

# Neuro-Optometric Exam and Concussion



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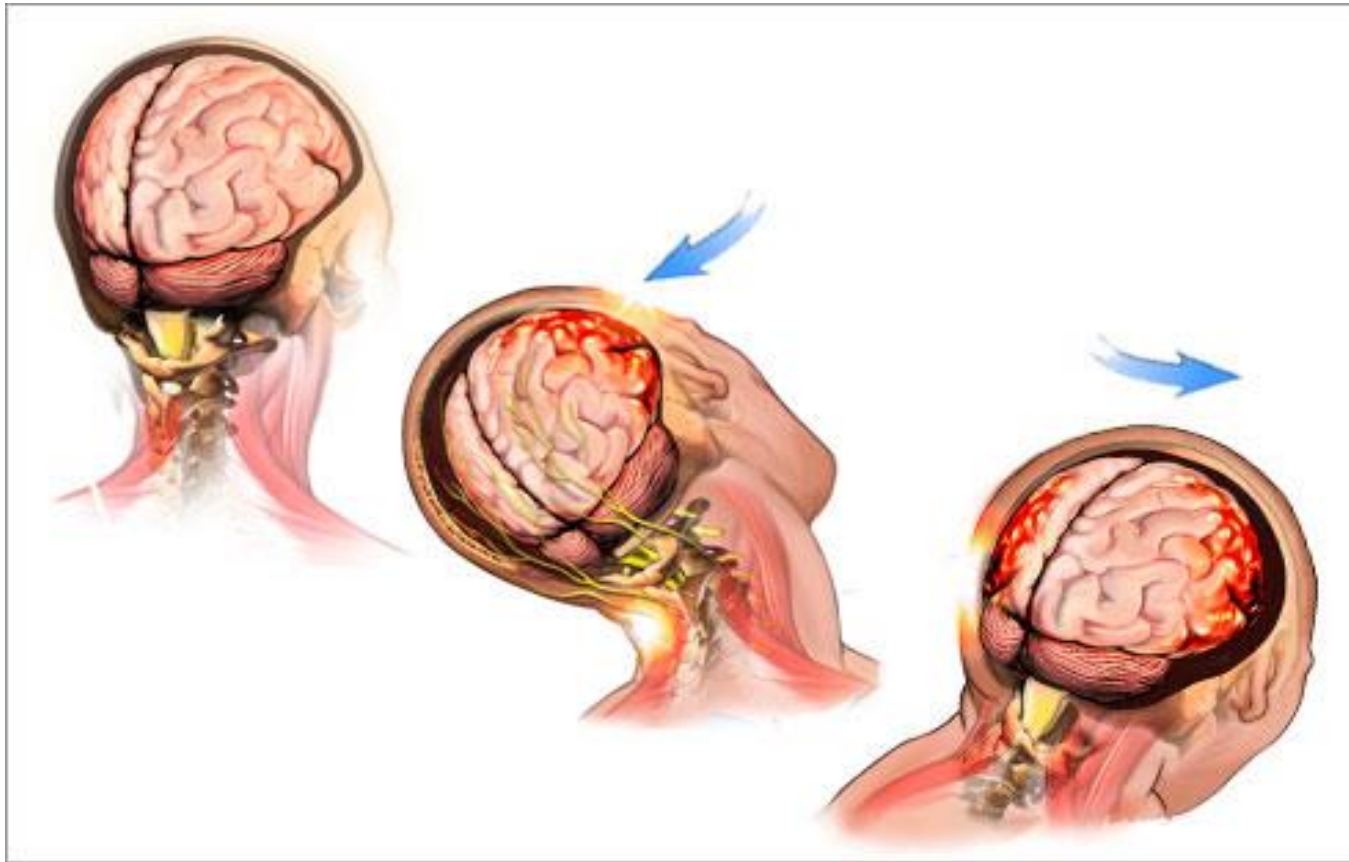
# Background

- 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.
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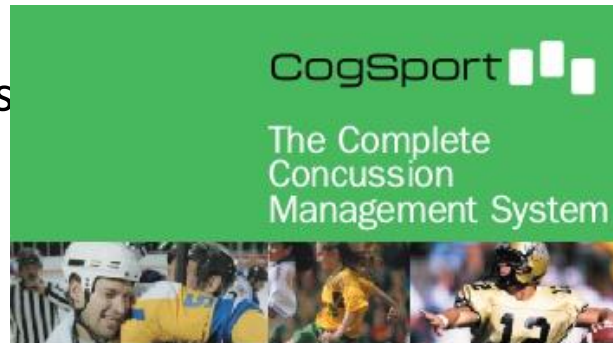
Image from Martin LJ. A visual guide to concussions and brain injuries. Webmd.com Accessed April 15, 2017.

<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



## What is CogSport?

CogSport is an easy to use series of computer-based neuropsychological tests designed for use by physicians to detect mild cognitive changes in concussed athletes.

CogSport provides an objective indication of brain function after concussion, and helps guide medical decisions about:

- return to play/work/training
- monitoring rehabilitation

## How is CogSport Different?



CogSport tests use a familiar playing cards, and only require the athlete to press one of two keys. Different cards are presented each time, giving unlimited equivalent forms.

## How does it work?

CogSport software is available via download from [www.cogsport.com](http://www.cogsport.com). Athletes take a "baseline" test before the season begins, and then again after an injury. The results are compared and provide an objective analysis of whether the athlete has returned to his/her "normal" cognitive state. Data files are transferred electronically, and clinical reports are returned via email within minutes.



Name: \_\_\_\_\_ Date / Time of Injury: \_\_\_\_\_ Examiner: \_\_\_\_\_  
Date of Assessment: \_\_\_\_\_

## What is the SCAT3?

The SCAT3 is a standardized tool for evaluating injured athletes for concussion and can be used in athletes aged from 12 years and older. It supersedes the original SCAT and the SCAT2 published in 2005 and 2008, respectively. For younger patients, ages 12 and under, please use the Child SCAT3. The SCAT3 is designed for use by medical professionals. If you are not qualified, please use the Sport Concussion Recognition Tool. Pre-season baseline testing with the SCAT3 can be helpful for interpreting post-injury test scores.

Specific instructions for use of the SCAT3 are provided on page 3. If you are not familiar with the SCAT3, please read through these instructions carefully. This tool may be freely copied in document form for distribution to individuals, teams, groups and organizations. Any revision or any reproduction in a digital form requires approval by the Concussion in Sport Group.

**NOTE:** The diagnosis of a concussion is a clinical judgment, ideally made by a medical professional. The SCAT3 should not be used solely to make, or exclude, the diagnosis of concussion in the absence of clinical judgment. An athlete may have a concussion even if their SCAT3 is "normal".

## What is a concussion?

A concussion is a disturbance in brain function caused by a direct or indirect blow to the head. It results in a variety of neuropsychological symptoms (some examples listed below) and most often does not involve loss of consciousness. Concussion should be suspected in the presence of any one or more of the following:

- Symptoms (e.g., headache), or
- Physical signs (e.g., unsteadiness), or
- Impaired brain function (e.g., confusion) or
- Abnormal behaviour (e.g., change in personality).

## SIDELINE ASSESSMENT

### Indications for Emergency Management

NOTE: A hit to the head can sometimes be associated with a more serious brain injury. Any of the following warrants consideration of activating emergency procedures and urgent transportation to the nearest hospital:

- Glasgow Coma score less than 15
- Defining mental status
- Potential skull injury
- Progressive, worsening symptoms or new neurological signs

### Potential signs of concussion?

If any of the following signs are observed after a direct or indirect blow to the head, the athlete should stop participation. He evaluated by a medical professional and should not be permitted to return to sport the same day if a concussion is suspected.

- Any loss of consciousness? ☐ Y ☐ N
- "Is he, how long?" ☐ Y ☐ N
- Balance or motor coordination problems (e.g., abnormal clumsiness, etc.) ☐ Y ☐ N
- Confusion or confusion (e.g., unable to respond appropriately to questions?) ☐ Y ☐ N
- Loss of memory ☐ Y ☐ N
- "Is he, how long?" ☐ Y ☐ N
- "Before or after the injury?" ☐ Y ☐ N
- Blank or vacant look ☐ Y ☐ N
- Visible facial injury in combination with any of the above ☐ Y ☐ N

## 1 Glasgow Coma Scale (GCS)

Best eye response (E)	1
No eye opening	2
Eye opening in response to pain	3
Eye opening spontaneously	4
Best verbal response (V)	1
No verbal response	2
Incomprehensible sounds	3
Inappropriate words	4
Confused	5
Oriented	6
Best motor response (M)	1
No motor response	2
Extension to pain	3
Abnormal flexion to pain	4
Flexion/Withdrawal to pain	5
Localizes to pain	6
Obeys commands	6

**Glasgow Coma score (E + V + M)**  
GCS should be recorded for all athletes in case of subsequent deterioration.

## 2 Maddocks Score<sup>3</sup>

"I am going to ask you a few questions, please listen carefully and give your best effort."

Modified Maddocks questions (1 point for each correct answer)	
What score are we at today?	0 - 1
Which half is it now?	0 - 1
Who scored in this match?	0 - 1
What team did you play last week / game?	0 - 1
Did your team win the last game?	0 - 1

**Maddocks score**  
Maddocks score is calculated for further diagnosis of concussion only and is not used for field testing.

### Notes: Mechanism of Injury (CMI) not what happened?

Any athlete with a suspected concussion should be REMOVED FROM PLAY, medically assessed, monitored for deterioration (i.e., should not be left alone) and should not drive a motor vehicle until cleared to do so by a medical professional. No athlete diagnosed with concussion should be returned to sports participation on the day of injury.

