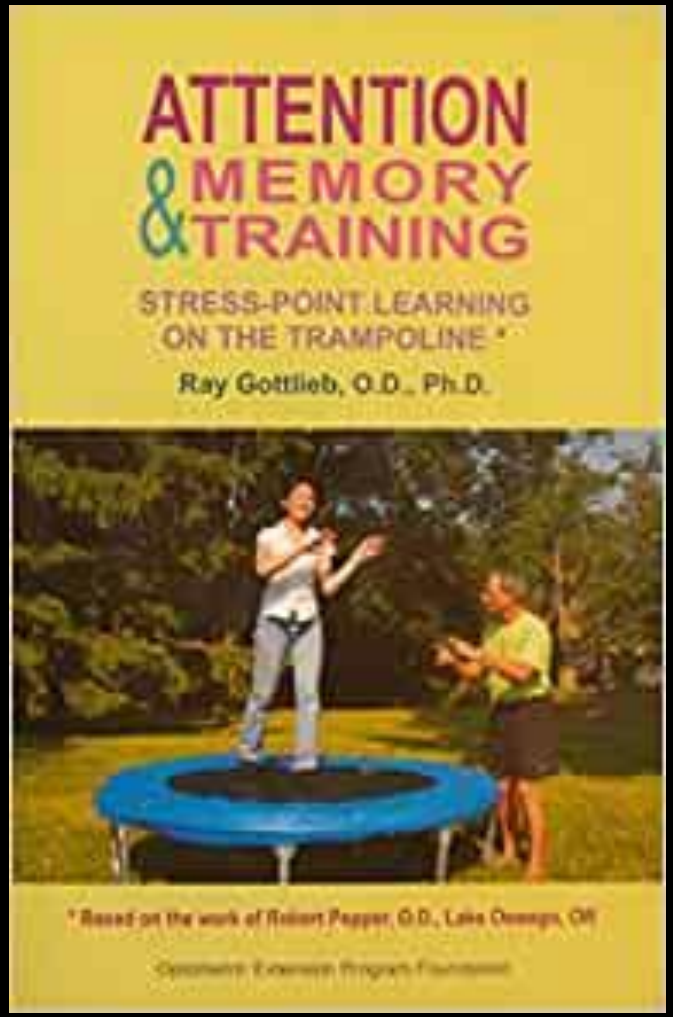
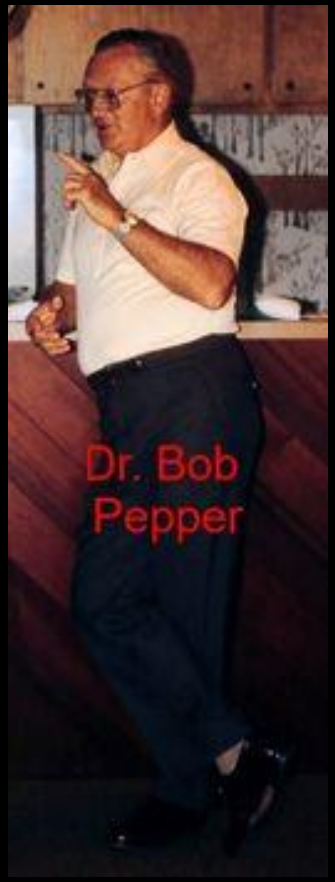
The Neurology of the Pepper Stress Test or What can we learn from the Emerging field of Functional Neurology?

Doug Major OD FAAO FCOVD and Nancy Major MS COVT


ATTENTION
& MEMORY
& TRAINING
STRESS-POINT LEARNING
ON THE TRAMPOLINE *
Ray Gottlieb, O.D., Ph.D.
* Based on the work of Robert Pepper, O.D., Lake Oswego, OR

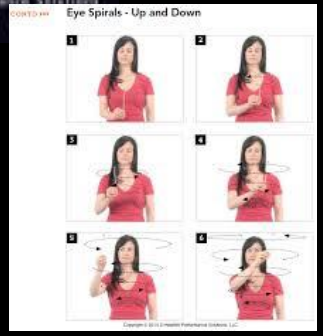

Dr. Bob
Pepper

Boulder Valley
VISION THERAPY

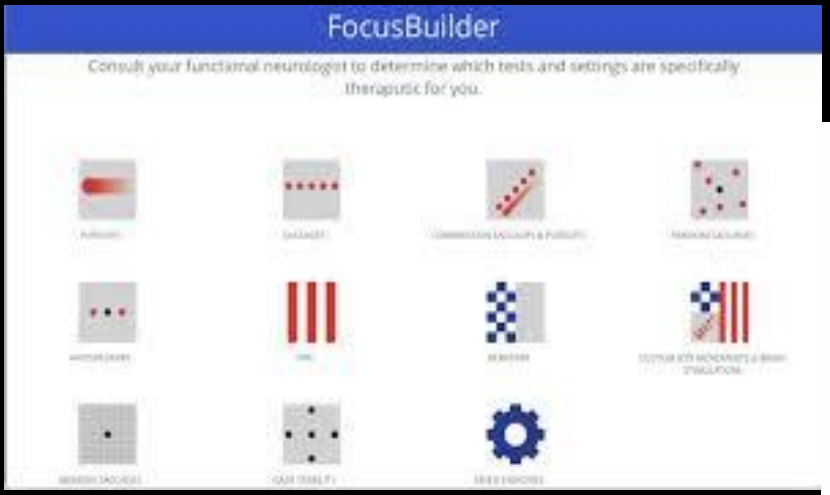
"You call yourself a visual scientist, you tell me why it works!"

