Neuro-Optometric Exam and Concussion

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Kaiser Permanente - San Rafael Optometry
Buck Institute

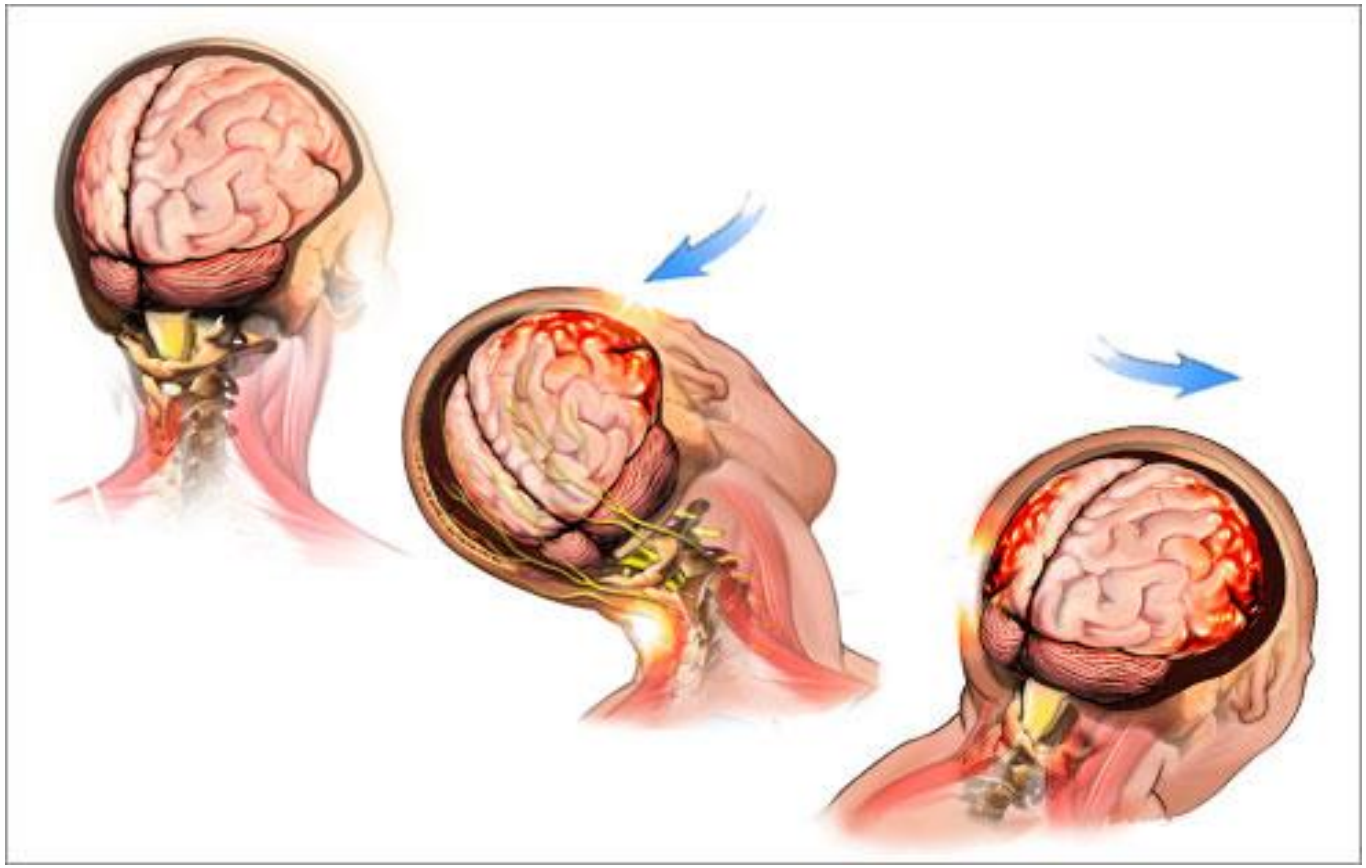
Background

- BS Biochemistry – Bucknell University
- OD –UC Berkeley School of Optometry
- Residency – Binocular Vision, Neuro-Optometry, Vision Therapy – UC Berkeley School of Optometry
- Director, Clinic Chief– UC Berkeley Sports Vision Clinic
  - Clinical Care and Research for Vision Problems in Concussion
- Clinical Instructor – UC Berkeley School of Optometry
- Clinical Research Funding – UC Regents, NIH SBIR
  - Financial Disclosures – C. Light Technologies
    - Clinical Research Consultant
- Neuro-Optometrist – Kaiser Permanente San Rafael

Goals/General Outline

- Discuss current paradigms (or national lack there of) for vision screening after concussion
- Go through the most common visual signs and symptoms seen after a concussion and their timelines for resolution (acute vs. chronic – PCS)
  - Afferent Visual Pathway (Ocular Health, Color Vision, Visual Fields, Pupils, Refractive Error)
  - Efferent Visual Pathway (Ocular motility)
  - Higher Order Pathways (Visual processing)
- Current/Future role for vision

Concussion - Controversy over a "Definition"



- McCrory P, Meeuwisse WH, Aubry M et al. Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. Br J Sports Med 2013;47:250-8.
- Harmon KG, Drezner JA, Gammons M, et al. American Medical Society for Sports Medicine position statement: concussion in sport. Br J Sport Med 2013;47:15-26.
- Kimpara H, Iwamoto M. Mild traumatic brain injury predictors based on angular accelerations during impacts. Ann Biomed Eng 2012;40:114-26.
- Zhang L, Yang K, King A. A proposed injury threshold for mild traumatic brain injury. J Biomech Eng 2004;126:226-36.
- P Reilly, R Bullock. Head Injury 2ed: Pathophysiology and Management, CRC Press 2005 Taylor and Francis, Florida

Image from Martin LJ. A visual guide to concussions and brain injuries. Webmd.com Accessed April 15, 2017. http://www.webmd.com/brain/ss/slideshow-concussions-brain-injuries

Common Diagnostic Tests for Concussion

- Self-report Symptom Checklists
- Brief cognitive assessment
  - SAC
  - SCAT-3
- Balance Tests
  - TGT
  - BESS
- Computer Based Neuropsychological Tests
  - ImPACT
  - CogSport
  - Headminder

Limitations/Difficulties in Concussion Diagnosis and Management

- No structural injury on conventional neuroimaging
- Advanced neuroimaging can show functional/structural damage BUT $$ and not readily available
- Under/over reporting of symptoms
- Under/over diagnosis
- Evolving definition
- Subjective nature of diagnosis
  - Symptom Scales
  - Intentional low baseline scores
- Incomplete understanding of pathophysiology
- Lack of data
- Variability among physicians

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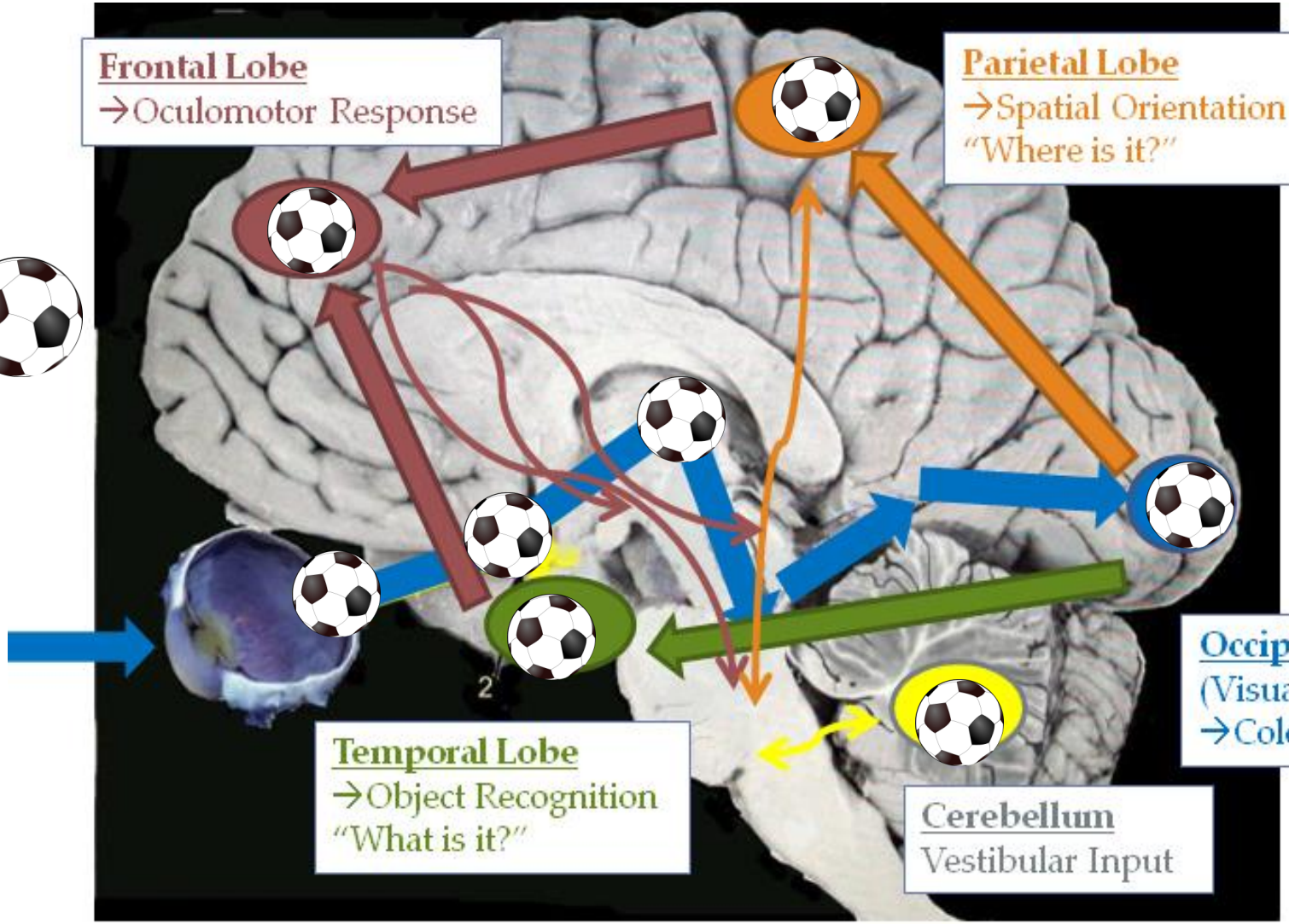
Role of Eyes in Concussion Diagnosis and Management:

1) Objective biomarker for brain dysfunction

2) Treatment of concussion

Visual Pathways in the Brain



Vision can be impacted in many different ways after injury!