# 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

- 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.
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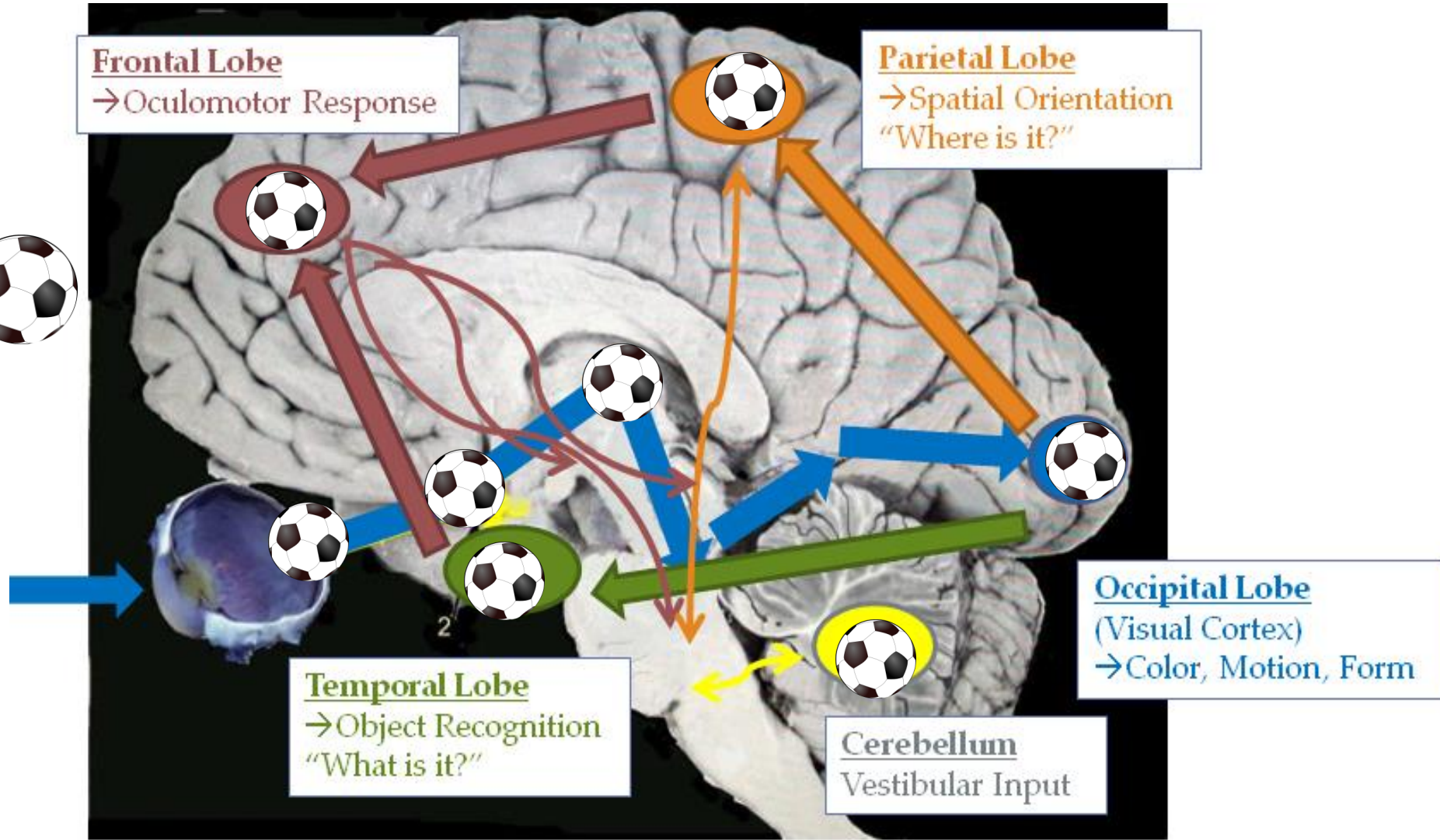
# Role of Eyes in Concussion Diagnosis and Management:

*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 foggiess
- 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

# Afferent Visual Pathway

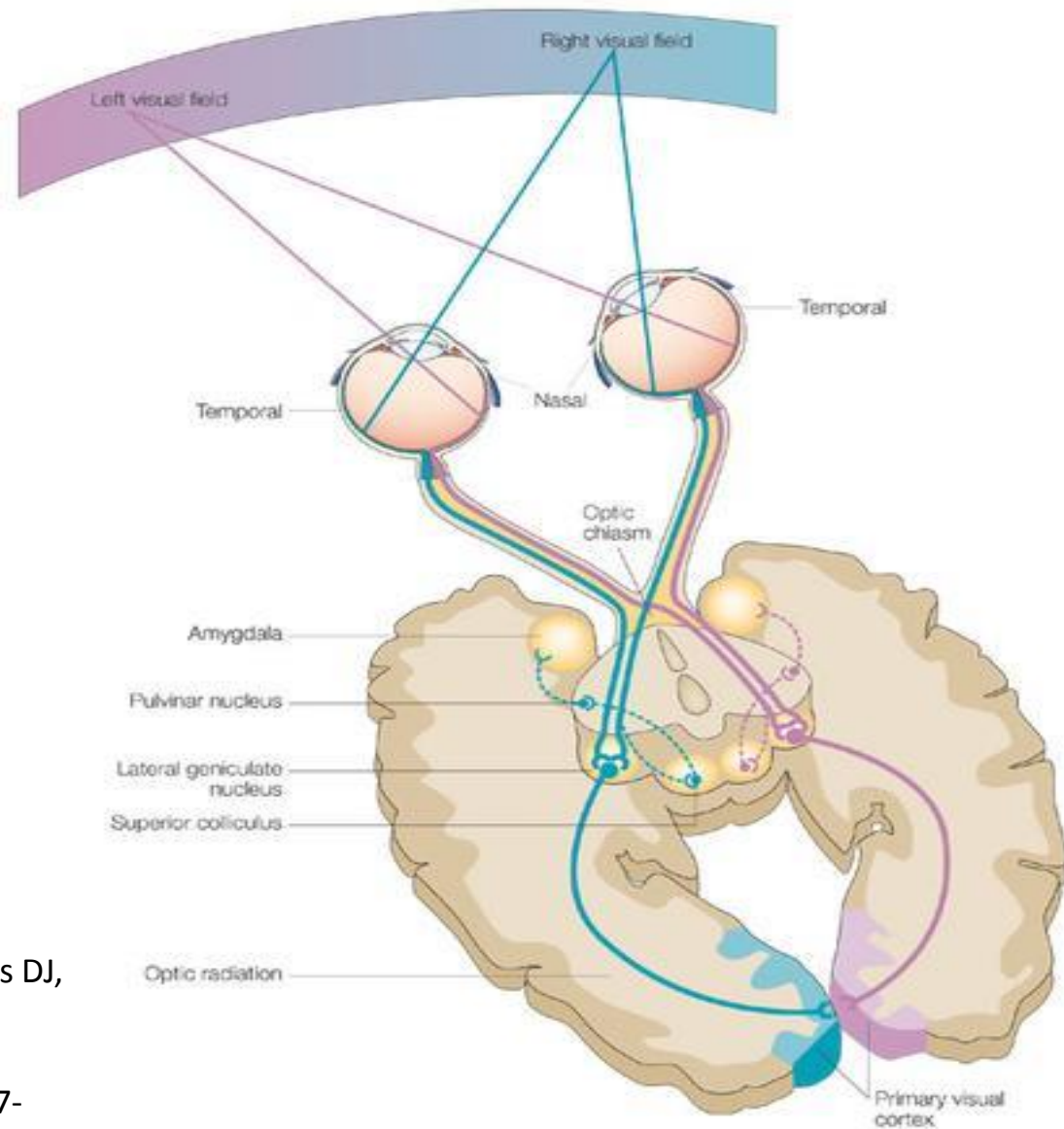
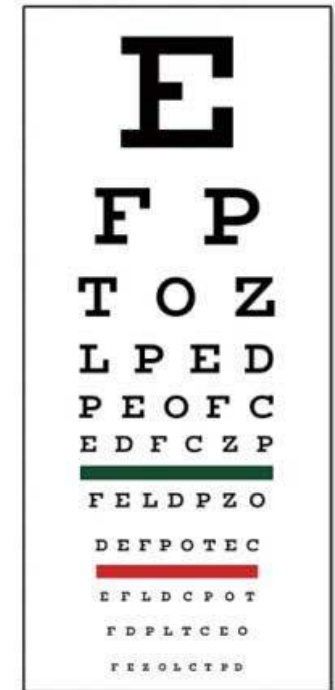
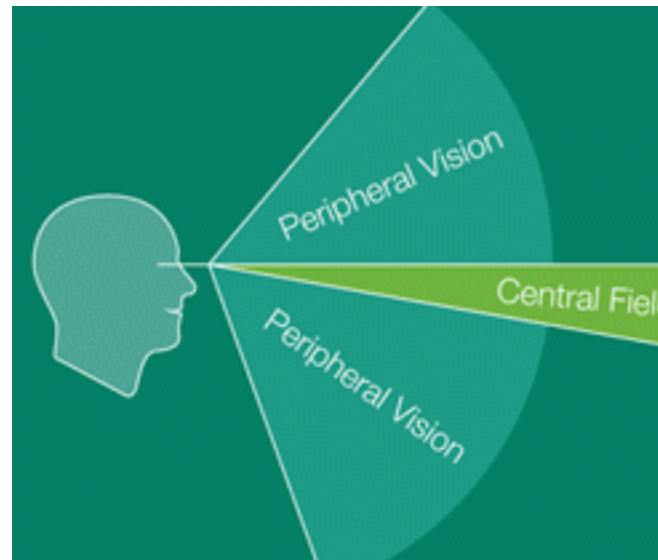
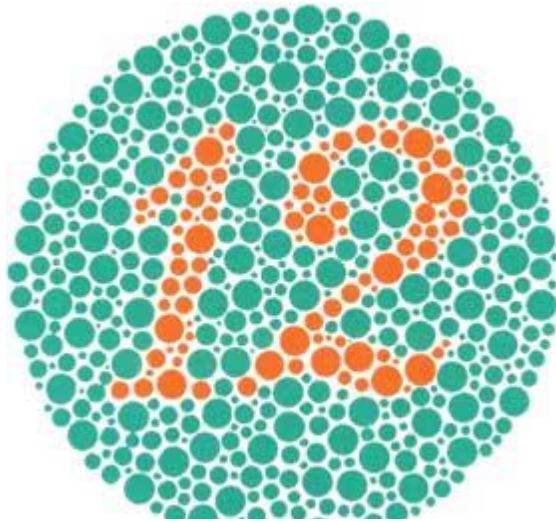
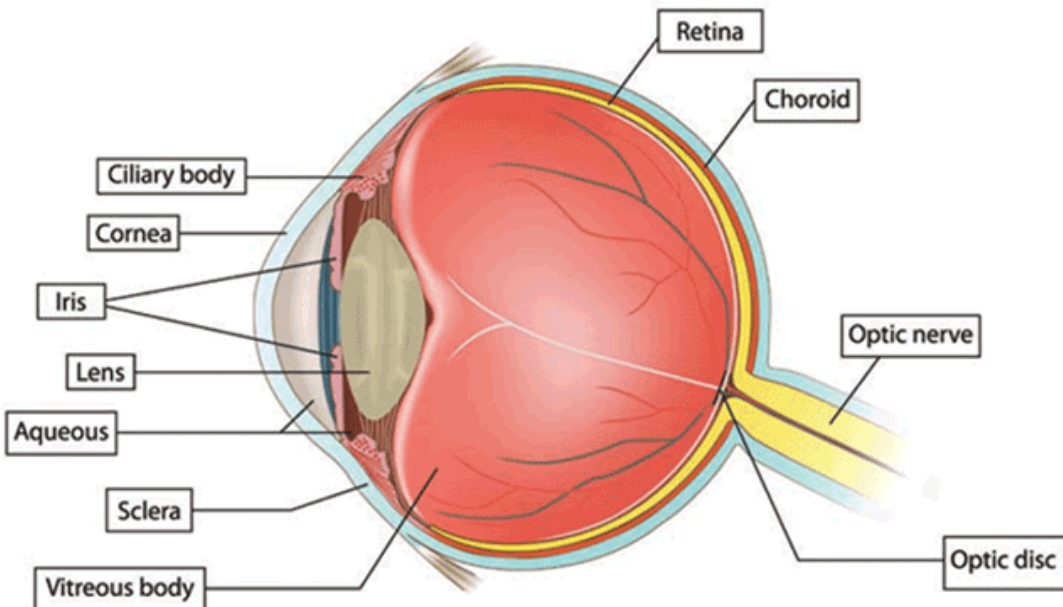