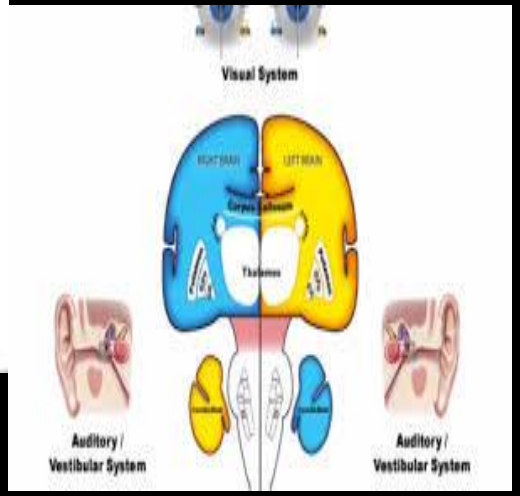
The Vision Gym

ZHEALTH
Performance Solutions

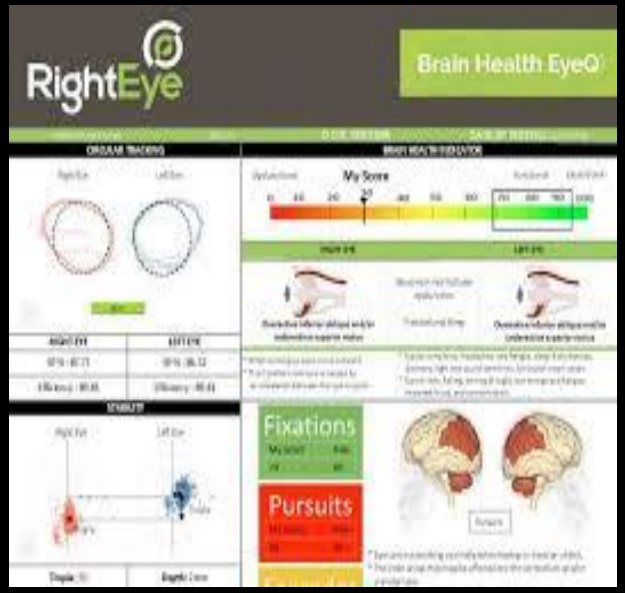


Dr Eric Cobb, Z Health University. 1000+ Athletic Trainers/therapist





FOCUS BUILDER, Dr. Cedrick Noel



Active Evolution

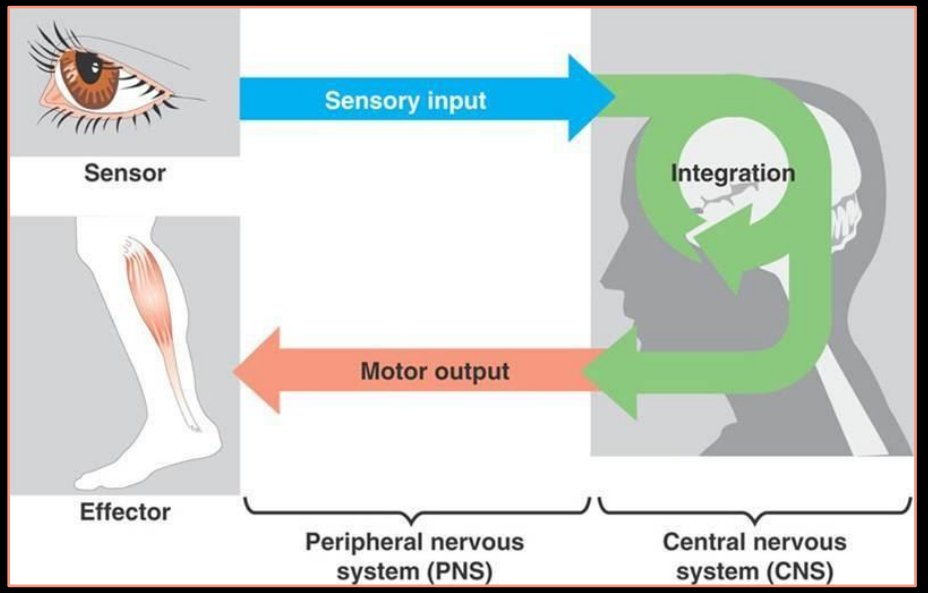
See Move Thrive

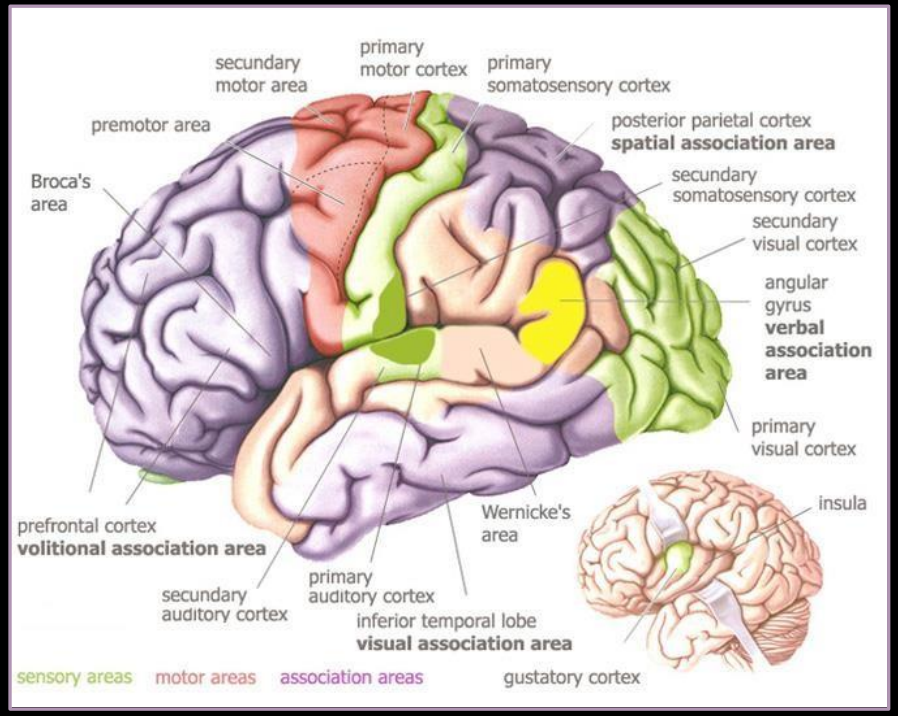
Dr. DeAnn Fitzgerald, Brain 2 Eye Academy

Let's Begin With Neurology Simplified

The Nervous System Does 3 Things

1. Receives Input (Afferent)
2. Decides What the Input Means and What to Do About It (Processing)
3. Creates Motor Output (Efferent)