Physical symptoms of a concussion:

- Dizziness
- Problems with balance
- Nausea and/or vomiting
- Balance problems
- Sensitivity to noise
- Sensitivity to light
- Blurred vision
- Headache
- Low energy level
- Unequal pupils
- Seeing flashing lights

Mental symptoms of a concussion:

- Difficulty remembering
- Confusion
- Inability to concentrate
- Inability to think clearly
- Mental fogginess
- Inability to remember new information
- Trouble paying attention
- Loss of focus

Sleep symptoms of a concussion:

- Sleeping more than usual
- Unable to fall asleep
- Sleeping less than usual

Emotional symptoms of a concussion:

- Easily angered or upset
- Feeling nervous or anxious
- Feelings of sadness
- Crying more than usual
- Lack of interest in usual activities
- Depression

Post-Concussive Visual Signs and Symptoms

- Currently Screened
  - Double Vision
  - Blurred Vision
  - Light Sensitivity
- In Addition/Actuality
  - Reading Difficulties
  - Eyestrain/Fatigue
  - Eye focusing problems
  - Eye Tracking Problems
  - Vision-Derived Nausea
  - Visual Inattention
  - Visual Anxiety/Crowding

Laukkanen H, Scheiman M, Hayes JR. Brain injury vision symptom survey (BIVSS) questionnaire. *Optom Vis Sci*. 2016;94(1):43-50.

Afferent Visual Pathway

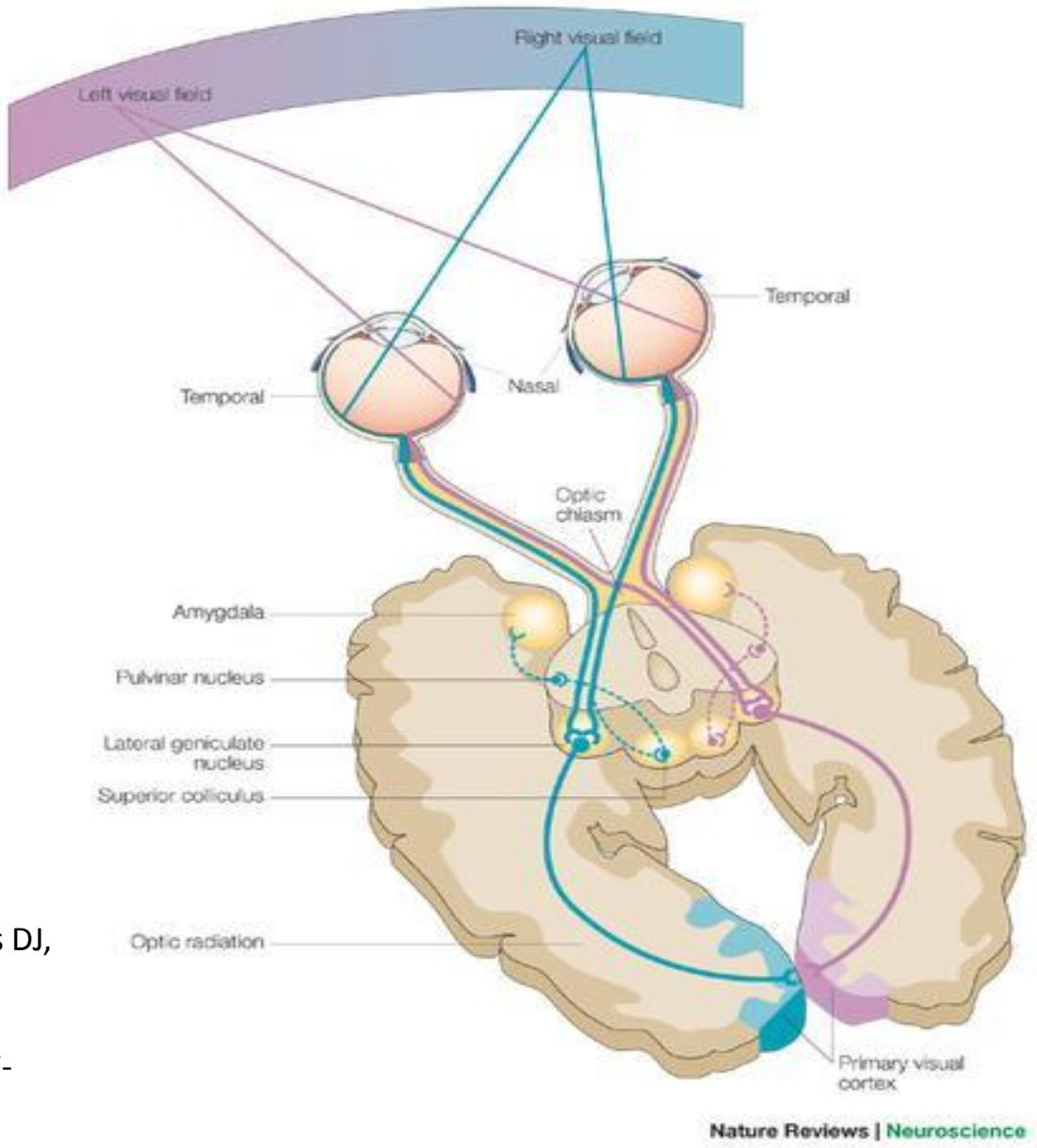
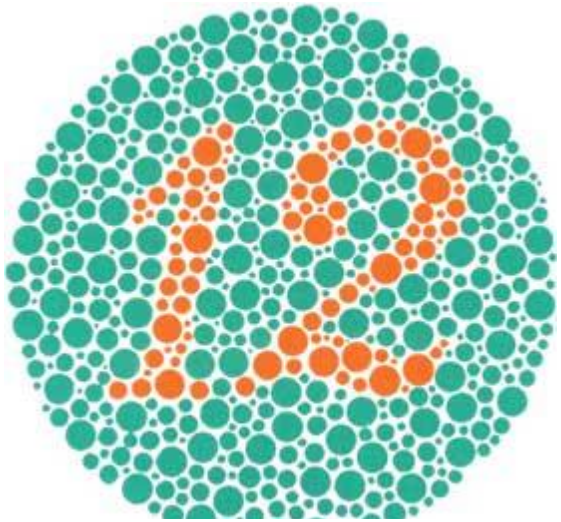
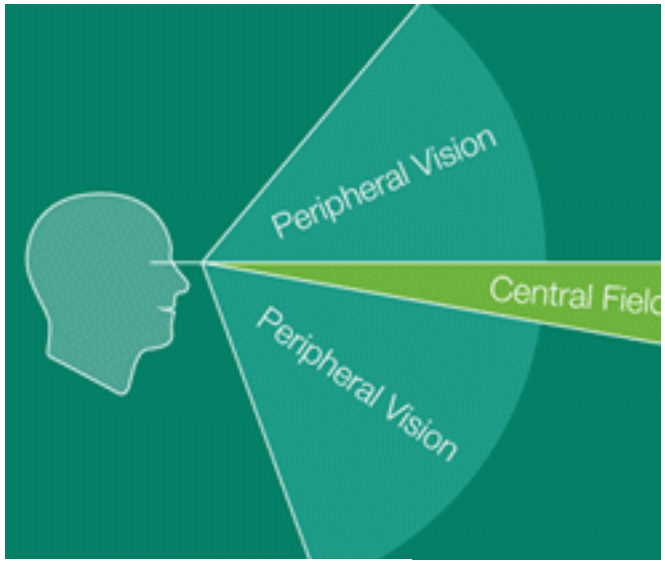
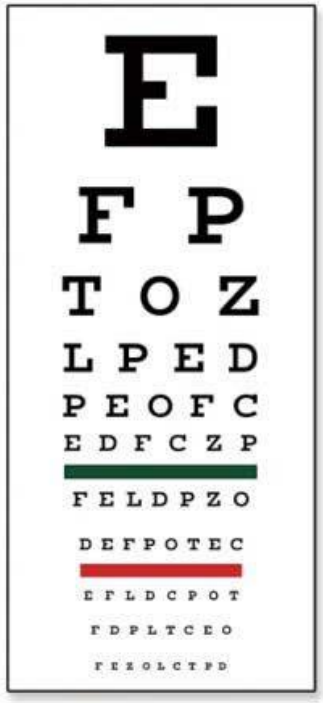


Image from - Hannula De, Simons DJ, Cohen NJ. Imaging implicit perception: promise and pitfalls. *Nature Rev Neurosci.* 2005;6:247-255/

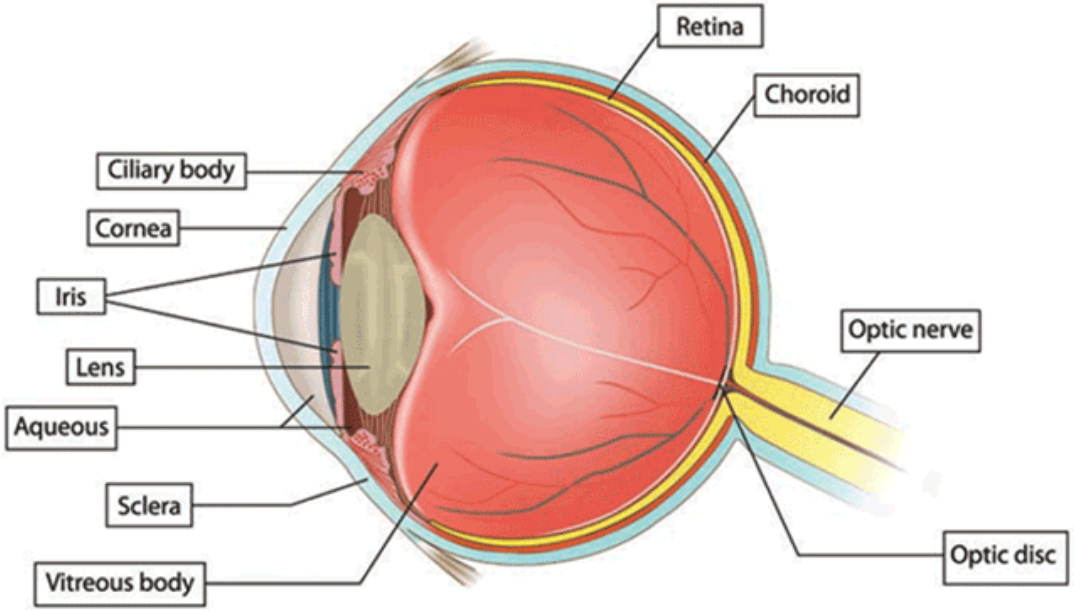
Afferent Visual Pathway – CN II







Snellen Chart



Post-Concussion Visual Signs

Ocular Health

- Traumatic Iritis
- Traumatic Optic Neuropathy
- Retinal changes
- Commotio Retinae
- Retinal Tear/Detachment

Pupil Findings

- Afferent
  - Increased average constriction latency
- Efferent
  - Parasympathetic
    - Slower average constriction velocity
  - Sympathetic
    - Decreased pupillary diameter
    - Slower peak dilation velocity
- Anisocoria?

Thiagarajan P, Ciuffreda K. Pupillary responses to light in chronic non-blast-induced mTBI. *Brain Injury*. 2015;29(12):1420-1425

Photophobia - Light Sensitivity

Etiology?? – Photophobia pathway?