Image from - Hannula De, Simons DJ, Cohen NJ. Imaging implicit perception: promise and pitfalls. *Nature Rev Neurosci.* 2005;6:247-255/

# 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?

# 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



# 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

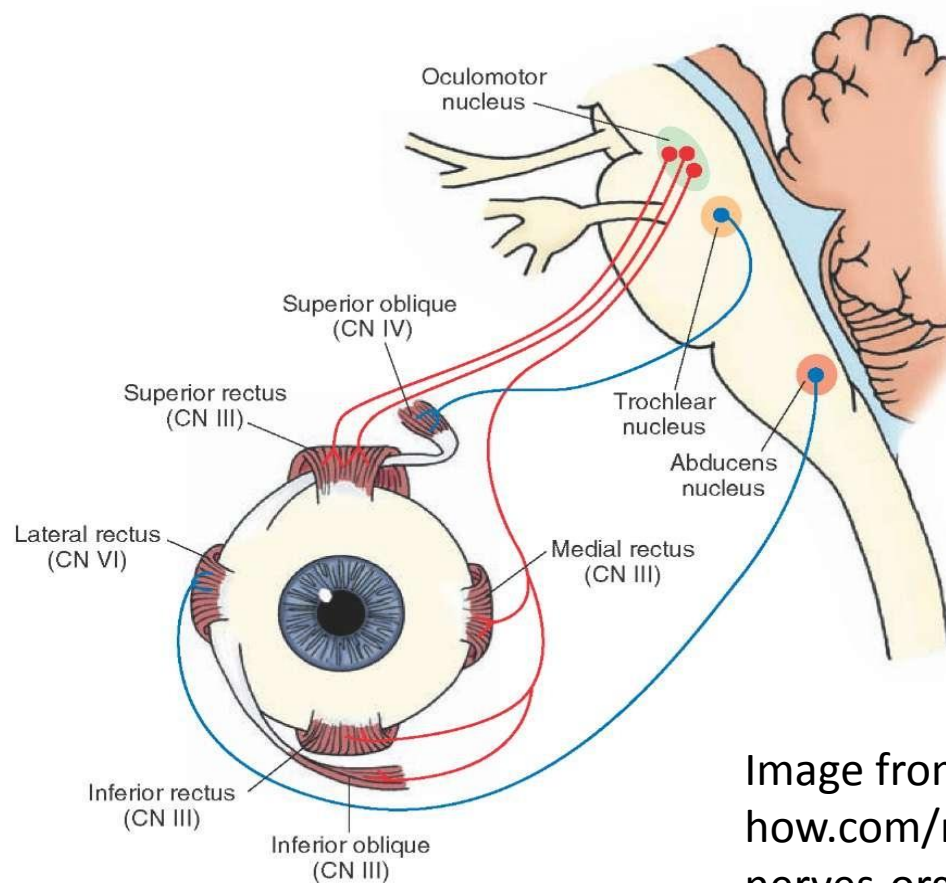


Image from <http://what-when-how.com/neuroscience/the-cranial-nerves-organization-of-the-central-nervous-system-part-4/>

# 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**

# 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

# VOMS Continued...

- **Women** have higher VOMS scores than 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 recovery time after sports-related concussion in youth and adolescent athletes. *AJSM* 2017;45(2):474-479

Kontos AP, Sufrinko A, Elbin RJ, Puskas 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<sup>27</sup>

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

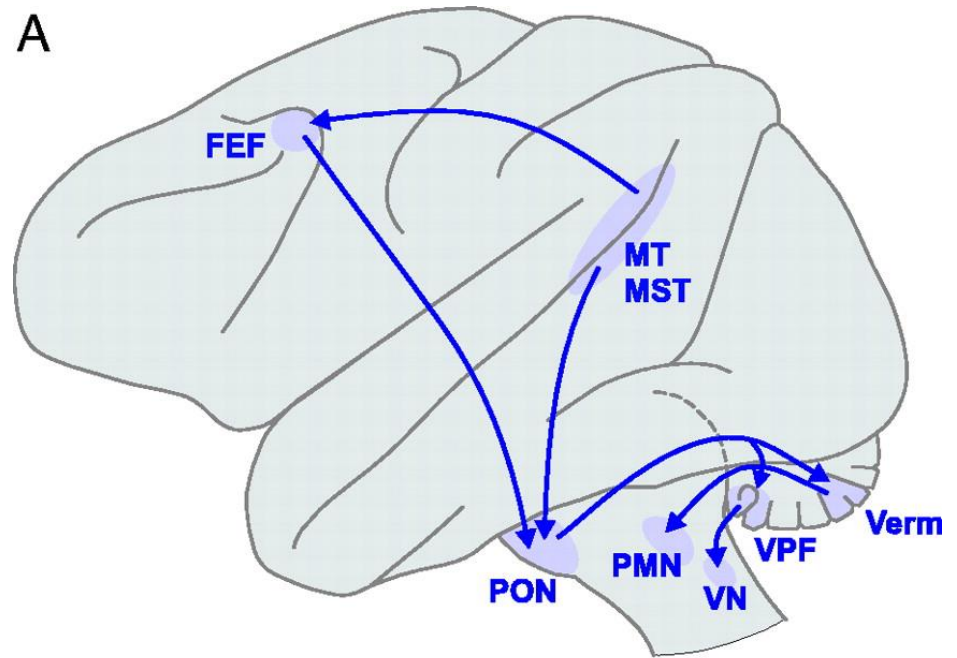
VOR, vestibulo-ocular reflex.

<sup>a</sup>Provocation of symptoms is rated on a scale from 0 to 10, with 0 being no symptoms and 10 being severe symptoms.