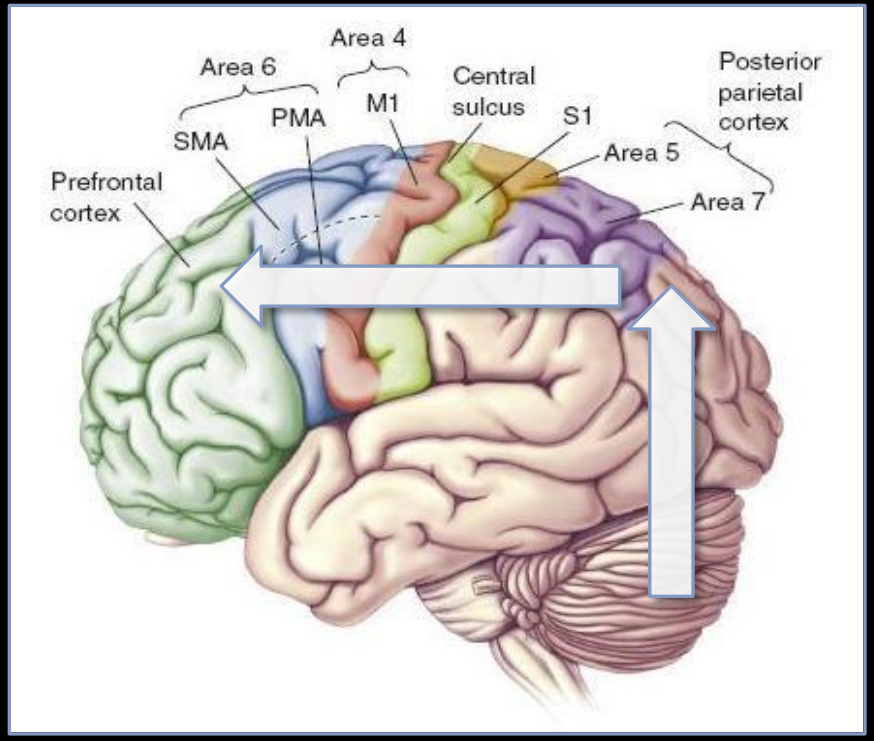


The Two Things Your Brain Needs to Stay Alive

1. **Fuel (Oxygen, Glucose)**
2. **Activation**

Understanding Activation

1. Brain's Basic Feeding Pattern
2. Things that are next to each other activate each other



Brainstem Stacking

Midbrain

- Near/Far
- Vergence
- Rhythm
- Resisted inhalation
- Flexor tone

Pons

- Trigeminal
- Abducens
- Facial
- Vestibulocochlear
- Extensor tone

Medulla

- Vagus
- Accessory
- Hypoglossa
- I Exhalation
- Flexor tone

Pepper upregulated the motor system to change vision outputs.

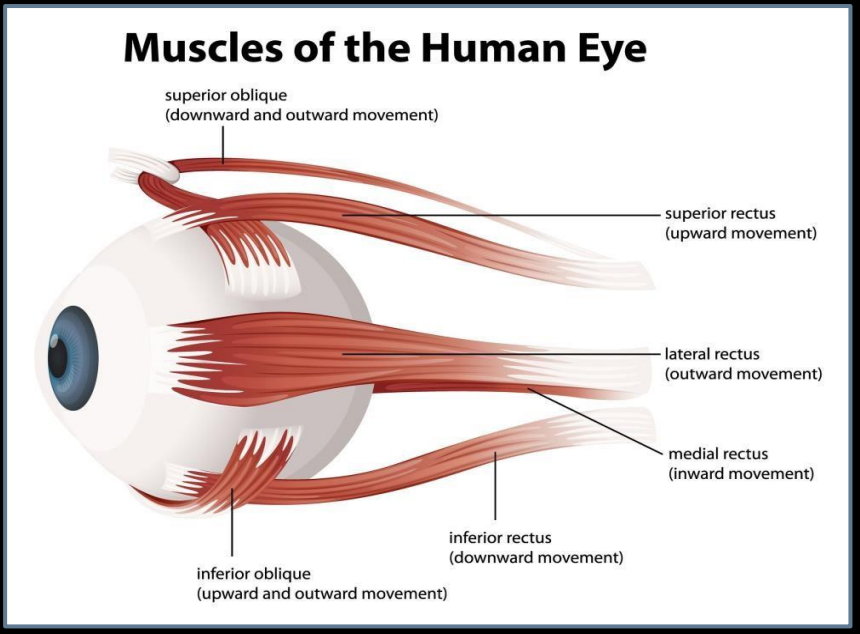
Cobb and others upregulates the vision system to change the motor outputs.

Immediate Application for Vision Therapy

Midbrain Convergence/Accommodation Centers
connected with
Motor Flexor Tone

Pons Divergence and Vestibular Centers
connected with
Motor Extensor tone

Oculomotor Reflexes

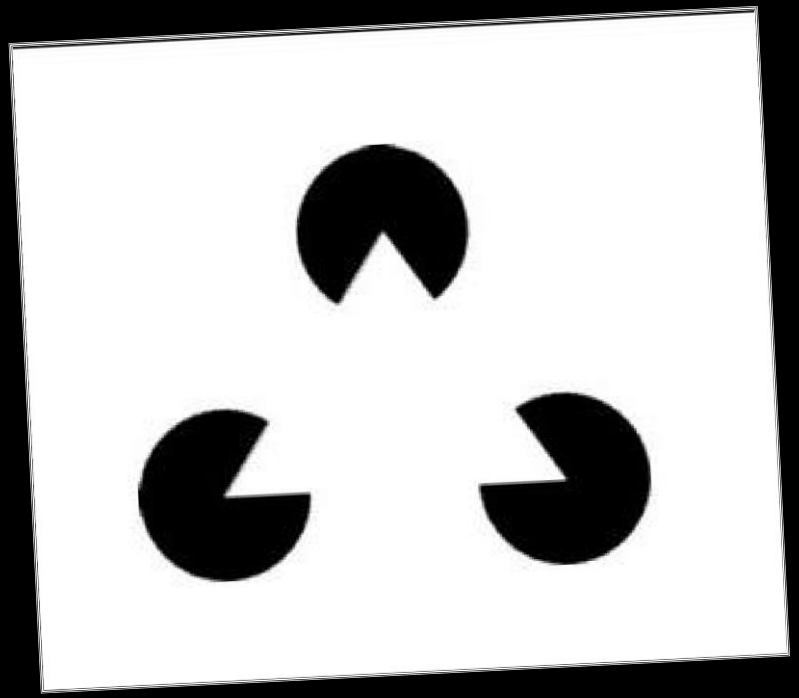


* *Eyes Up: Facilitates Extension*
* *Eyes Down: Facilitates Flexion*
* *Eyes Right: Facilitates Right Rotation, Right Extension, Left Flexion*
* *Eyes Left: Facilitates Left Rotation, Left Extension, Right Flexion*

Job #1 – Survival!

Is The Body More Oriented Toward Survival or Performance?

Fight/freeze/Flight
Fetal Position
FLEXION!



Survival processing in the brain can be summed up in two words:

PATTERN RECOGNITION
(or more simply: PREDICTION)

Accurate PEDICTION reduces THREAT/RISK/PAIN

Job #1 – Survival!