- Ocular Photophobia
  - Iritis
    - Flash light test
    - Asymmetric
  - Pupil problems
  - Dry Eye
- Neurological Photophobia
  - TBI
  - Migraines
- Pharmacologic

Management

- Sunglasses outside OKAY
- Sunglasses inside – TRY TO AVOID
  - Wearing dark glasses indoors → dark adaptation of the retina → aggravation of light sensitivity
- Visors/Hats
- Mild Tints
  - Wavelength matters

Katz BJ, Digre KB. Diagnosis, pathophysiology, and treatment of photophobia. *Surv Ophth*. 2016;61:466-477

Visual Signs it may be MORE than a Concussion

- Pupils
  - Dilated/Fixed
  - APD
  - Anisocoria
- Reduced BCVA
- Visual Field Defects
- Cranial Nerve Palsy
- Ocular Health Problem
  - Optic nerve edema, pallor, etc

Efferent Visual Pathway
CN III, IV, VI, Parasympathetic, Sympathetic -Eye Movements

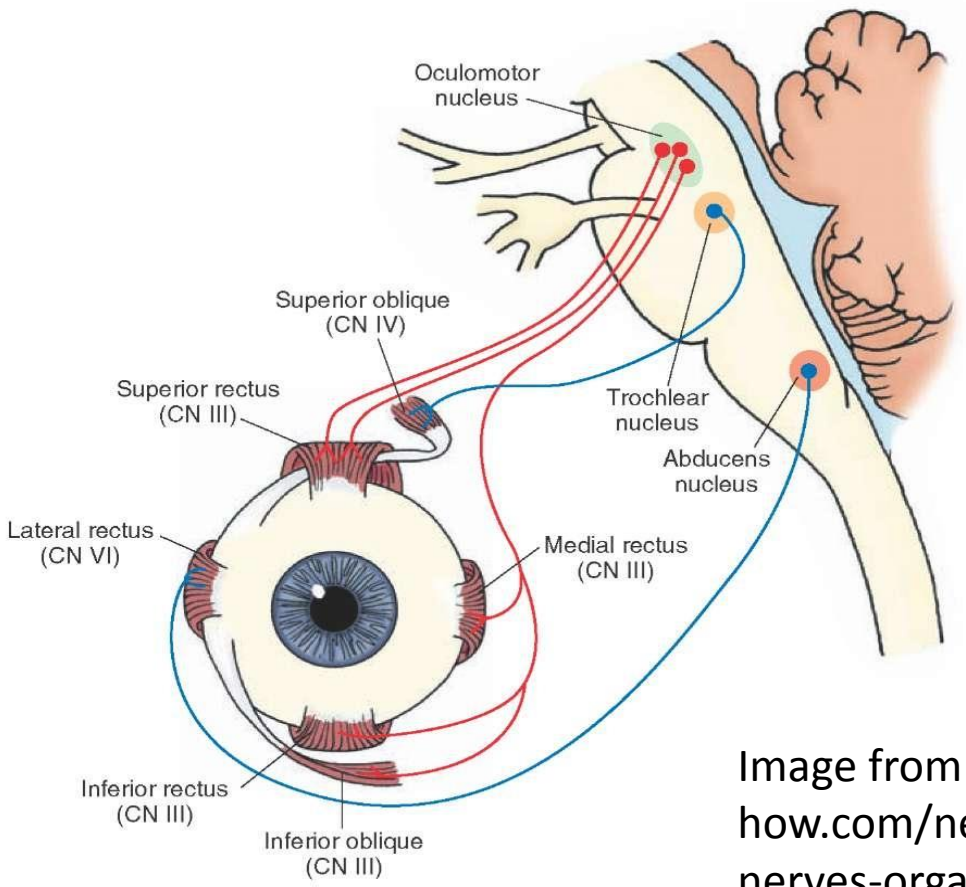


Image from http://what-when-how.com/neuroscience/the-cranial-nerves-organization-of-the-central-nervous-system-part-4/

Vestibulo-ocular dysfunction in pediatric sport-related concussion (SRC)

- Retrospective review of all patients with acute SRC (presenting 30 days or less post injury) and PCS (3 or more symptoms for at least 1 month) referred to a multidisciplinary pediatric concussion program from 9/2013-7/2014
- Methods - Clinical Hx, Physical, PCSS, VOD
  - VOD Complaint (dizziness, blurred vision, etc) + Sign (Abnormal pursuits, saccades, VOR)
- Results - n=101, age 14.2 +/-2.3 years, 76.2% with acute SRC (n=77) and 23.8% with PCS (n=24)
  - Mean duration of Sx was 40 days for pts w/ acute SRC and VOD vs. 21 days for acute SRC without VOD.
- Conclusions: Evidence of VOD in acute SRC and PCS. VOD was a significant risk factor for development of PCS

Ellis MJ, Cordingley D, Vis S, Reimer K, Leiter J, Russell K. Vestibulo-ocular dysfunction in pediatric sports-related concussion. J Neurosurg Pediatr 2015:16:248-255

What Determines Concussion Resolution?

- Balance Recovery <7 days
- Symptom Scores 5-14 days
- Cognitive Recovery 7-21 days
- Oculomotor Recovery 21-28 days

Other Factors

Litigation
Worker's Compensation
Individual Motivation
(Athlete, Military)
Age
Gender
Concussion History
Premorbid Factors
Injury Severity
Type/Timing of Treatment

Collins M, Kontos A, Okonkwo D. et al. Statements of Agreement from the Targeted Evaluation and Active Management (TEAM) Approaches to Treating Concussion Meeting Held in Pittsburgh, October 15-16, 2015. *Neurosurgery*. Dec 2016;79(6):912-929.

Role of Eyes in Concussion Diagnosis: *VOMS (Vestibular/Ocular Motor Screening) Assessment*

Vestibular/Ocular Domains Assessed

1. Smooth Pursuit
2. Horizontal and Vertical Saccades
3. Convergence
4. Horizontal and Vertical VOR
5. Visual Motion Sensitivity

- 61% of adolescent concussed athletes reported symptom provocation after at least 1 VOMS item
- All VOMS items were positively correlated to the PCSS (Post Concussion Symptom Scale) total symptom score
- VOMS was nearly 90% accurate in identifying patients with concussion from controls

Mucha A, Collins MW, Elbin RJ, et al. A brief vestibular/ocular motor screening (VOMS) assessment to evaluate concussions: preliminary findings. Am J Sports Med 2014;42:2479-86.

VOMS Continued…

- Women have higher VOMS scores then males (Sufrinko 2017)
- Symptom provocation/clinical abnormality associated with all domains (except convergence and accommodation) can delay recovery time after SRC in youth and adolescents (Anzalone 2017)
- VOMS does NOT provoke vestibular symptoms in healthy adolescents (Yorke 2017)
- VOMS measures unique aspects of vestibular-ocular function other than those measured in the BESS (Balance Error Scoring System) or KD (King-Devick Test) with good reliability (Yorke 2017)
- In collegiate athletes, VOMS had a high internal consistency with an 11% false-positive rate at baseline – mostly female or history of motion sickness (Kontos 2016).

Anzalone AJ, Blueitt D, Case T, McGuffin T, Pollard K, Garrison JC, Jones MT, Pavur R, Turner S, Oliver JM. A positive Vestibular/Ocular Motor Screening (VOMS) is associated with increased recoverty time after sports-related concussion in youth and adolescent athletes. *AJSM* 2017;45(2)474-479

Kontos AP, Sufrinjo A, Elbin RJ, Puskar A, Collins MW. Reliability and associated risk factors for performance on the Vestibular/Ocular Motor Screening (VOMS) tool in healthy collegiate athletes. *AJSM* 2016;44(6):1400-1406

Sufrinko AM, Mucha A, Covassin T, Marchetti G, Elbin RJ, Collins MW, Kontos AP. Sex differences in vestibular/ocular and neurocognitive outcomes after sport-related concussion. *Clin J Sport Med* 2017;27:133-138.

Yorke AM, Smith L, Babcock M, Alsalaheen B. Validity and reliability of the Vestibular/Ocular Motor Screening and associations with common concussion screening tools. *Sports Health*. 2017;9(2): 174-180.

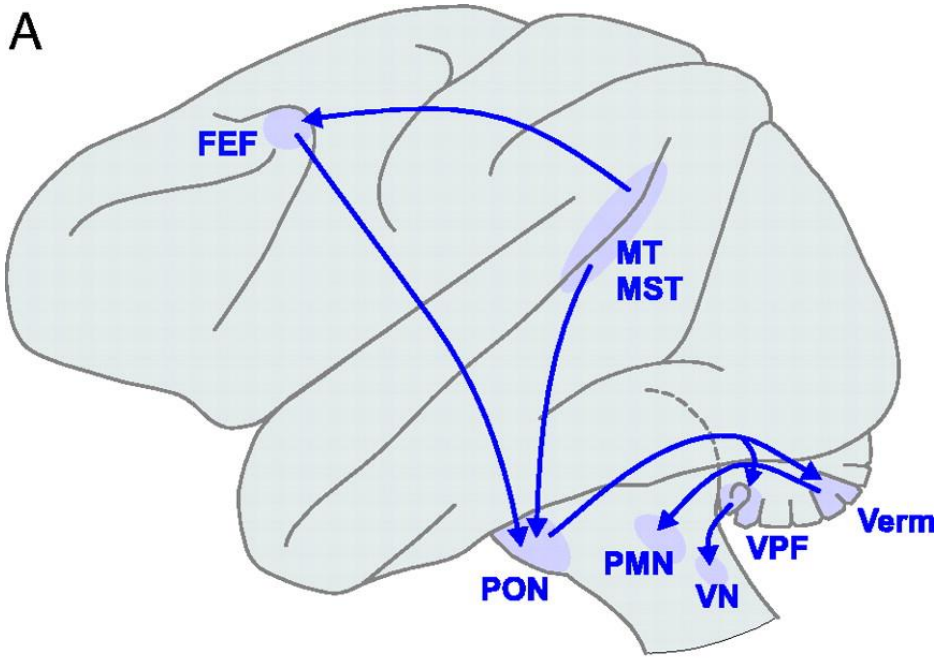
Table 1. Vestibular/Ocular Motor Screening (VOMS) for concussion[27]

VOMS Test	Headache[a]	Dizziness[a]	Nausea[a]	Fogginess[a]	Total Symptom Score[b]
Baseline symptoms					
Smooth pursuit					
Horizontal saccades					
Vertical saccades					
Near point convergence Measure 1: _____ Measure 2: _____ Measure 3: _____					
Horizontal VOR					
Vertical VOR					
Visual motion sensitivity					

VOR, vestibulo-ocular reflex.
[a]Provocation of symptoms is rated on a scale from 0 to 10, with 0 being no symptoms and 10 being severe symptoms.
[b]Total symptom score = change in headache from baseline + change in dizziness from baseline + change in nausea from baseline + change in fogginess from baseline for each of the VOMS test items.