<sup>b</sup>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

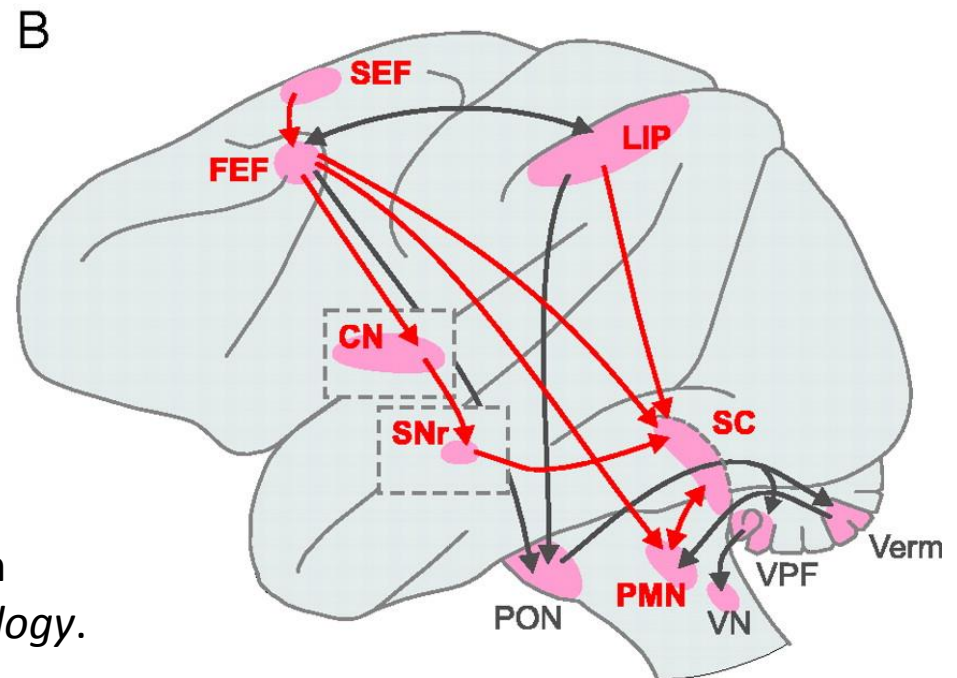
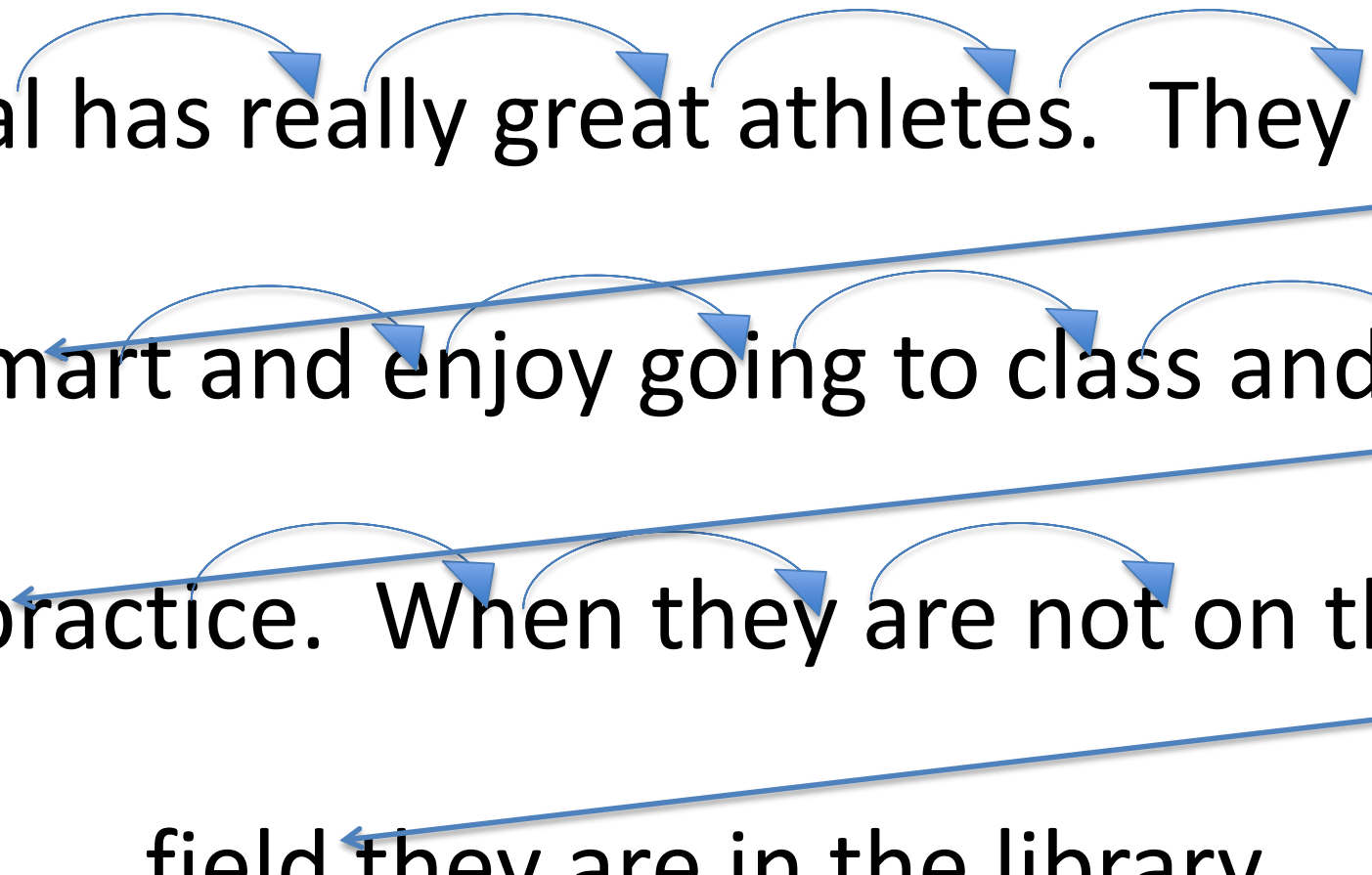
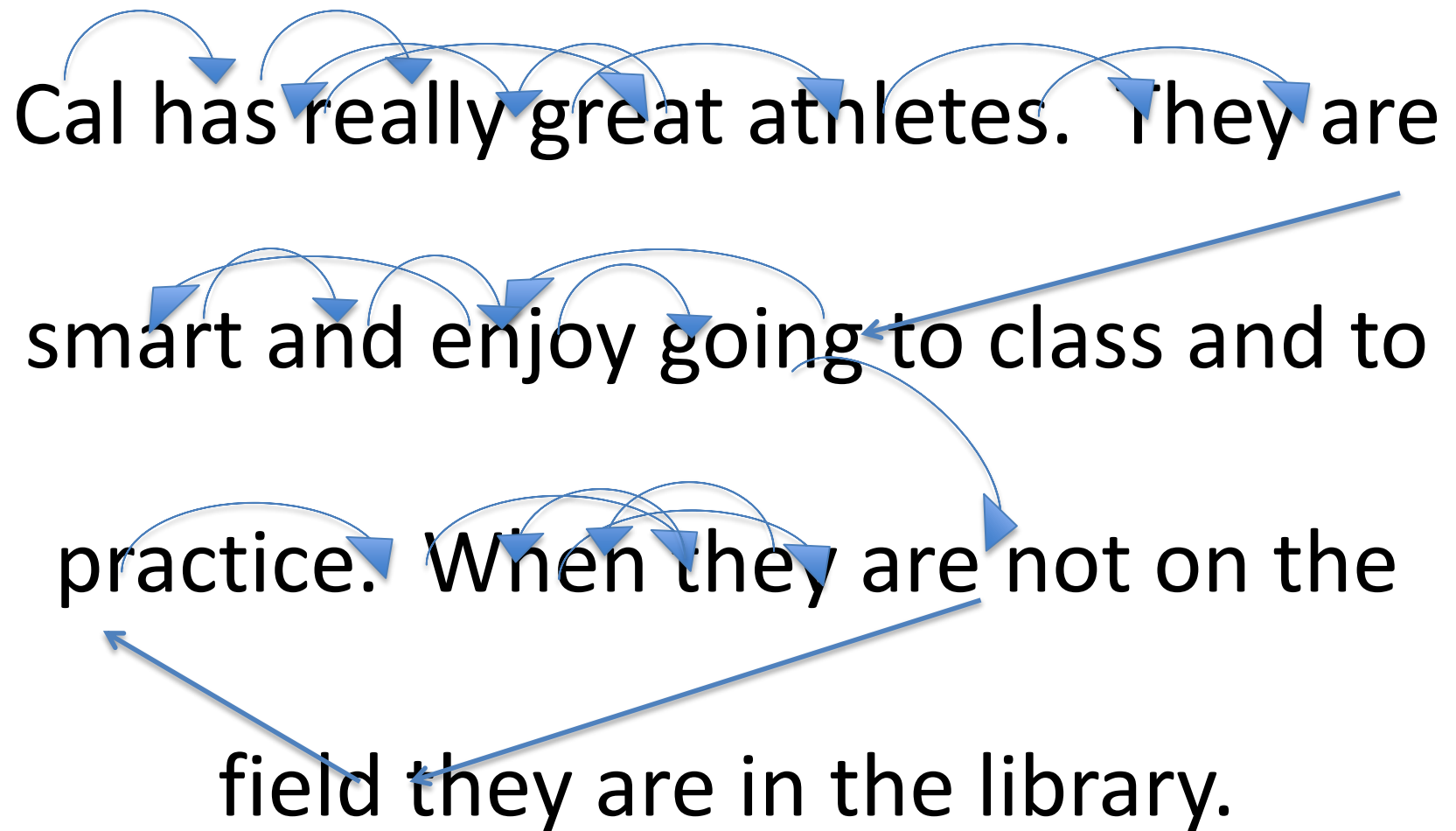


Image from: Krauzlis RJ. Recasting the Smooth Pursuit Eye Movement System, *J Neurophysiology*. 2004;91(2):591-603

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.