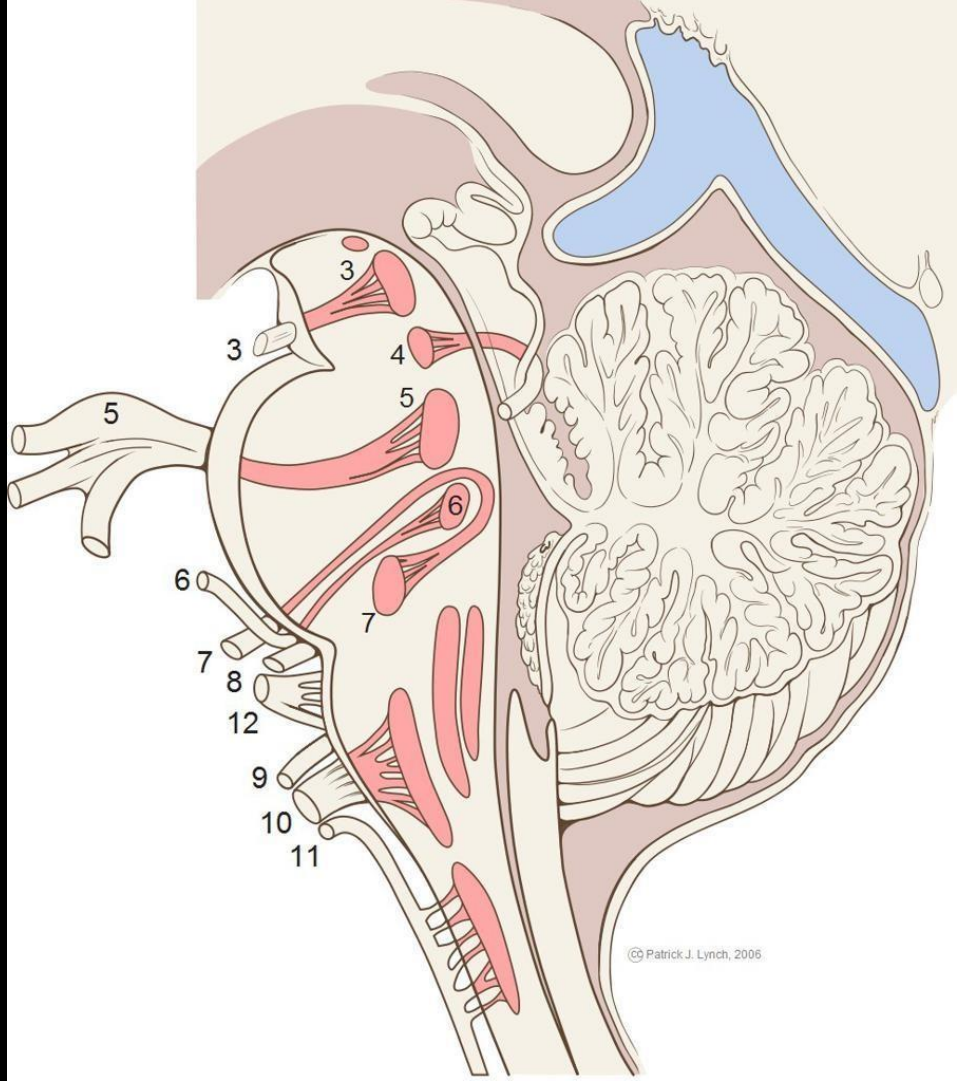
What happens when the brain can't predict accurately?

- Pain
- Weakness
- Fatigue
- Nausea
- Migraines
- Dizziness
- Tension/Inflexibility

Cranial Nerve EOM Insertions for:

1. Fight/Flight

2. Rest/Digest
   Feed/Breed



Cranial Nerve Insertions

III. Oculomotor FLEXOR

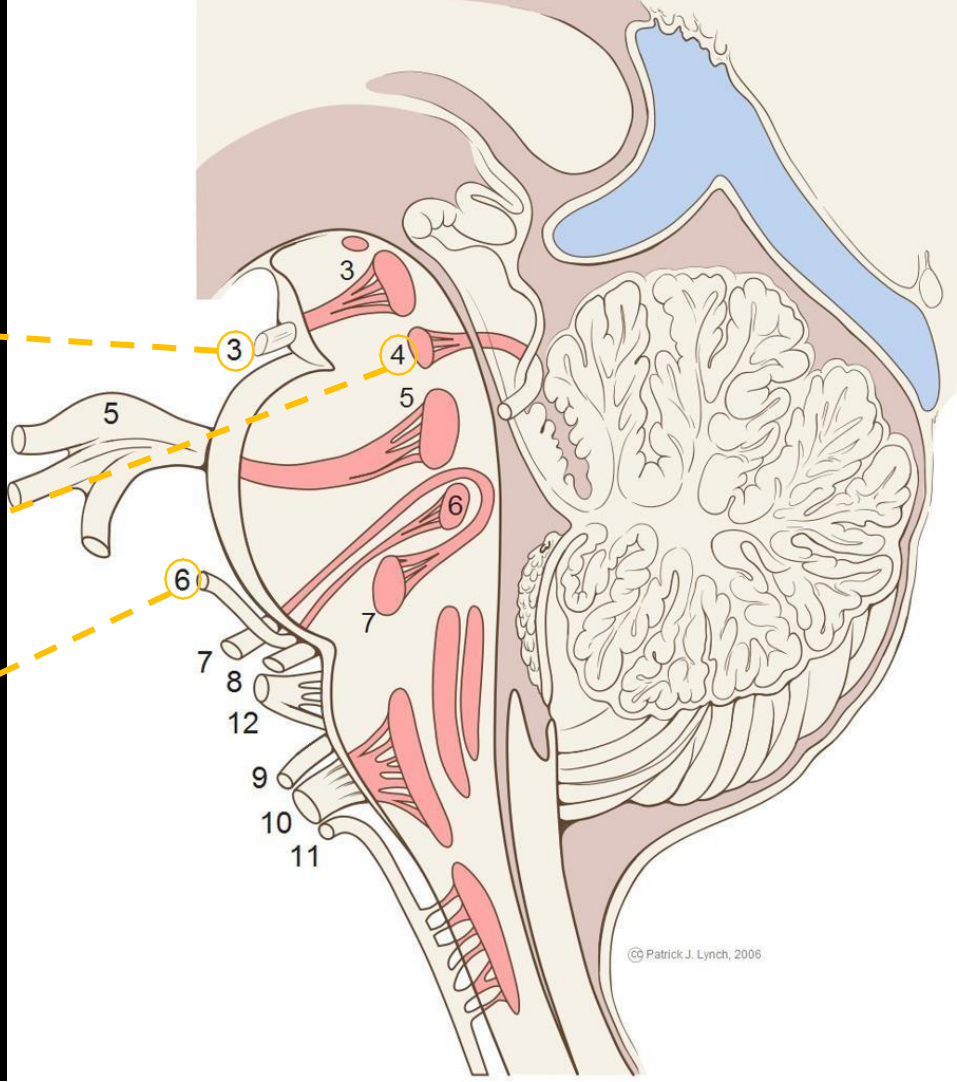
Inferior Rectus
Inferior Oblique
Medial Rectus
Superior Rectus