Yorke AM, Smith L, Babcock M, Alsalaheen B. Validity and reliability of the Vestibular/Ocular Motor Screening and associations with common concussion screening tools. *Sports Health*. 2017;9(2): 174-180.

Pursuits



Saccades

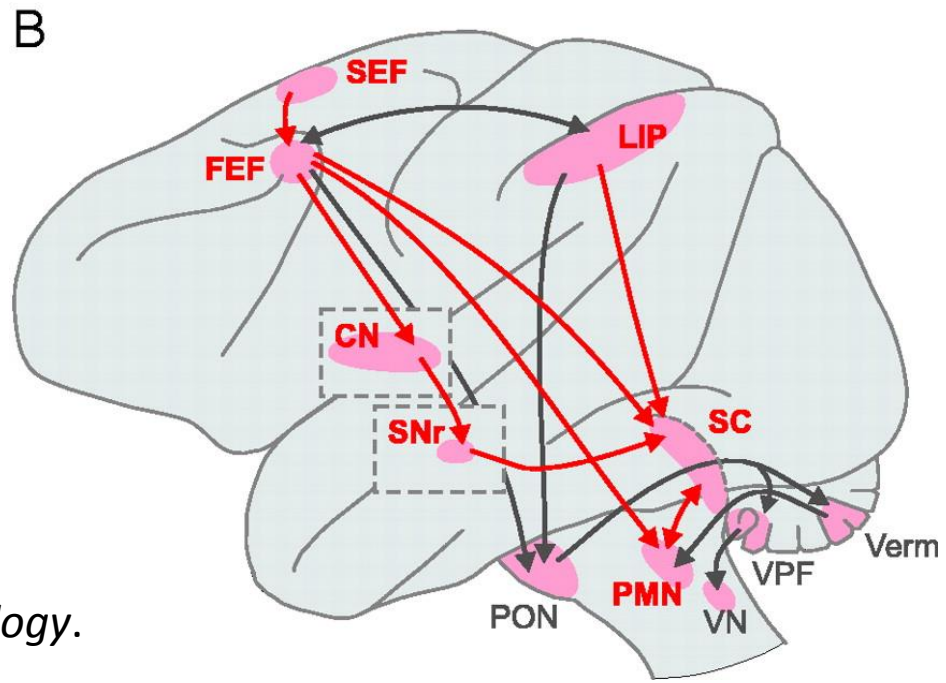
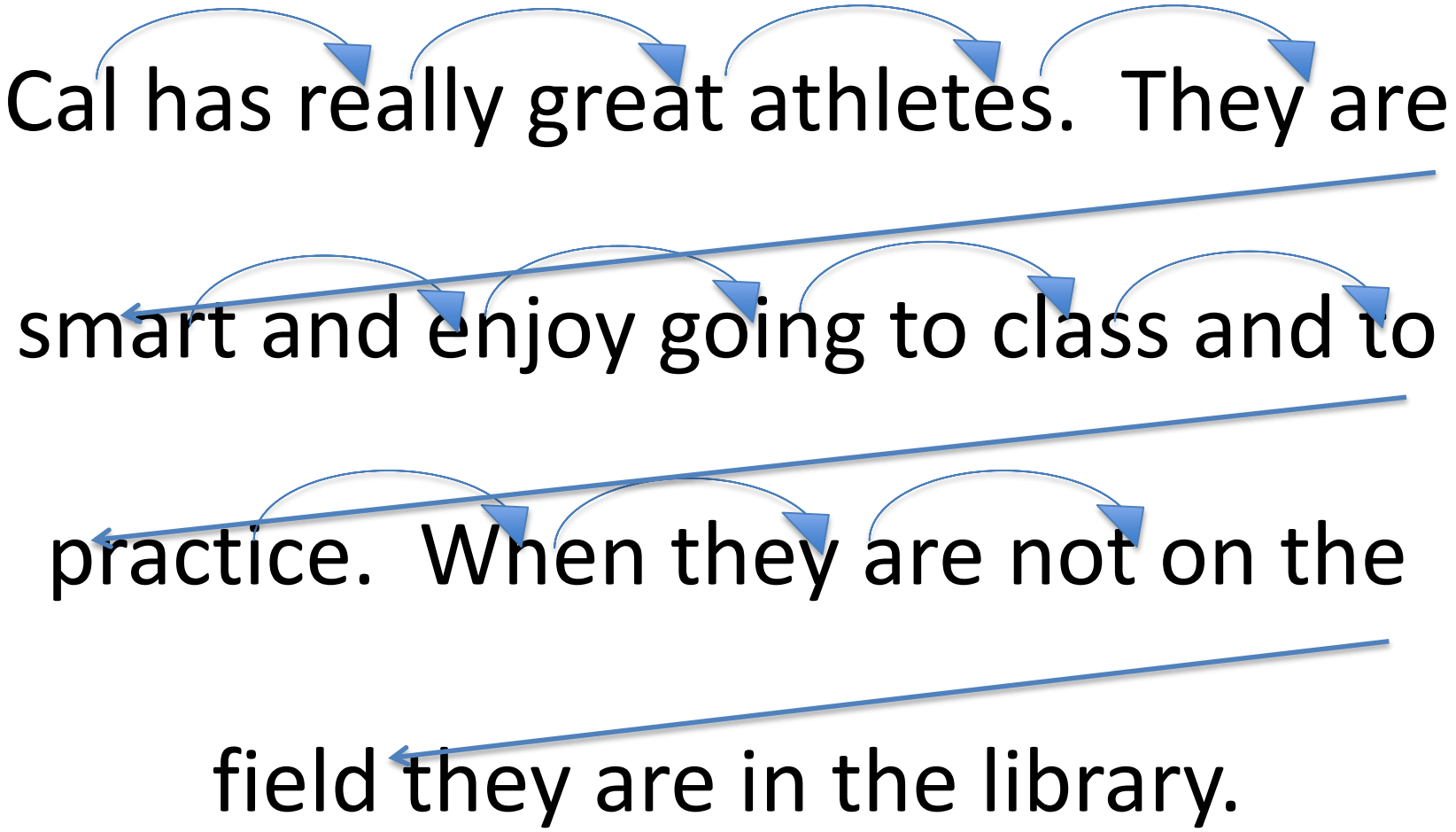
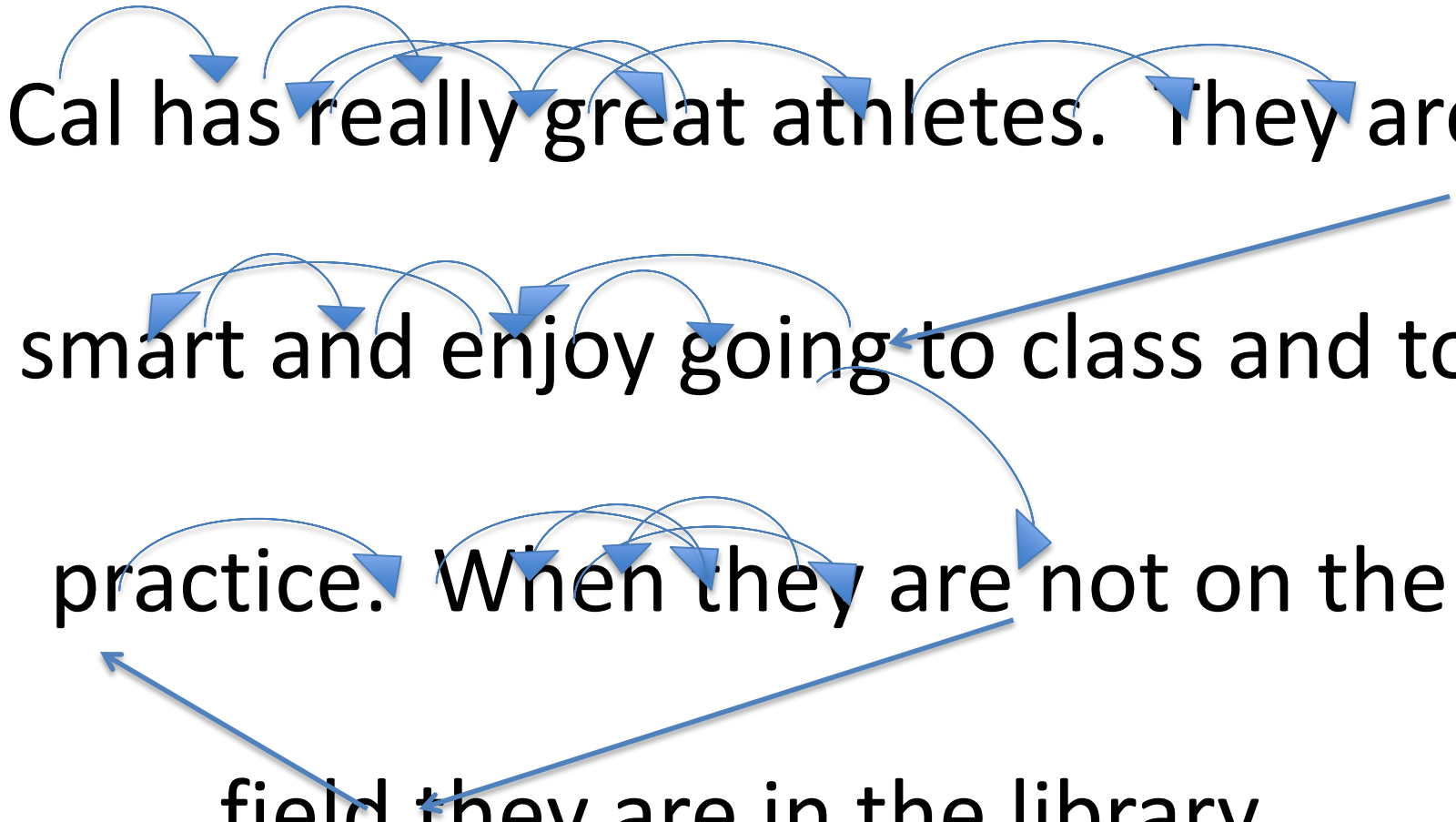


Image from: Krauzlis RJ. Recasting the Smooth Pursuit Eye Movement System, *J Neurophysiology*. 2004;91(2):591-603