A diagram illustrating word segmentation in a sentence. The sentence is split into four lines. Blue curved arrows point from the end of one word to the start of the next word across the lines. Additionally, three long blue diagonal lines with arrowheads at the start point to the beginning of each line, likely indicating line boundaries or a reading path.

Cal has really great athletes. They are  
smart and enjoy going to class and to  
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field they are in the library.



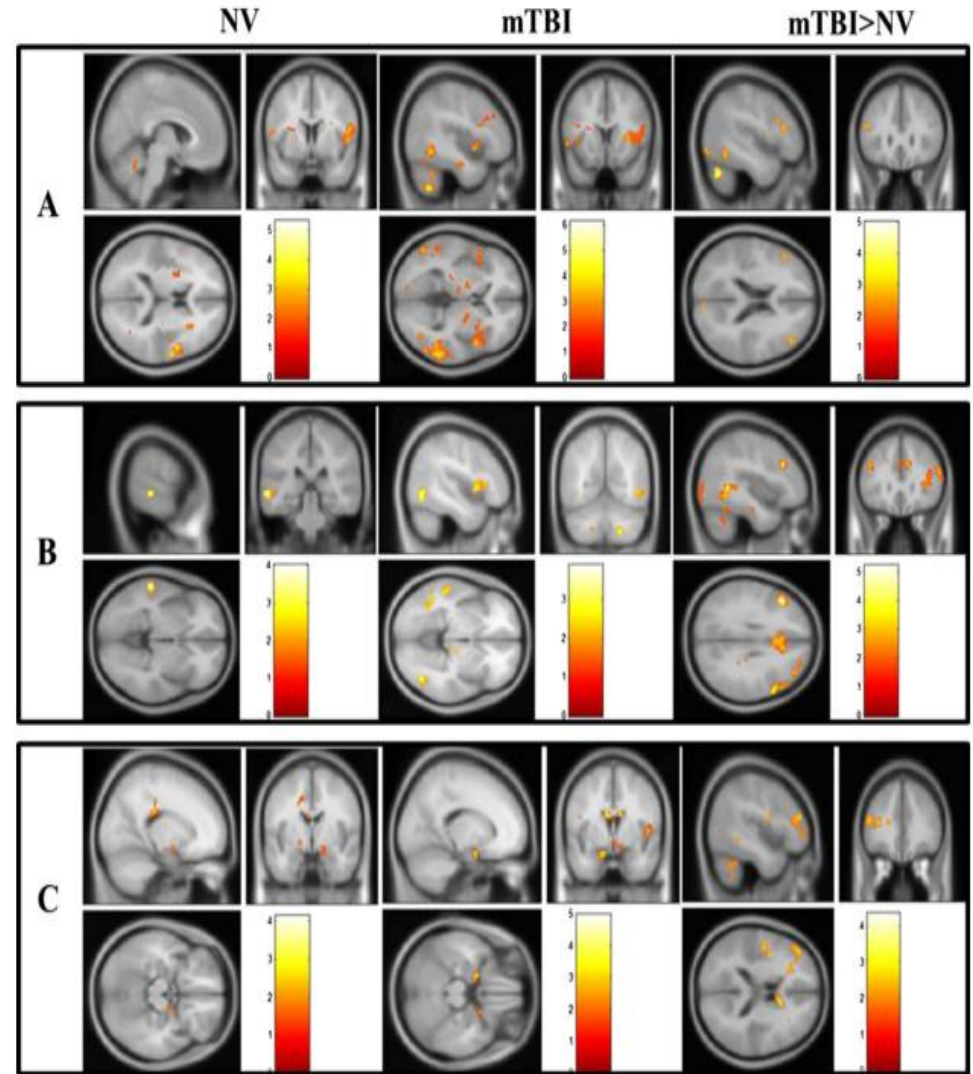
The diagram consists of blue arrows indicating relationships between words in the text. Curved arrows connect 'Cal' to 'has', 'has' to 'really', 'really' to 'great', 'great' to 'athletes', 'athletes' to 'They', 'They' to 'are', 'are' to 'smart', 'smart' to 'and', 'and' to 'enjoy', 'enjoy' to 'going', 'going' to 'to', 'to' to 'class', 'class' to 'and', 'and' to 'to', 'to' to 'practice', 'practice' to 'When', 'When' to 'they', 'they' to 'are', 'are' to 'not', 'not' to 'on', 'on' to 'the', 'the' to 'field', 'field' to 'they', 'they' to 'are', 'are' to 'in', 'in' to 'the', and 'the' to 'library'. Two long straight arrows also point from 'going' to 'practice' and from 'field' to 'library'.

# King-Devick

<p>DEMONSTRATION CARD</p>	<p>TEST I</p> <p>2 — 5 — 8 — 0 — 7</p> <p>3 — 7 — 9 — 4 — 6</p> <p>5 — 3 — 1 — 6 — 4</p> <p>7 — 9 — 7 — 3 — 5</p> <p>1 — 5 — 4 — 9 — 2</p> <p>6 — 5 — 5 — 7 — 3</p> <p>3 — 1 — 8 — 6 — 4</p> <p>5 — 3 — 7 — 5 — 2</p>																																																																																
<p>TEST II</p> <table border="0"> <tbody> <tr><td>3</td><td>7</td><td>5</td><td>9</td><td>0</td></tr> <tr><td>2</td><td>5</td><td>7</td><td>4</td><td>6</td></tr> <tr><td>1</td><td>4</td><td>7</td><td>6</td><td>3</td></tr> <tr><td>7</td><td>9</td><td>3</td><td>9</td><td>0</td></tr> <tr><td>4</td><td>5</td><td>2</td><td>1</td><td>7</td></tr> <tr><td>5</td><td>3</td><td>7</td><td>4</td><td>8</td></tr> <tr><td>7</td><td>4</td><td>6</td><td>5</td><td>2</td></tr> <tr><td>9</td><td>0</td><td>2</td><td>3</td><td>6</td></tr> </tbody> </table>	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	<p>TEST III</p> <table border="0"> <tbody> <tr><td>5</td><td>4</td><td>1</td><td>8</td><td>0</td></tr> <tr><td>4</td><td>6</td><td>3</td><td>5</td><td>9</td></tr> <tr><td>7</td><td>5</td><td>4</td><td>2</td><td>7</td></tr> <tr><td>3</td><td>2</td><td>6</td><td>9</td><td>4</td></tr> <tr><td>1</td><td>4</td><td>5</td><td>1</td><td>3</td></tr> <tr><td>9</td><td>3</td><td>4</td><td>8</td><td>5</td></tr> <tr><td>5</td><td>1</td><td>6</td><td>3</td><td>1</td></tr> <tr><td>4</td><td>3</td><td>5</td><td>2</td><td>7</td></tr> </tbody> </table>	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
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# 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 ( $p\text{-value} < 0.05$  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