IV. Trochlear FLEXOR

Superior Oblique*

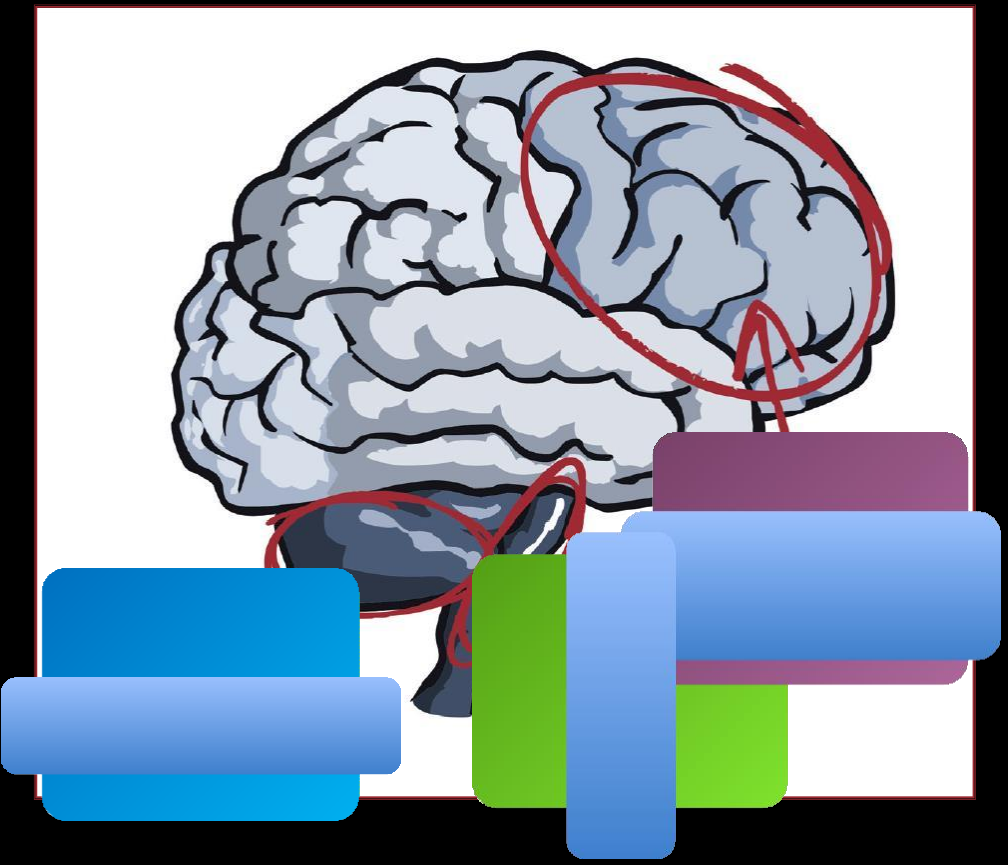
VI. Abducens EXTENSOR

Lateral Rectus



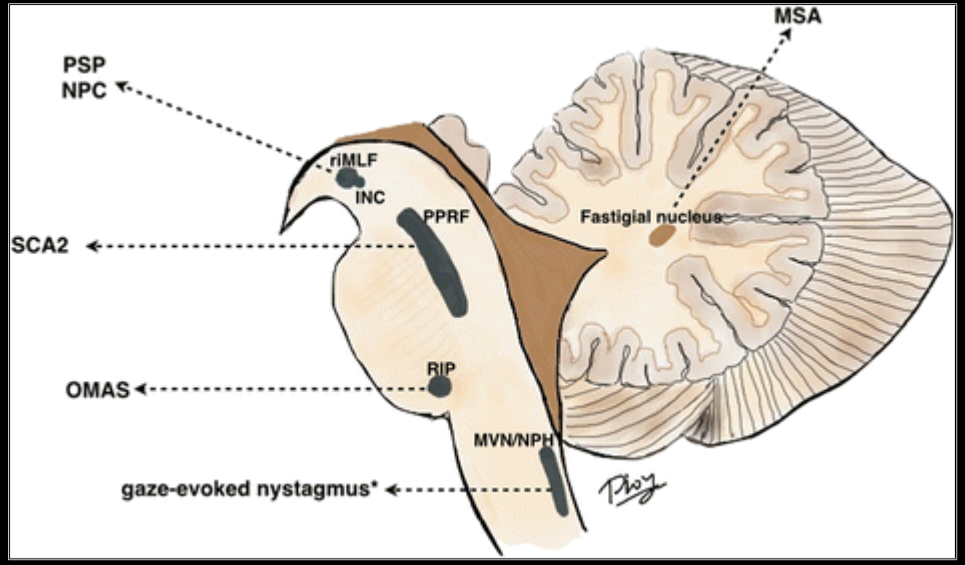
Job #2 – Movement!

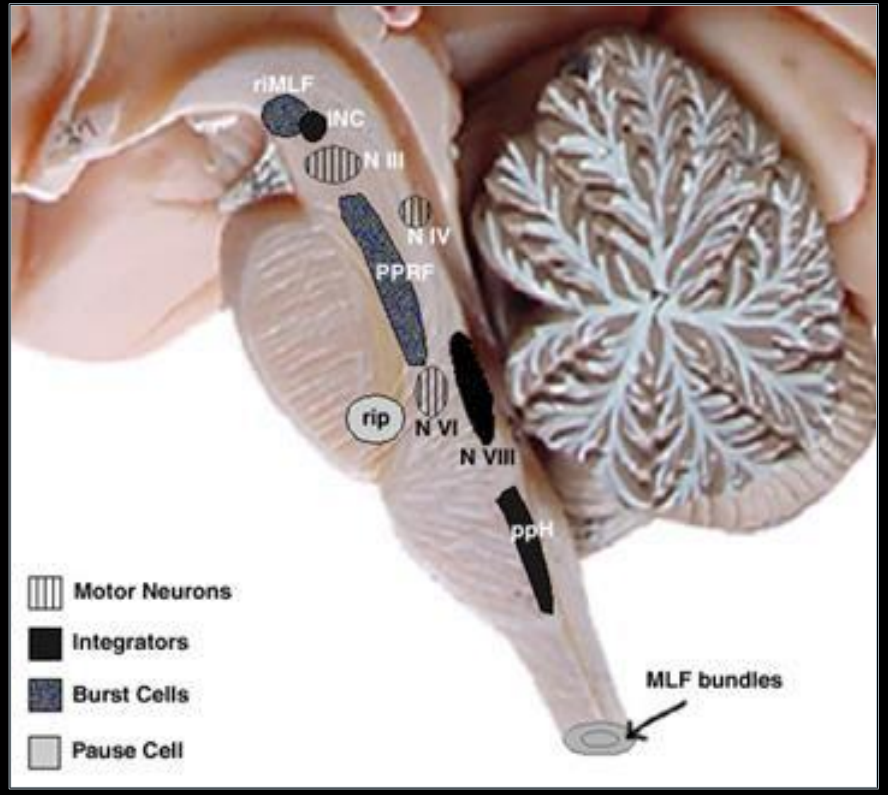
Understanding the Neurology of Movement



1. **Frontal Lobe** (Cortex) – Initiates Movement
2. **Cerebellum** – Coordinates Movement and “Fixes” Errors
3. **Pontomedullary Reticular Formation** (PMRF) – Posture, Global Muscle Tone, and Autonomic Control