Cal has really great athletes. They are
smart and enjoy going to class and to
practice. When they are not on the
field they are in the library.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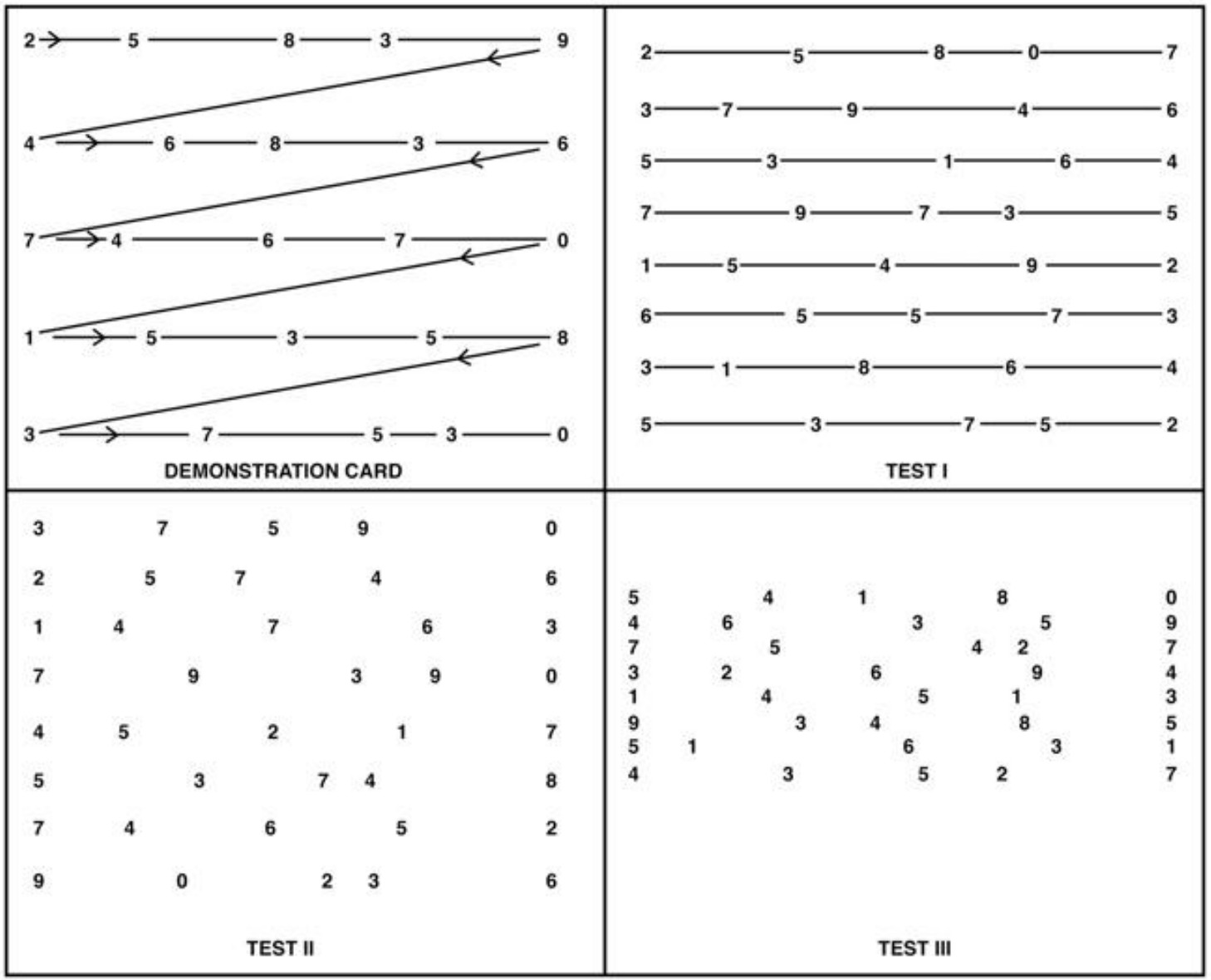
King-Devick


2 5 8 3 9
4 6 8 3 6
7 4 6 7 0
1 5 3 5 8
3 7 5 3 0
DEMONSTRATION CARD
2 5 8 0 7
3 7 9 4 6
5 3 1 6 4
7 9 7 3 5
1 5 4 9 2
6 5 5 7 3
3 1 8 6 4
5 3 7 5 2
TEST I
3 7 5 9 0
2 5 7 4 6
1 4 7 6 3
7 9 3 9 0
4 5 2 1 7
5 3 7 4 8
7 4 6 5 2
9 0 2 3 6
TEST II
5 4 1 8 0
4 6 3 5 9
7 5 4 2 7
3 2 6 9 4
1 4 5 1 3
9 3 4 8 5
5 1 6 3 1
4 3 5 2 7
TEST III

fMRI of Acute Oculomotor Deficits in Concussed Athletes

- n=9, 7 days post-concussion
- n=9, age, sex match normal volunteers
- Fixation, Reflexive saccades, anti-saccades, memory guided saccades, self-paced saccades
- fMRI - widespread increased activation of multiple brain areas following concussion in response to oculomotor tasks
  - Longer latency time, worse position errors, fewer number of self-paced saccades

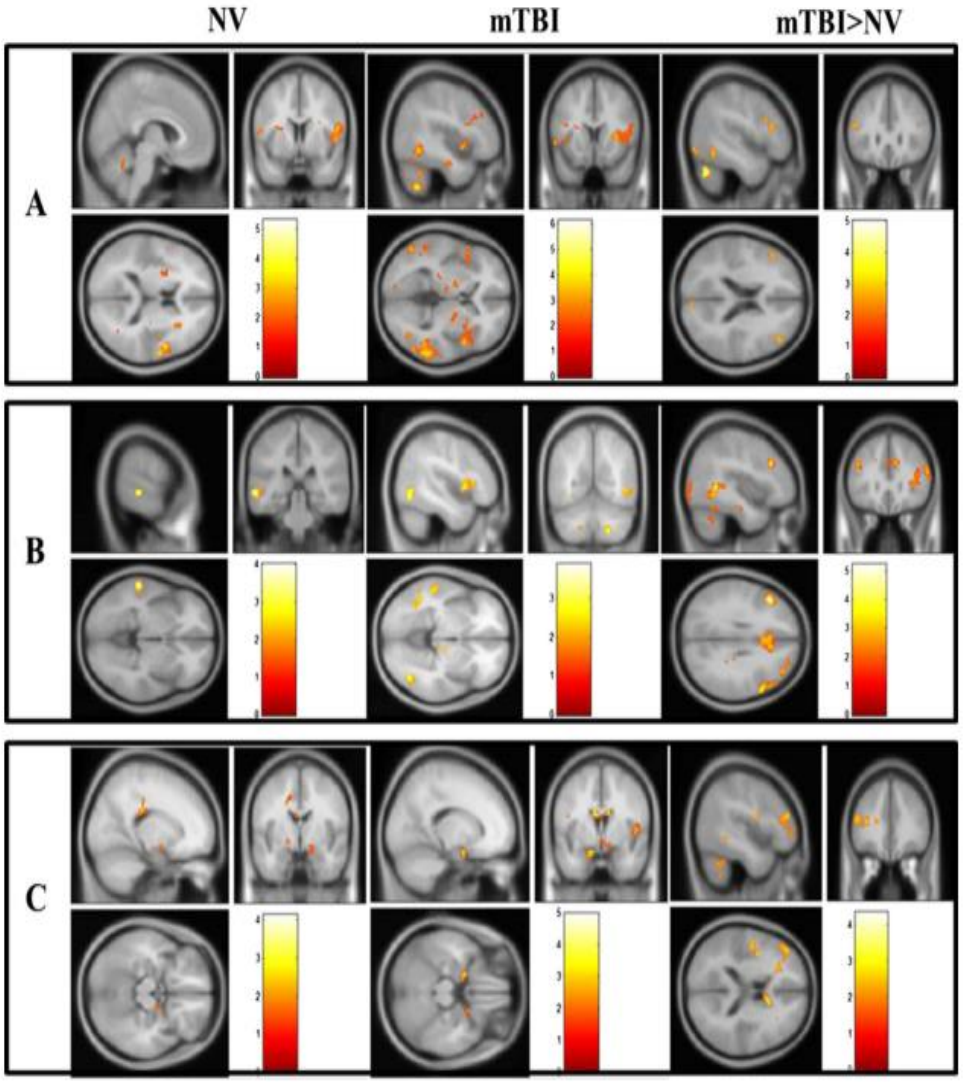


Fig. 2 Significant (p-value<0.05 FDR) fMRI activation patterns in sagittal, coronal, and axial planes for normal volunteers (NV), concussed (mTBI), and increased activation in concussed compared to normal volunteers (mTBI>NV) in (**a**) Anti-saccades, (**b**) Self-paced Saccades, (**c**) Memory Guided Saccade tasks. Color bars representative of t-values

Johnson B, Zhang K, Hallett M, Slobounov S. Functional neuroimaging of acute oculomotor deficits in concussed athletes. Brain Imaging Behav 2015;9:564-73

Accommodation

- When the eye changes refractive power by altering the shape of the lens to focus on objects at different distances
- ie – How the eye focuses on things