# 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



# Accommodative Pathway

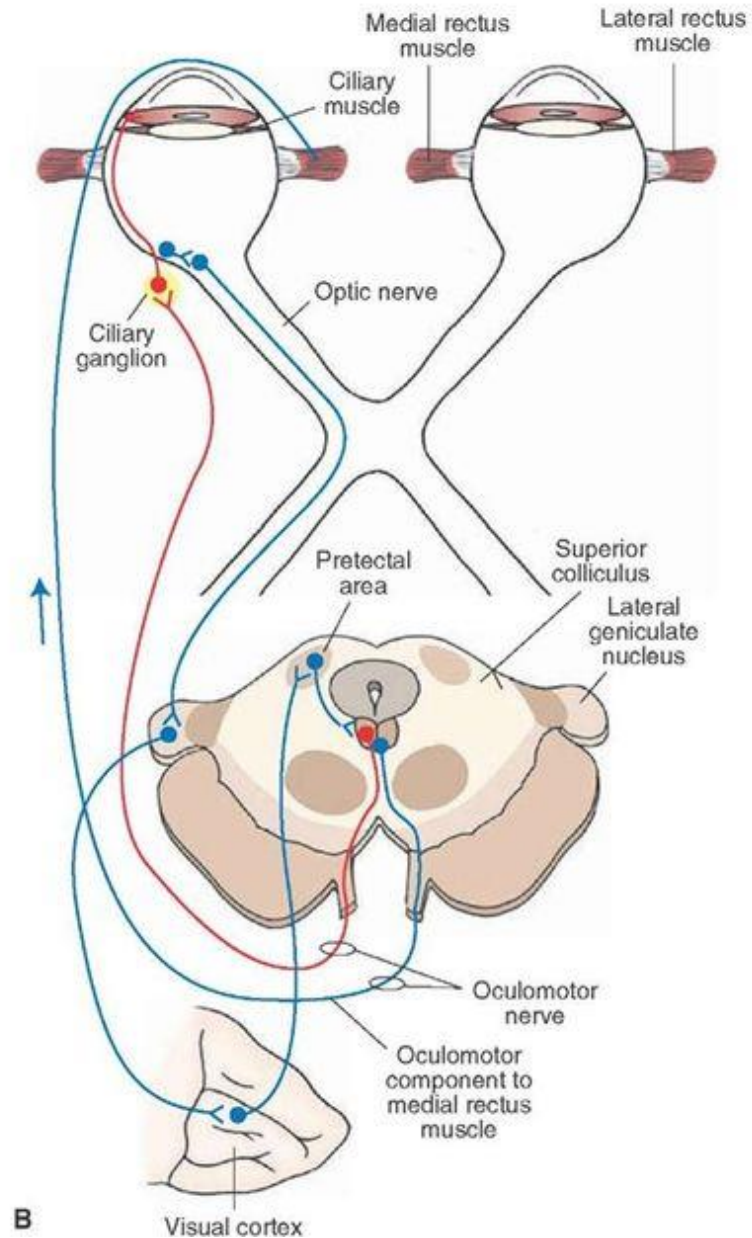
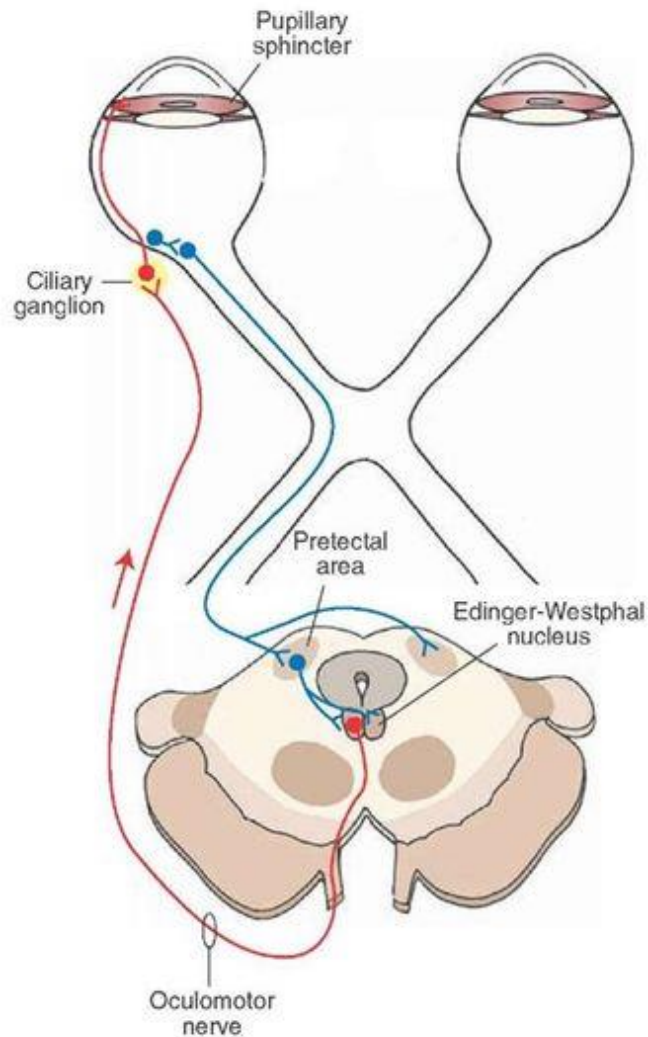


Image from <http://what-when-how.com/neuroscience/the-cranial-nerves-organization-of-the-central-nervous-system-part-4/>

# Accommodative Insufficiency

In the twentieth century, art was judged with respect to the existing state of the medium. What mattered was the kind of rupture it made, the unexpected formal elements it brought into play, the way it displaced the conventions of the genre or the tradition. The prize at the end of the evaluative process was a different sense of what art could be, a new realm of possibility for the aesthetic. Today all that has changed, definitively.

The backdrop against which art now stands out is a particular state of society. What an installation, a performance, a concept or a mediated image can do is to mark a possible or real shift with respect to the laws, the customs, the measures, the mores, the technical and organizational devices that define how we must behave and how we may relate to each other at a given time and in a given place. What we look for in art is a different way to live, a fresh chance at coexistence.

How does that chance come to be? Expression unleashes affect, and affect is what touches. Presence, gesture and speech transform the quality of contact between people, they create both breaks and junctions, and the expressive techniques of art are able to multiply those immediate charges along a thousand pathways of the mind and the senses. An artistic event does not need an objective judge. You



# Accommodative Infacility



$\sin(2\theta) = 2\sin\theta\cos\theta$   
 $\cos(2\theta) = \cos^2\theta - \sin^2\theta$   
 $\tan(2\theta) = \frac{2\tan\theta}{1 - \tan^2\theta}$

Given  $2\cos(x+50^\circ) \equiv \sin(x+40^\circ)$   
 Show, with using a calculator (who even does that?) that  $\tan x = \frac{1}{3}\tan 40^\circ$

What do I know?  
 $\tan x = \frac{\sin x}{\cos x} = \frac{2\cos(x+50^\circ)}{\sin(x+40^\circ)}$   
 $\sin(x+40^\circ) = \sin x \cos 40^\circ + \cos x \sin 40^\circ$   
 $2(\cos x \cos 50^\circ - \sin x \sin 50^\circ) = \sin x \cos 40^\circ + \cos x \sin 40^\circ$   
 $2\cos x \cos 50^\circ - 2\sin x \sin 50^\circ = \sin x \cos 40^\circ + \cos x \sin 40^\circ$   
 $2\cos x \cos 50^\circ - \sin x \cos 40^\circ = \cos x \sin 40^\circ + \sin x \sin 50^\circ$   
 $\cos x(2\cos 50^\circ - \sin 40^\circ) = \sin x(\sin 50^\circ + \cos 40^\circ)$   
 $\tan x = \frac{2\cos 50^\circ - \sin 40^\circ}{\sin 50^\circ + \cos 40^\circ}$

$2\sin x \sin 50^\circ + \sin x \cos 40^\circ + \sin 40^\circ \cos x = 2\cos x \cos 50^\circ$   
 $2\sin x \sin 50^\circ + \sin x \cos 40^\circ = 2\cos x \cos 50^\circ - \sin 40^\circ \cos x$   
 $\sin x(2\sin 50^\circ + \cos 40^\circ) = \cos x(2\cos 50^\circ - \sin 40^\circ)$   
 $\tan x = \frac{2\sin 50^\circ + \cos 40^\circ}{2\cos 50^\circ - \sin 40^\circ}$

Hence solve for  $0 \leq \theta \leq 360^\circ$   
 $2\cos(2\theta + 50^\circ) = \sin(2\theta + 40^\circ)$   
 to 1 d.p.  
 $\tan 2\theta = \frac{1}{3}\tan 40^\circ$   
 $2\theta = \arctan\left(\frac{1}{3}\tan 40^\circ\right) = 15.63^\circ$   
 $\theta = 7.8^\circ$

Using calc, find the coords of the turning point of  $y = f(x) = 25x^2e^{2x} - 16$ ,  $x \in \mathbb{R}$   
 $\frac{dy}{dx} = 50xe^{2x} + 2(25x^2)e^{2x} = 50xe^{2x}(1 + 2x)$   
 $0 = 50xe^{2x}(1 + 2x)$   
 $x = 0$  or  $x = -\frac{1}{2}$   
 Coords  $(-1, 25e^{-2} - 16)$

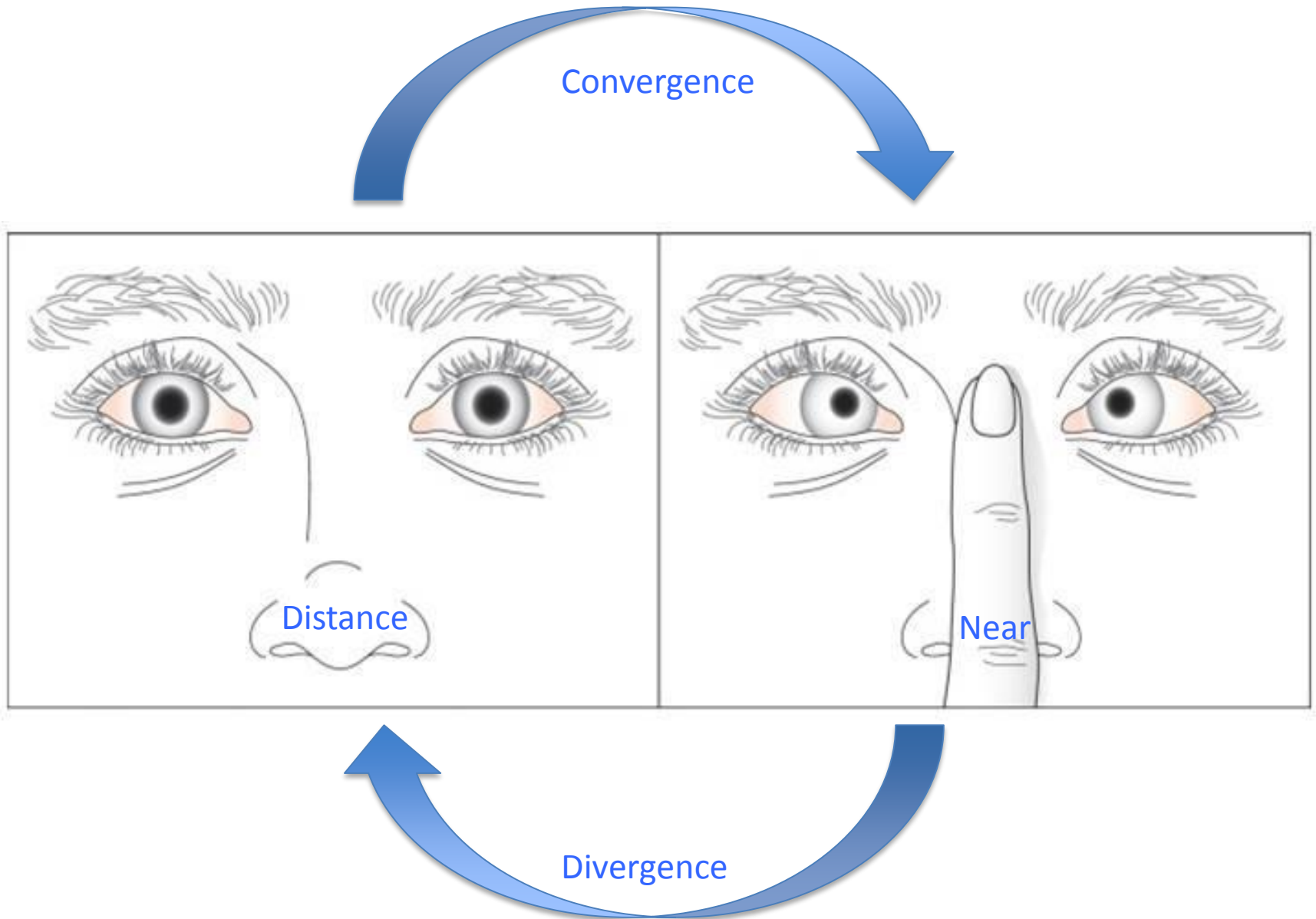
Show that  $f(x) = 0$  can be written as  $x = \pm \frac{4}{5}e^{-x}$   
 $25x^2e^{2x} - 16 = 0$   
 $25x^2 = 16e^{-2x}$   
 $x = \pm \frac{4}{5}e^{-x}$