Neural Integrators EYE and BODY Movers

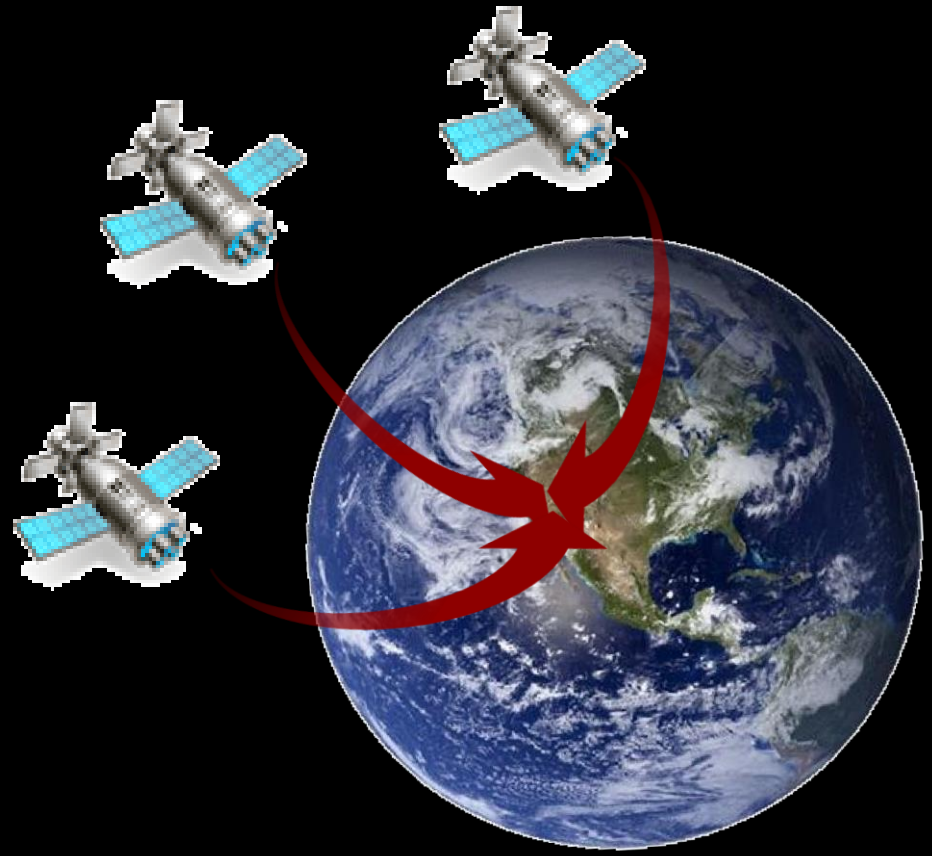




Horizontal Eye Movement = **Medulla**

Vertical Eye Movement =**Midbrain**

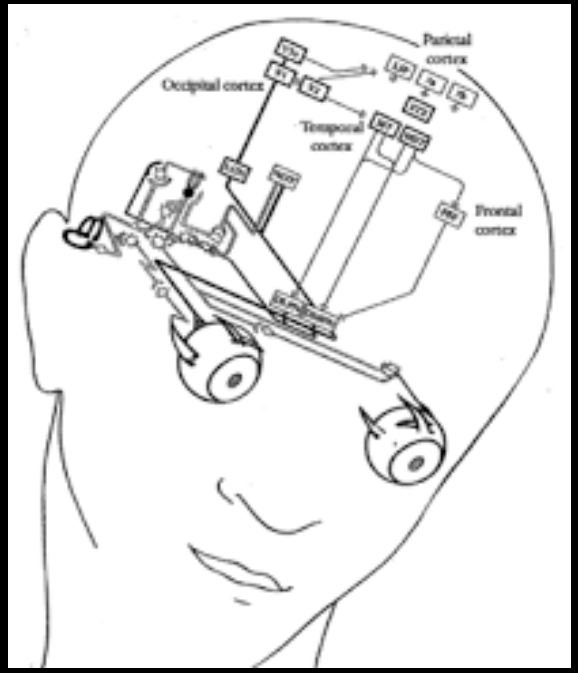
Sensory MATCHING = Correct Body MAPPING



Two requirements for sensory matching:

1. Clear Information from the Three Systems

2. Correct Integration in the Brain



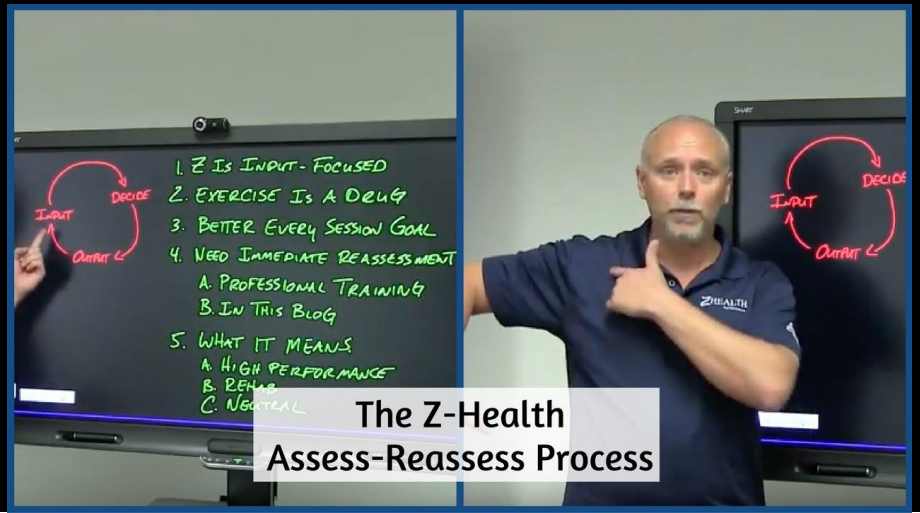
BODY MAPS: Input from JOINTS and Muscles

VISUAL MAPS: Input from EOM and RETINA

Sensory Mismatch – The Possible Consequences
REDUCE PREDICTABILITY-INCREASED THREAT!