AccommodativePathway

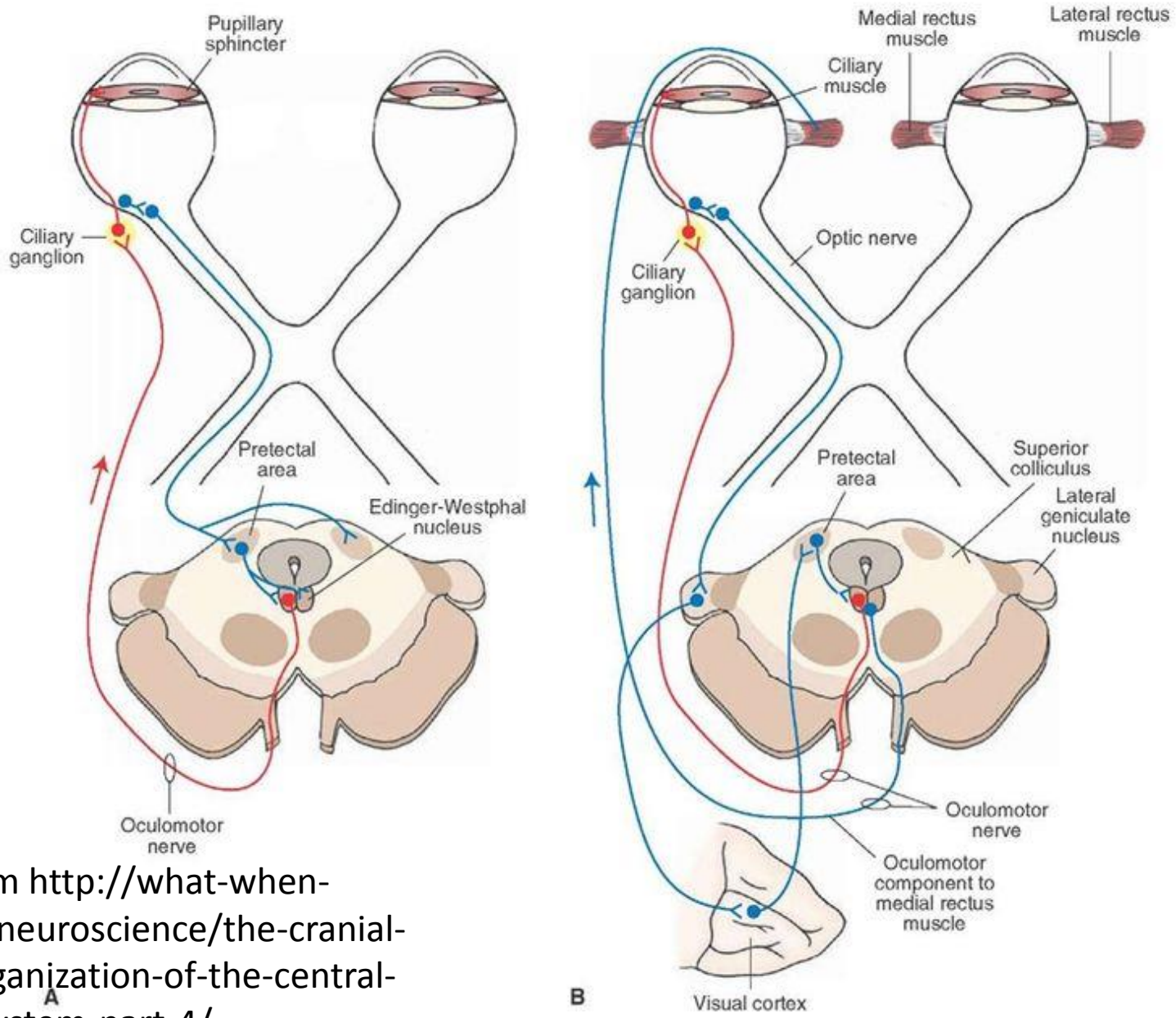
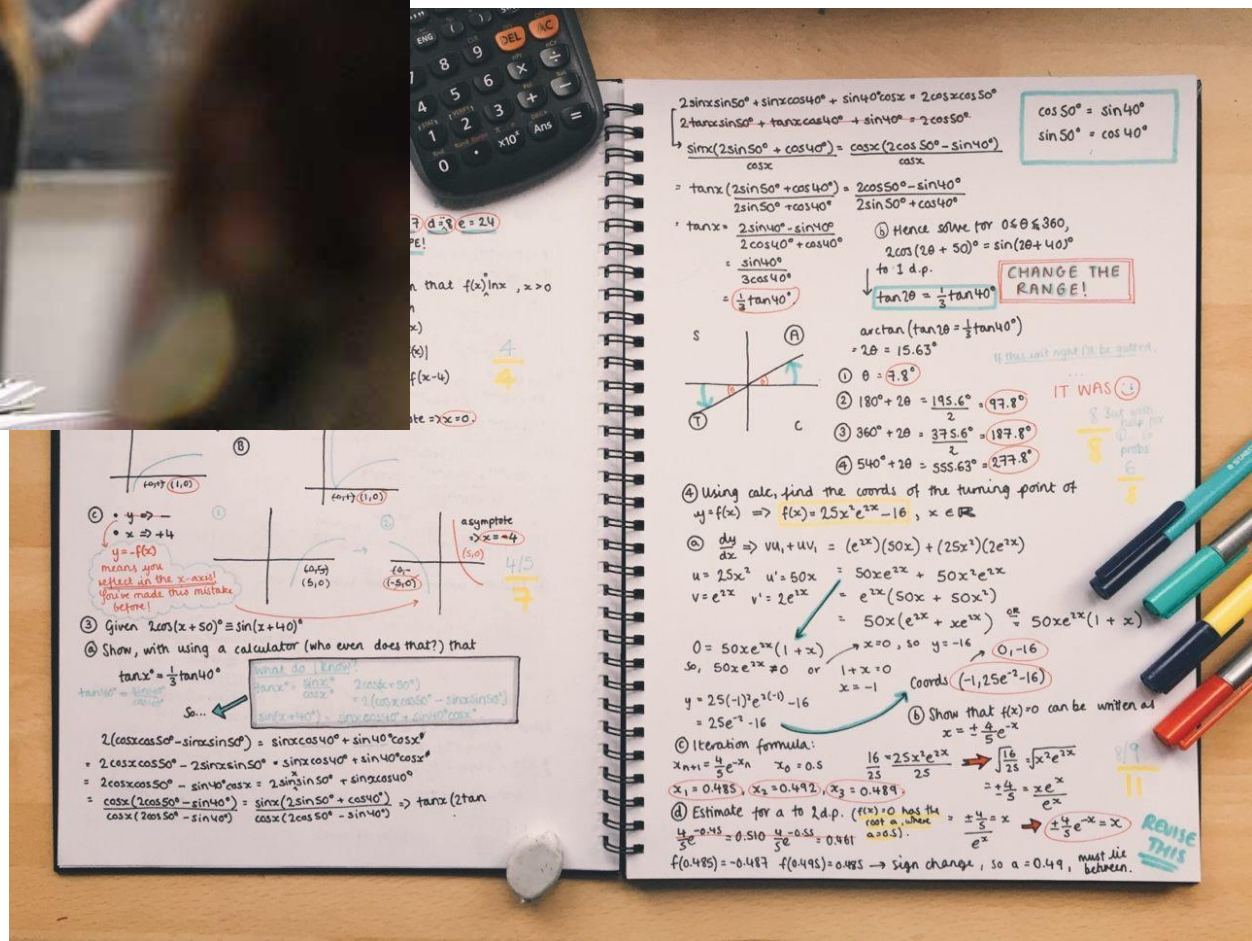


Image from http://what-when-how.com/neuroscience/the-cranial-nerves-organization-of-the-central-nervous-system-part-4/