Iteration formula:  
 $x_{n+1} = \frac{4}{5}e^{-x_n}$   
 $x_0 = 0.5$   
 $x_1 = 0.485$ ,  $x_2 = 0.492$ ,  $x_3 = 0.489$   
 Estimate for  $a$  to 2 d.p.  
 $f(0.485) = -0.487$ ,  $f(0.495) = 0.485$  → sign change, so  $a = 0.49$ , must lie between.

# Accommodative Spasm

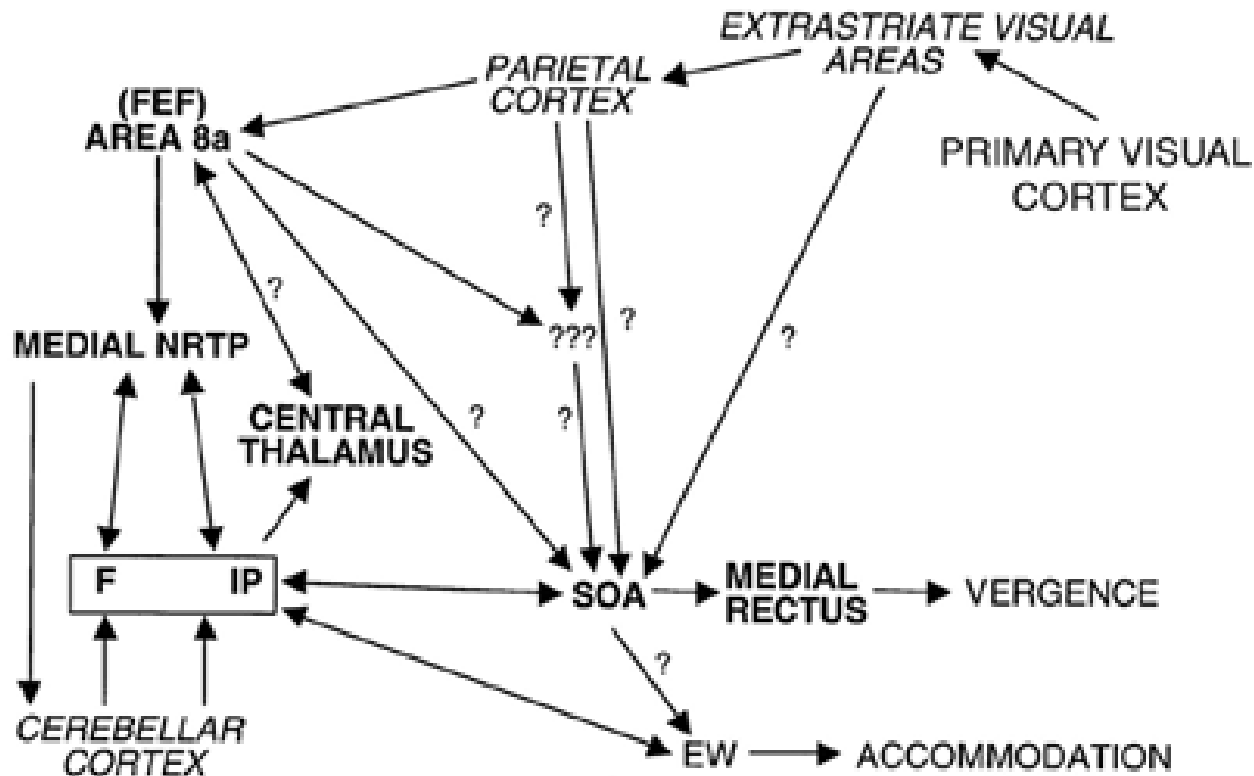
There once was a little girl who could not read very well. She complained that the print was blurry and moving. She could not keep her place on the page. She went to her optometrist to get help. Her optometrist recommended vision therapy and told the girl that there was a solution to her vision problems. 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



# Convergence Insufficiency Vergence Dysfunction

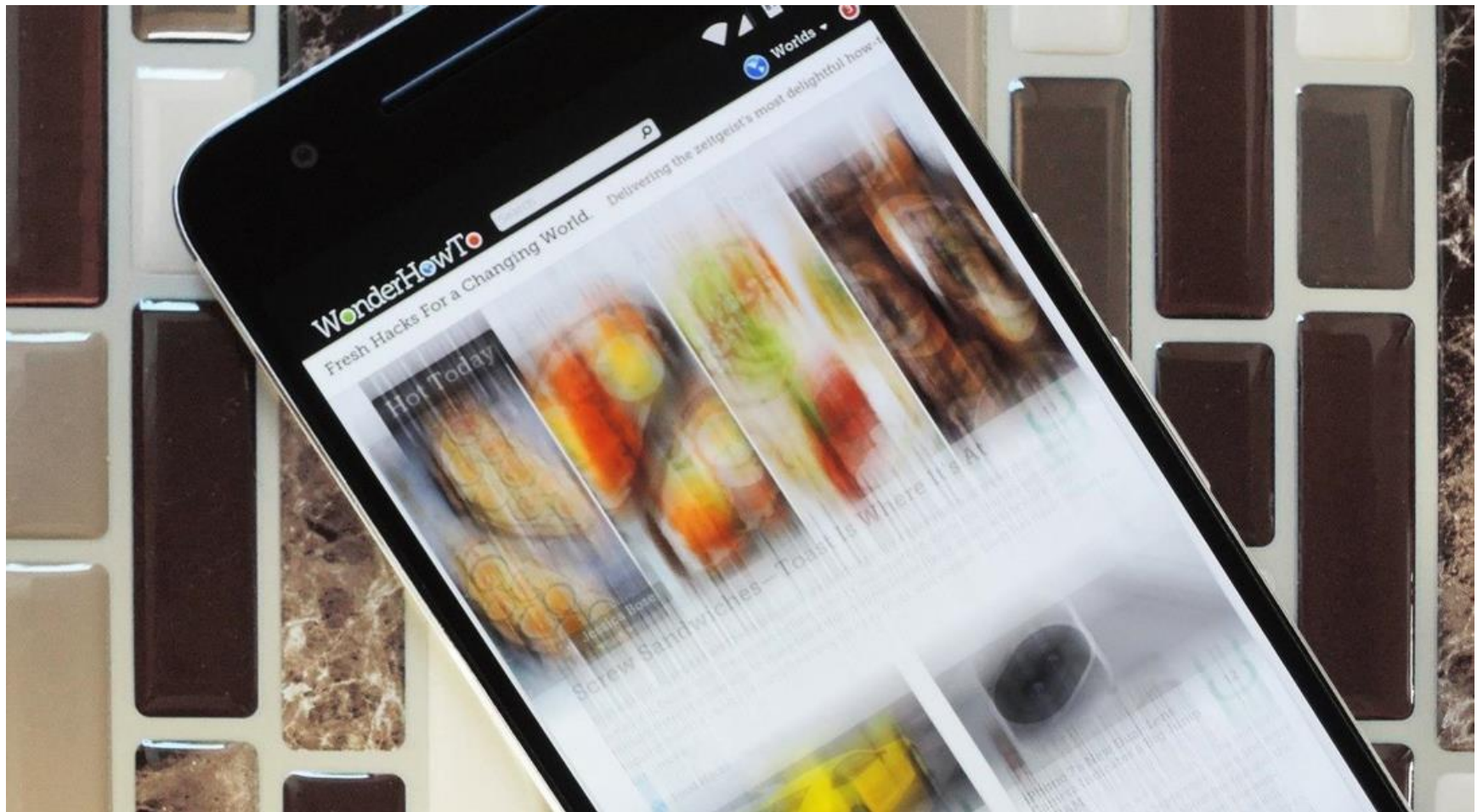
double vision can look like this:

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

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!

Double vision makes it  
difficult to read  
and comprehend.