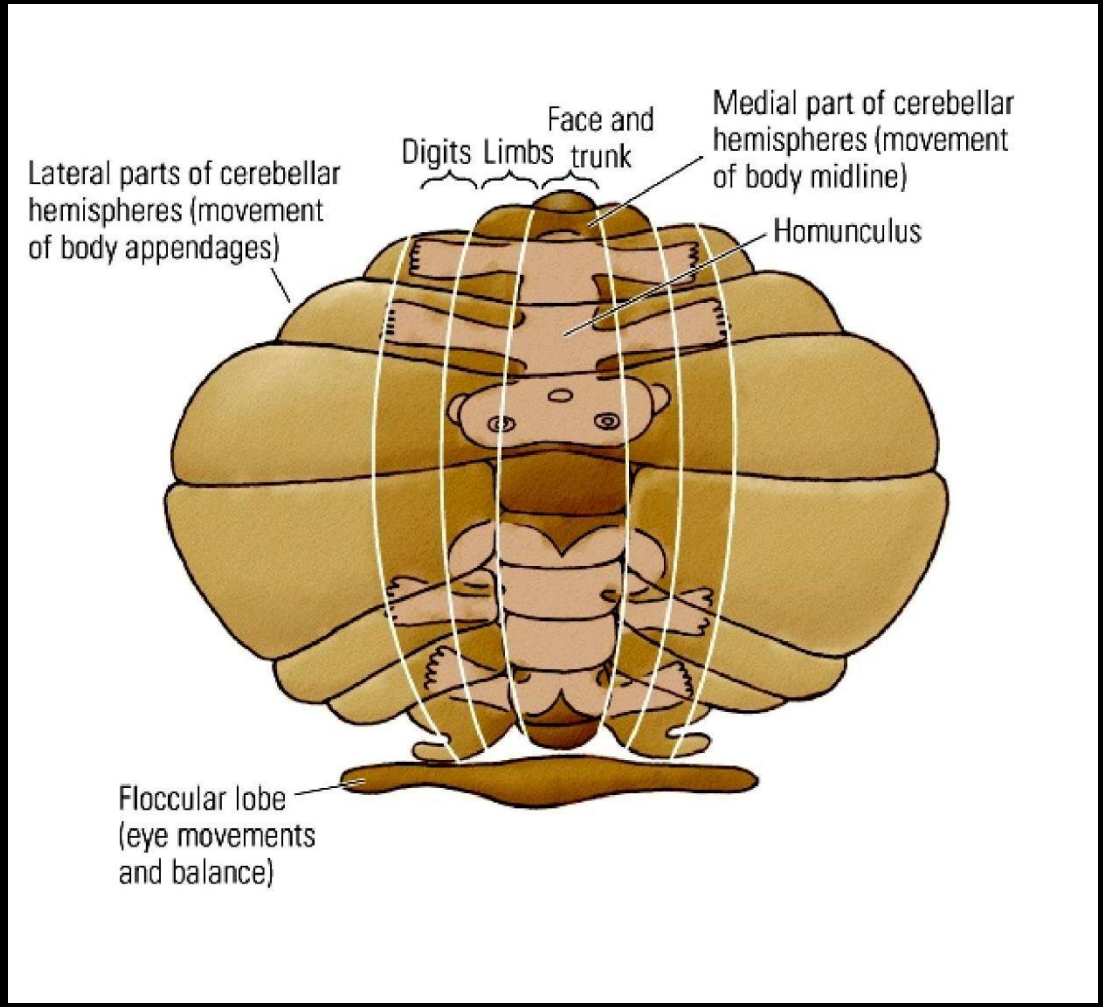
1. Vertigo
2. Motion Sickness
3. Muscle Tension
4. Scoliosis
5. Fascial Winding
6. Pain
7. Weakness
8. Poor Coordination
9. Anxiety
10. Depression
11. ADHD
12. Etc.

INACCURATE Brain Sensory and Motor Mapping can be ASSESSED by Immediate Changes in FLEXION and EXTENSION Range and Accuracy

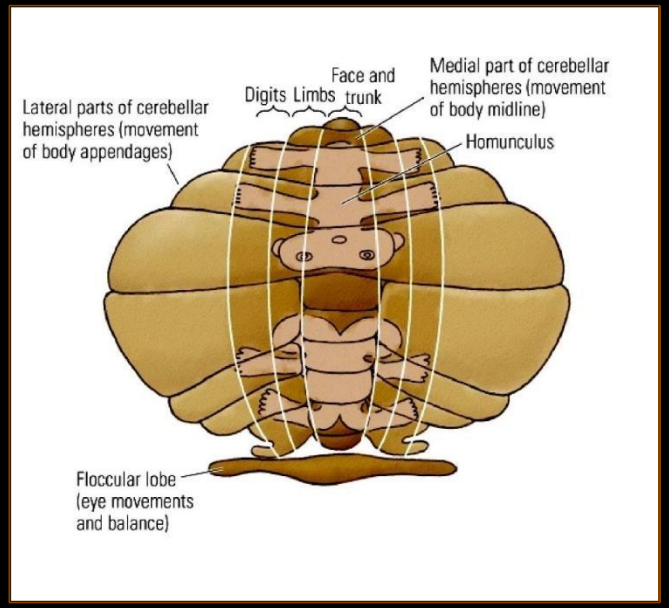


Cerebellar IMPORTANCE

Where the MAPS are corrected, learning, and stored



Cerebellar Dysfunction



MOVEMENT Findings

1. Accuracy
2. Balance
3. Coordination

Pathways: Spino, Cerebro,Vestibuar Cerebellar.

"Most people associate motor function with arms and legs and physical activity [...] but mounting evidence shows that movement is crucial to every other brain function, including memory, emotion, language, and learning. As we will see, our 'higher' brain functions have evolved from movement and still depend on it."