Accommodative Insufficiency

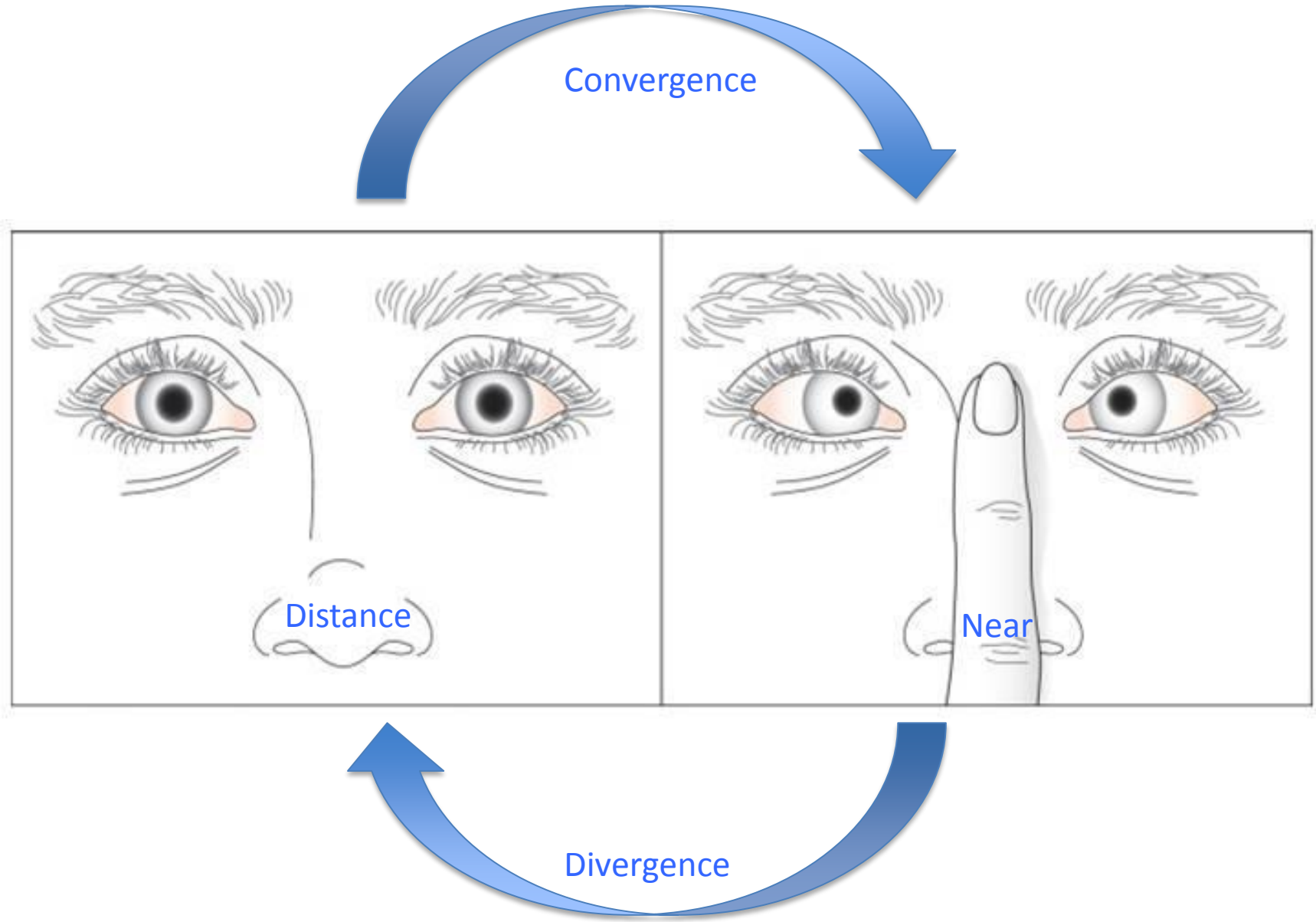
Accommodative Infacility



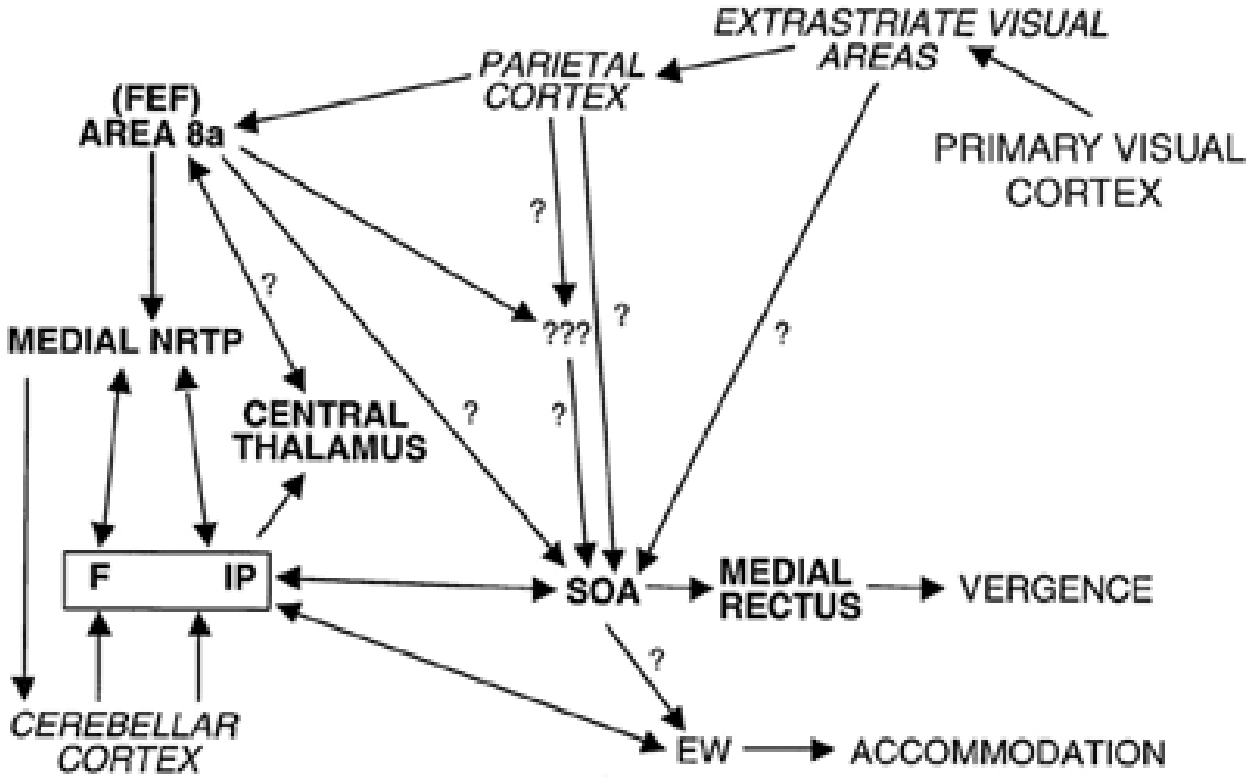
Accommodative Spasm

There once was a little girl who could not read very well. She complained that the print was blurry and moving. She could not keep her place on the page. She went to her optometrist to get help. Her optometrist recommended vision therapy and told the girl that there was a solution to her vision problems. The girl began vision therapy and saw drastic improvements in her reading, writing, and most of all how she saw the world. The vision therapy made a huge difference in her life!

Convergence/Divergence



Vergence Pathway

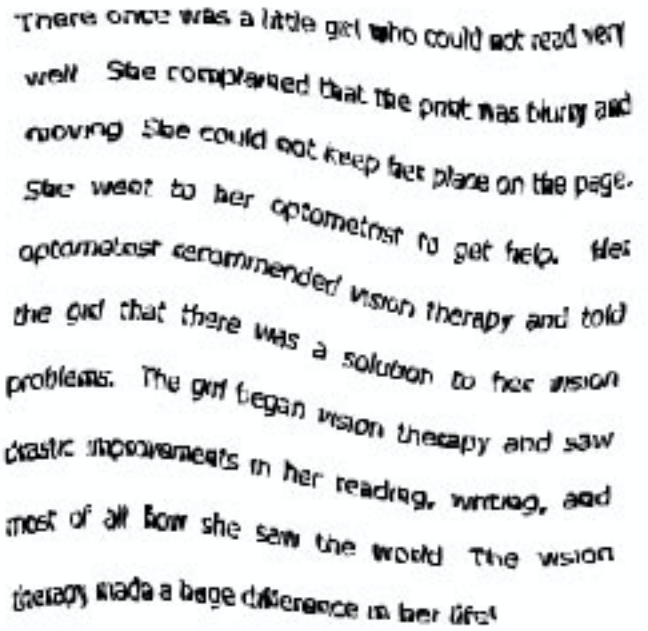


Gamlin P. Neural Mechanisms for the Control of Vergence Eye Movements. Ann N Y Acad Sci. 2002 Apr;856:264-72

Convergence Insufficiency
Vergence Dysfunction

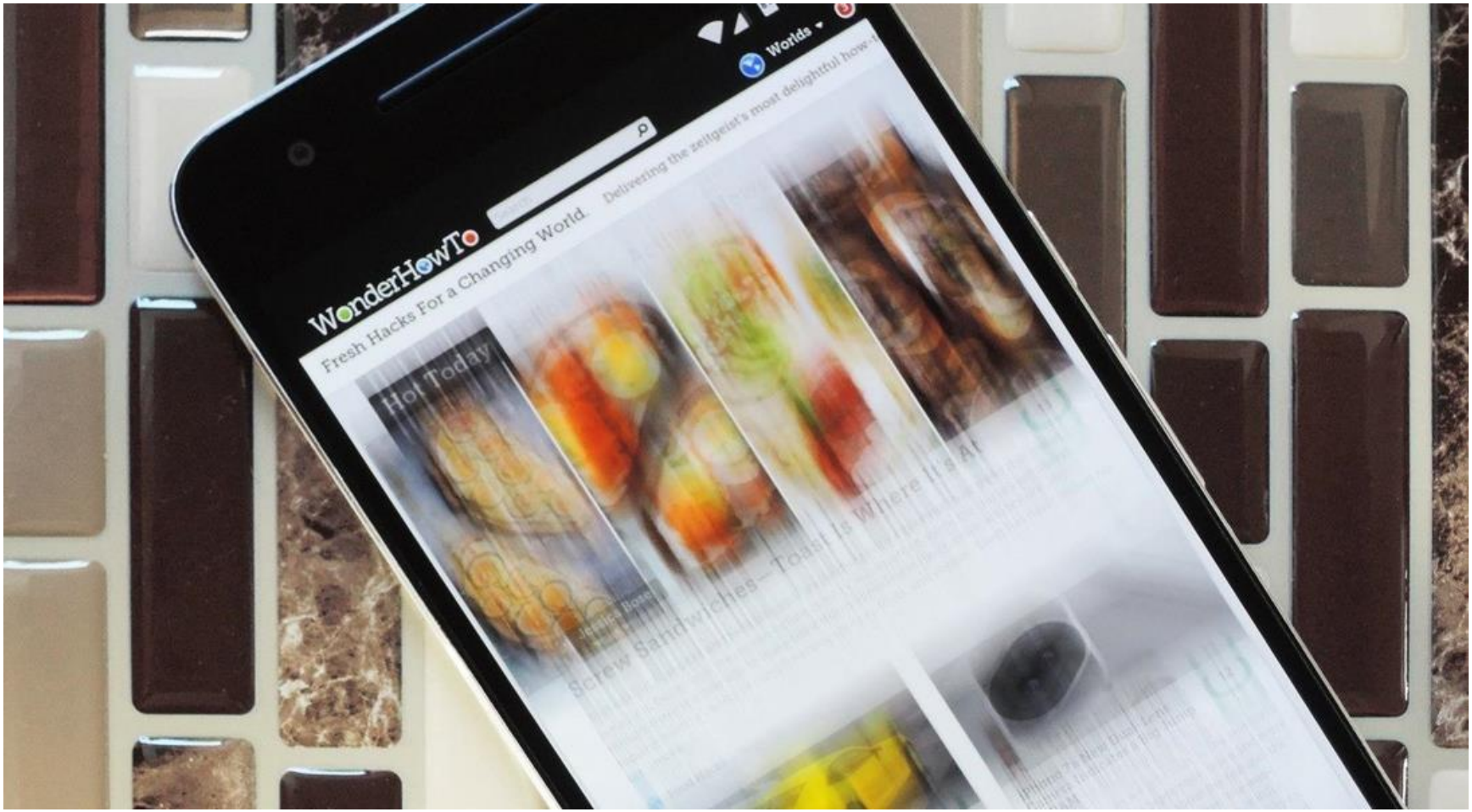
double vision can look like this:

double vision
double vision
double vision
double vision
double vision
double vision



Double vision makes it difficult to read and comprehend.