# Visual-Evoked Nausea



# Visual Motion in Daily Life

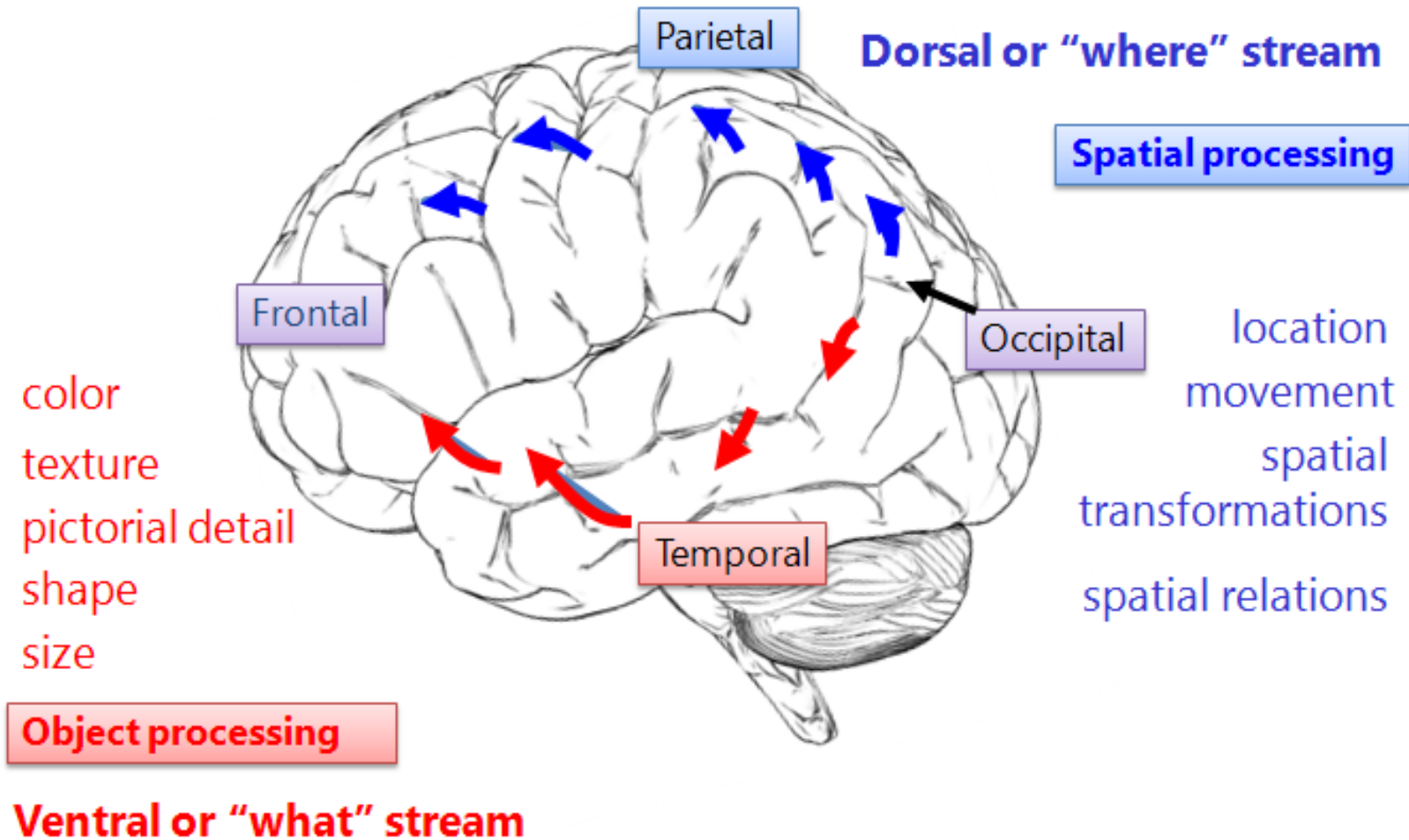


# Visual-Vestibular Motion in Sport

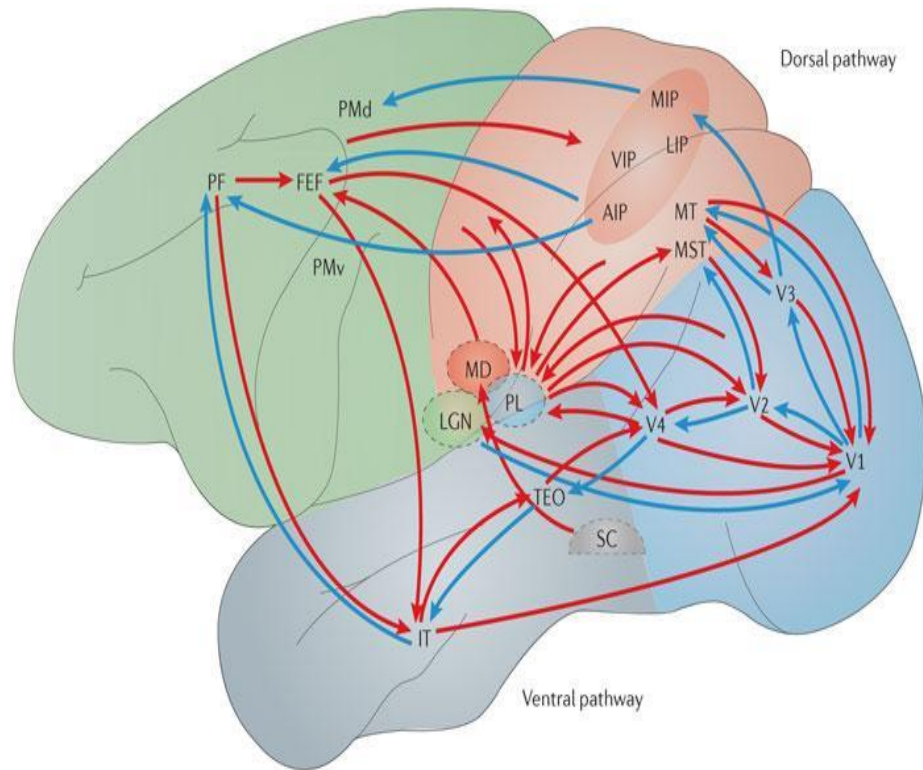




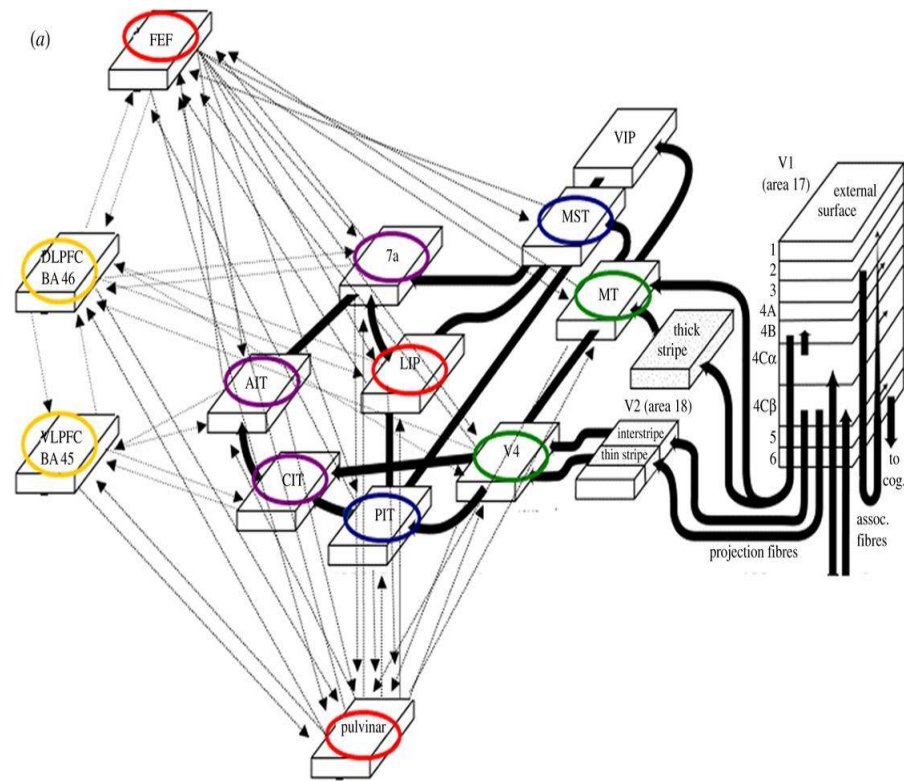
# Higher Order Visual Processing



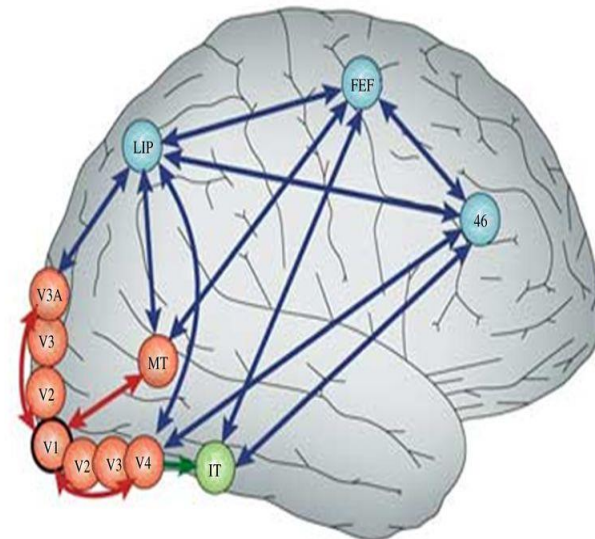
# Visual Attention and Visual Processing



Nature Reviews | Neuroscience



(b)



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)

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!

# 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/quizzes
  - 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

# 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.

Broglia 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



# 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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