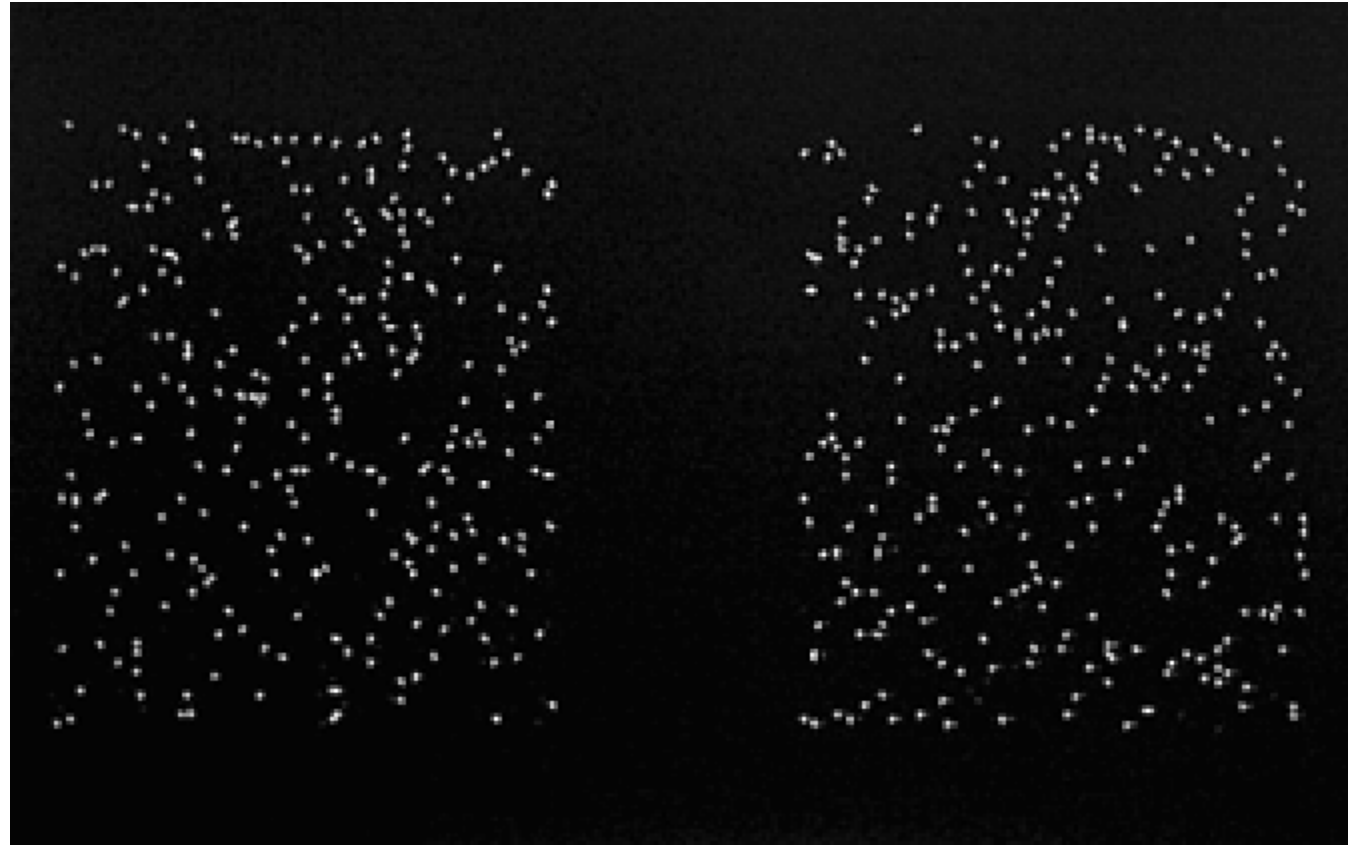
Ambient
Processing



Motion Sensitivity/Visual Vertigo



Coherent Motion Threshold: Elevated with Motion Sensitive Individuals

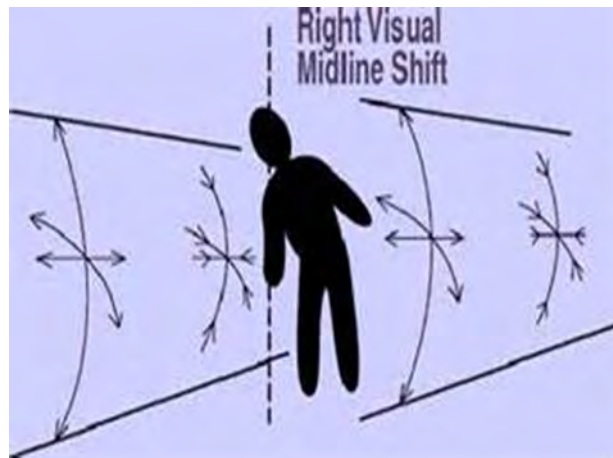
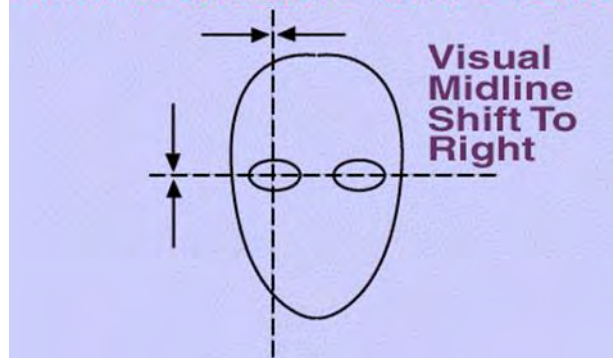


Critical Flicker Frequency Threshold: Elevated with Light Sensitive Individuals



Egocentric Spatial Localization Tests

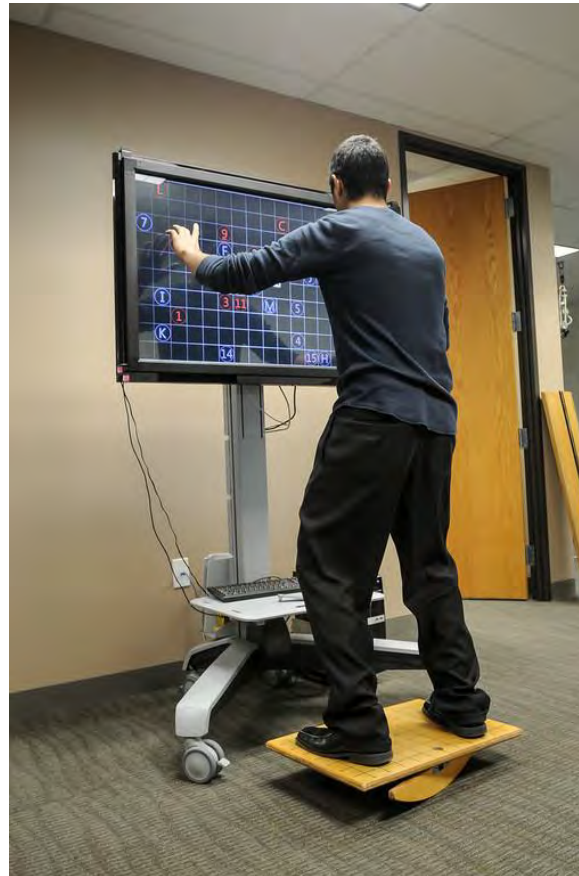
VISUAL MIDLINE SHIFT TEST



Hx of concussion & attention allocation

- Poltavski et al. *Frontal theta-gamma ratio is a sensitive index of concussion history in athletes on tasks of visuo-motor control.* Nature/Scientific Reports: (2019) 9:17565
- The sensitivity of EEG to history of concussion was explored in 81 asymptomatic youth athletes (18 with a history of concussion, ages 13–18) during visual-motor activities that vary in working memory, processing speed demands and motor output requirements.
- The history of concussion group showed a reduction in the theta to gamma power spectral density (PSD) ratio, indicating the persistence of altered attentional processing in athletes with history of concussion.

Neuro-Optometric Vision Rehabilitation



Neuro-Optometric Vision Rehabilitation: A.K.A Vision Therapy, Orthoptics, Oculomotor Training

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

5 Components of Effective Neuro-Optometric Vision Rehabilitation

1. Motivation
2. Feedback
3. Repetition
4. Sensory-motor mismatch
5. Intermodal integration

IV. Non-Vision Based Problems

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

Brain Injury Vision Symptom Survey (BIVSS)

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

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

<http://www.doctorbruce.net/wp-content/uploads/2019/04/BIVSS-Checklist.pdf>

Thank You!



<https://noravisionrehab.org/>