Visual-Evoked Nausea



Visual Motion in Daily Life

Visual-Vestibular Motion in Sport

Higher Order Visual Processing

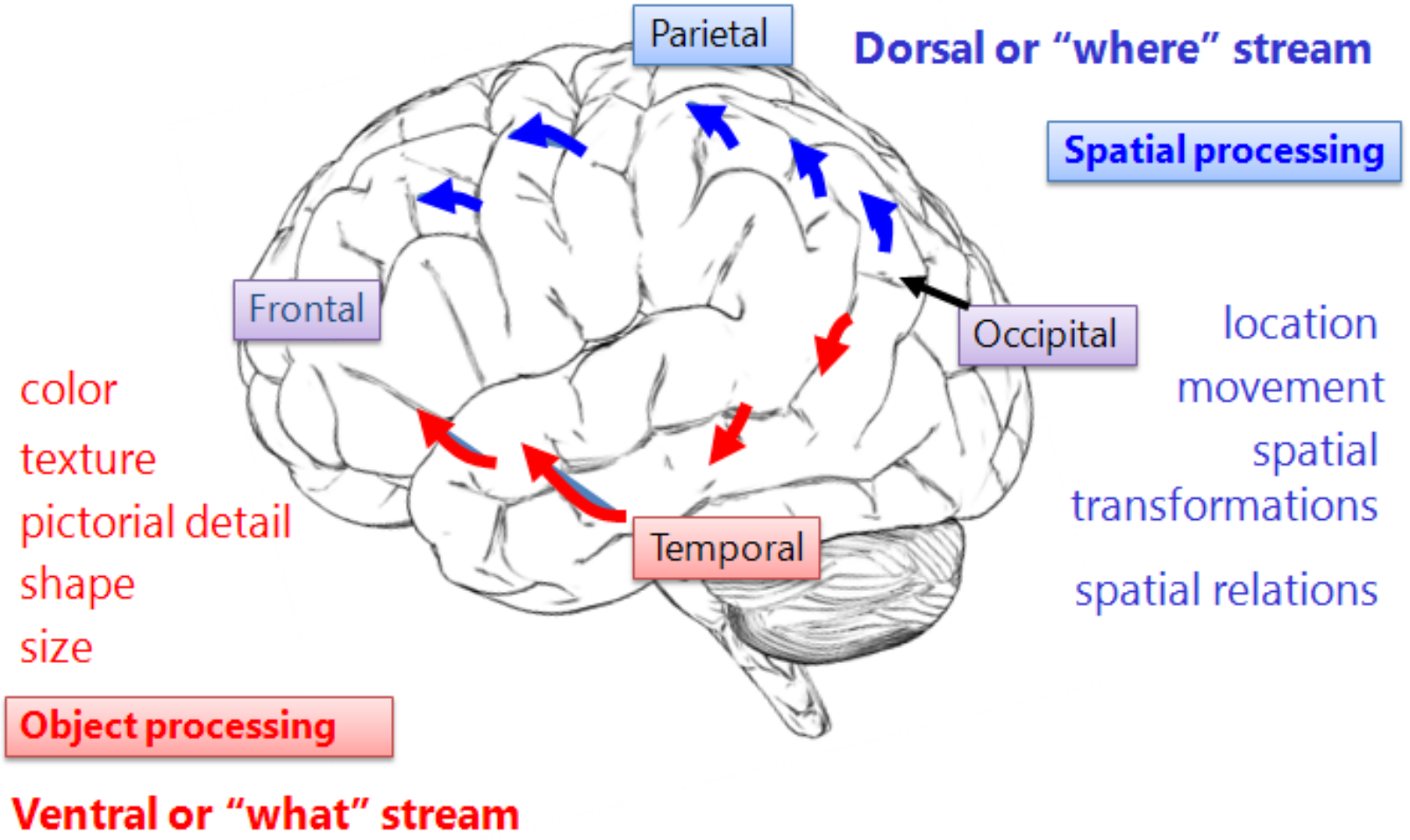
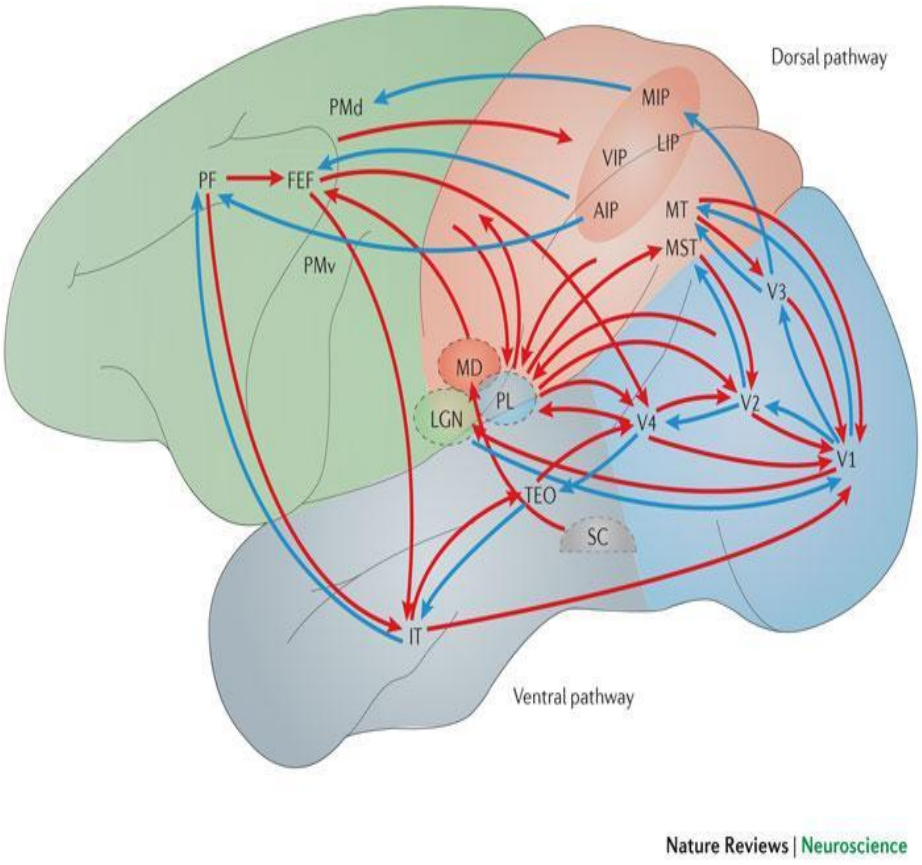
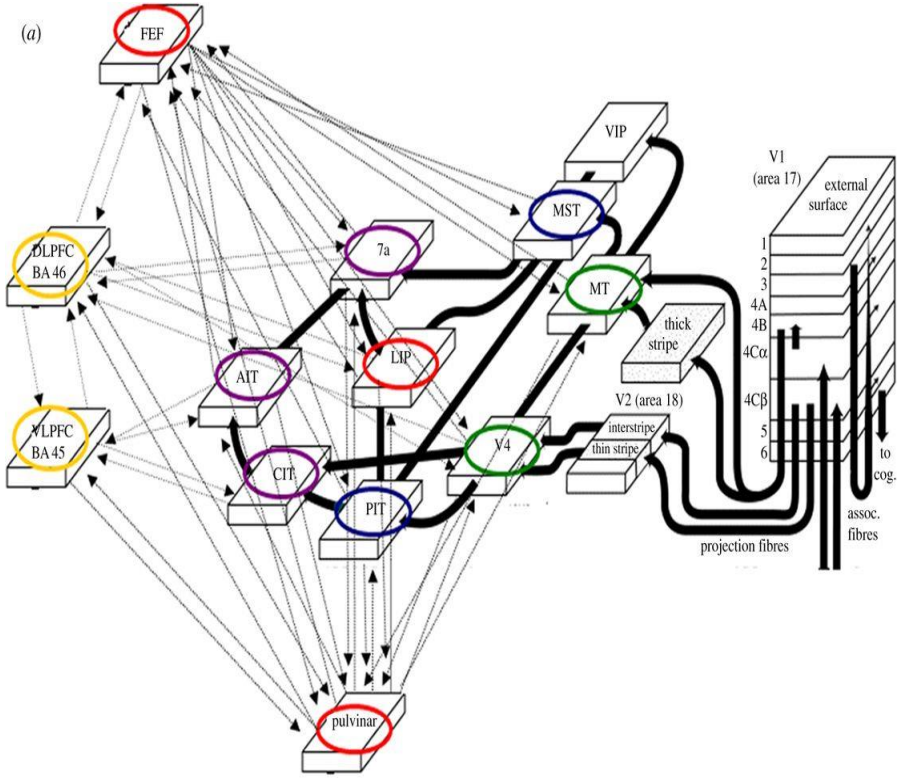
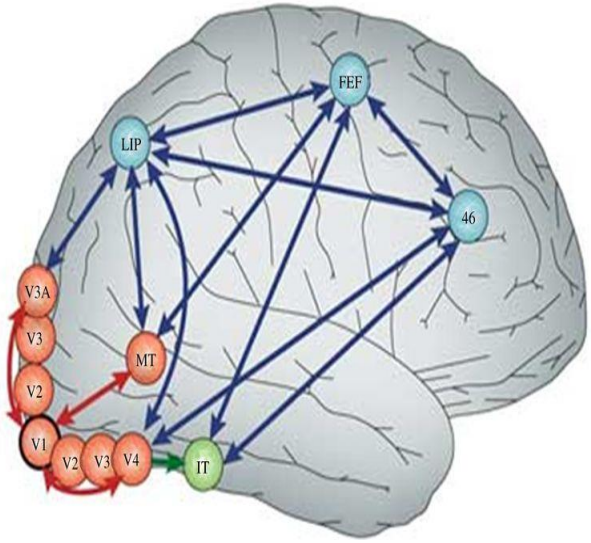


Image from: http://www.nmr.mgh.harvard.edu/mkozhevnlab/?page_id=663

Visual Attention and Visual Processing







Gilbert C, Li W. Top-down influences on visual processing. *Nature Rev Neurosci*. 2013;14:350-363

Raffone A, Srinivasan N, van Leeuwen C. The interplay of attention and consciousness in visual search, attentional blink and working memory consolidation. *Phil Trans R Soc B.* 2014:369.

Visual Crowding (Simultanagnosia)

Thereoncewasalittlegirlwhocouldnotreadverywell.
Shecomplainedthattheprintwasblurryandmoving.
Shecouldnotkeepherplaceonthepage.Shewentto
heroptometristtogethelp.Heroptometristrecommen
dedvisiontherapyandtoldthegirlthattherewasa
solutiontohervisionproblems.Thegirlbeganvision
therapyand sawdrasticimprovementsinherreading,
writing,andmostofallhowshesawtheworld.The
visiontherapymadeahugedifferenceinherlife!

Visual Crowding in Daily Life

Prescribed Accommodations/Advocations

- Visual Motion Sensitivity/Visual Crowding
  - Removal from gym/dance class, band/orchestra, school assemblies
  - Double spaced text, increased font size, line guides
- Oculomotor Dysfunction
  - Delay tests/quizes
  - Reduce amount of homework
  - Increase time on tests/assignments
    - Planned breaks
  - Note taker
- TEMPORARY MODIFICATIONS

Directions for the future?

TEAM Approach to Concussion - 2015

- **Multidisciplinary Assessment**
  - Review mechanism of Injury
  - Relevant medical history
  - Symptom Checklist
  - Neurocognitive Screening/Neuropsychological Evaluation
  - Balance Assessment
  - Vestibular Screening/Examination
  - Oculomotor Function Screening/Examination
  - Neurological Evaluation
  - Cervical Spine Evaluation
  - Psychological Evaluation
  - Neuroimaging prn

Collins M, Kontos A, Okonkwo D. et al. Statements of Agreement from the Targeted Evaluation and Active Management (TEAM) Approaches to Treating Concussion Meeting Held in Pittsburgh, October 15-16, 2015. *Neurosurgery*. Dec 2016;79(6):912-929.

TEAM Approach to Concussion - 2015

- Concussions are a **treatable injury**
  - More active/target approaches are better than prescribed rest alone
- Active Rehabilitation
  - Vestibular Therapy
  - Oculomotor/Vision Therapy
  - Behavioral Therapy

Collins M, Kontos A, Okonkwo D. et al. Statements of Agreement from the Targeted Evaluation and Active Management (TEAM) Approaches to Treating Concussion Meeting Held in Pittsburgh, October 15-16, 2015. *Neurosurgery*. Dec 2016;79(6):912-929.

Broglio SP, Collins M, Williams RM, Mucha A, Kontos A. Current and emerging rehabilitation for concussion: a review of the evidence. *Clin Sports Med*. 2015;34(2):213-231

Role for Vision Therapy?

- n=220 individuals with TBI (n=160) or CVA (n=60)
- Computer based query in clinical population 2000-2003, selected those who completed optometric VT program TBI (n=33), CVA (n=7)
- Results: 90% of TBI and 100% with CVI had treatment success
  - Marked/total improvement in at least 1 primary symptom and at least 1 primary sign
  - Improvements remained stable at retesting 2-3 months later

Table 2 Categories of oculomotor symptoms and signs

Symptom
Blur
Diplopia
Impaired global sense of depth perception
Increased sensitivity to visual motion (caused by oculomotor-based impairment of dynamic version and/or vergence)
Eye strain
Headache
Avoidance of near vision tasks
Oculomotor-based reading difficulty (e.g., loss of place when reading, skipping lines when reading, and misreading or missing words when reading)
Difficulty with global scanning (e.g., problems navigating in busy streets, stores, malls, etc.)
Sign
Reduced amplitude of accommodation
Increased lag of accommodation
Reduced relative accommodation
Slowed accommodative facility
Uncorrected hyperopia/astigmatism (caused by inability to compensate)
Receded near point of convergence
Restricted relative convergence (BO) at far and near
Restricted overall fusional vergence ranges at far and near
Abnormal Developmental Eye Movement (DEM) test results
Low grade-level equivalent performance on the Visagraph II
Impaired versional ocular motility

Ciuffreda KJ, Rutner D, Kapoor N, Suchoff I, Craid S, Han ME. Vision therapy for oculomotor dysfunctions in acquired brain injury: A retrospective analysis. Optom 2008: 79: 18-22.

Clinical Pearls

- The visual system is commonly affected in concussion
- The majority of visual problems self-resolve after concussion in 3-4 weeks, but some patients may need active therapy for full recovery
- When in doubt refer

Thank you! Questions?

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Slide Photo References

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