– Dr. John Ratey

A User's Guide to the Brain: Perception, Attention, and the Four Theaters of the Brain. John Ratey. 2001

Clinical and Functional Imaging Changes Induced from Vision Therapy in Patients with Convergence Insufficiency

Tara L. Alvarez, Mitchell Scheiman, Elio M. Santos, Cristian Morales, Chang Yaramothu,
John Vito d'Antonio-Bertagnolli, Suril Gohel, Bharat B. Biswal, and Xiaobo Li

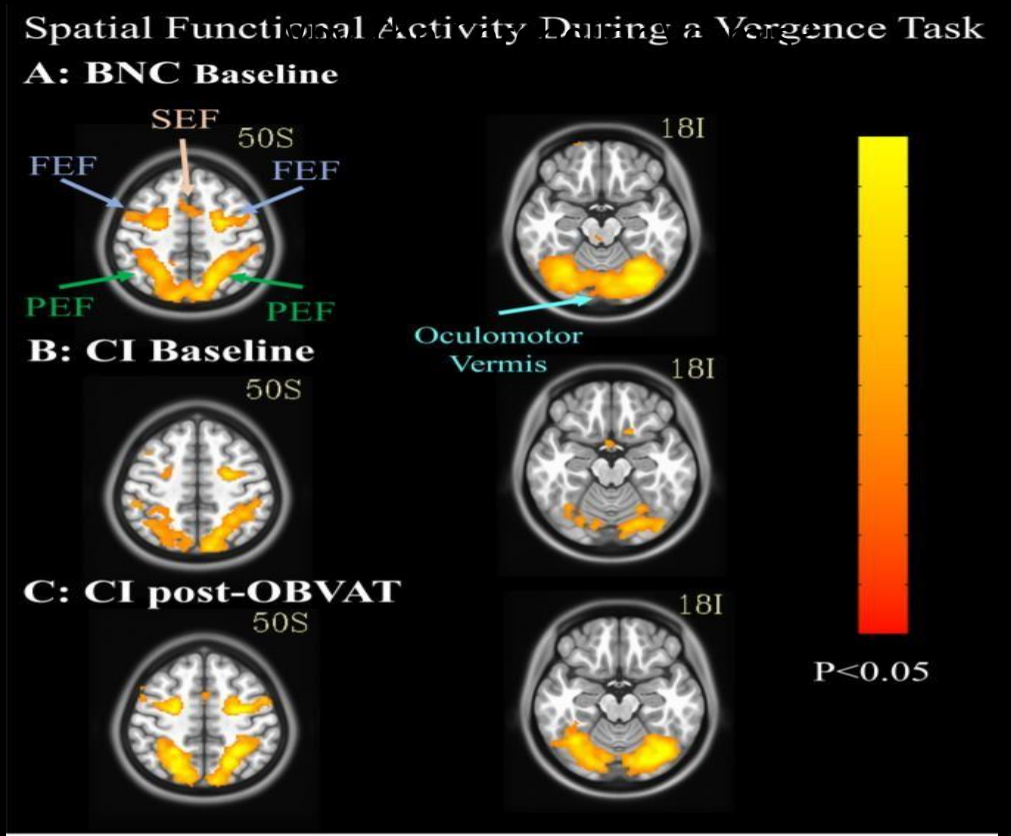


Figure 5: Group-level spatial activation of frontal eye fields (FEF), supplementary eye field (SEF), parietal eye fields (PEF) from axial slice 50S and oculomotor vermis from axial slice 18I using one sample *t*-test of BOLD signal and canonical waveform of experimental design. Data from 25 BNC (plots 5A), 25 CI patients at baseline (plots 5B) and same 25 CI patients post-OBVAT (plots 5C).

Oculomotor Vermis CHANGES with VT

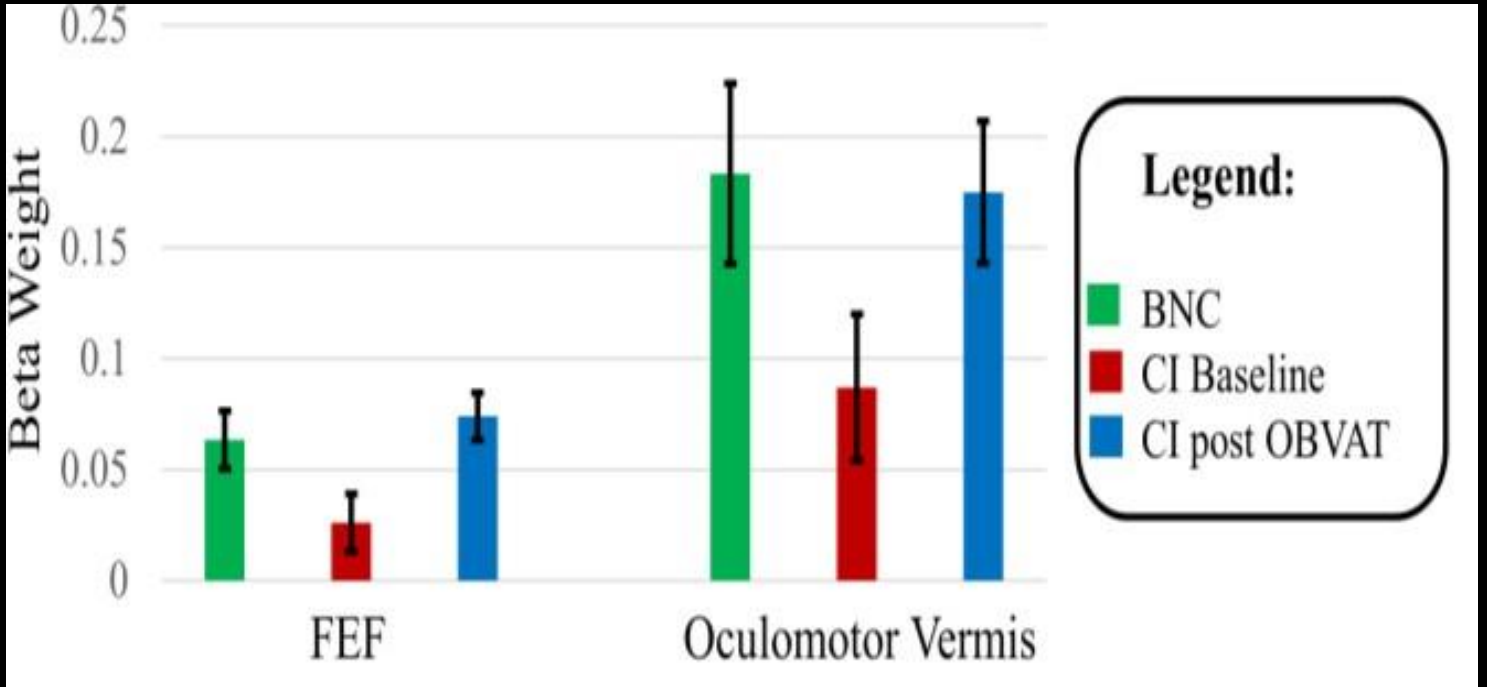


Figure 6: Functional activity mean beta weight ± standard error of mean (SEM) from a 7 mm sphere within Right FEF [MNI (in mm): 26R 8A 52S] and Functional activity mean beta weight ± SEM from a 5 mm sphere within Left Cerebellar Declive called Oculomotor Vermis [MNI: 26L 69P 17I].

The Cerebellum and Eye Alignment

"Acquired esotropia in cerebellar dysfunction is well described but under-recognised. . . . Our aim in this article is to demonstrate that diplopia due to cerebellar esotropia can be the first manifestation of the underlying disorder and as such the condition may be misdiagnosed."

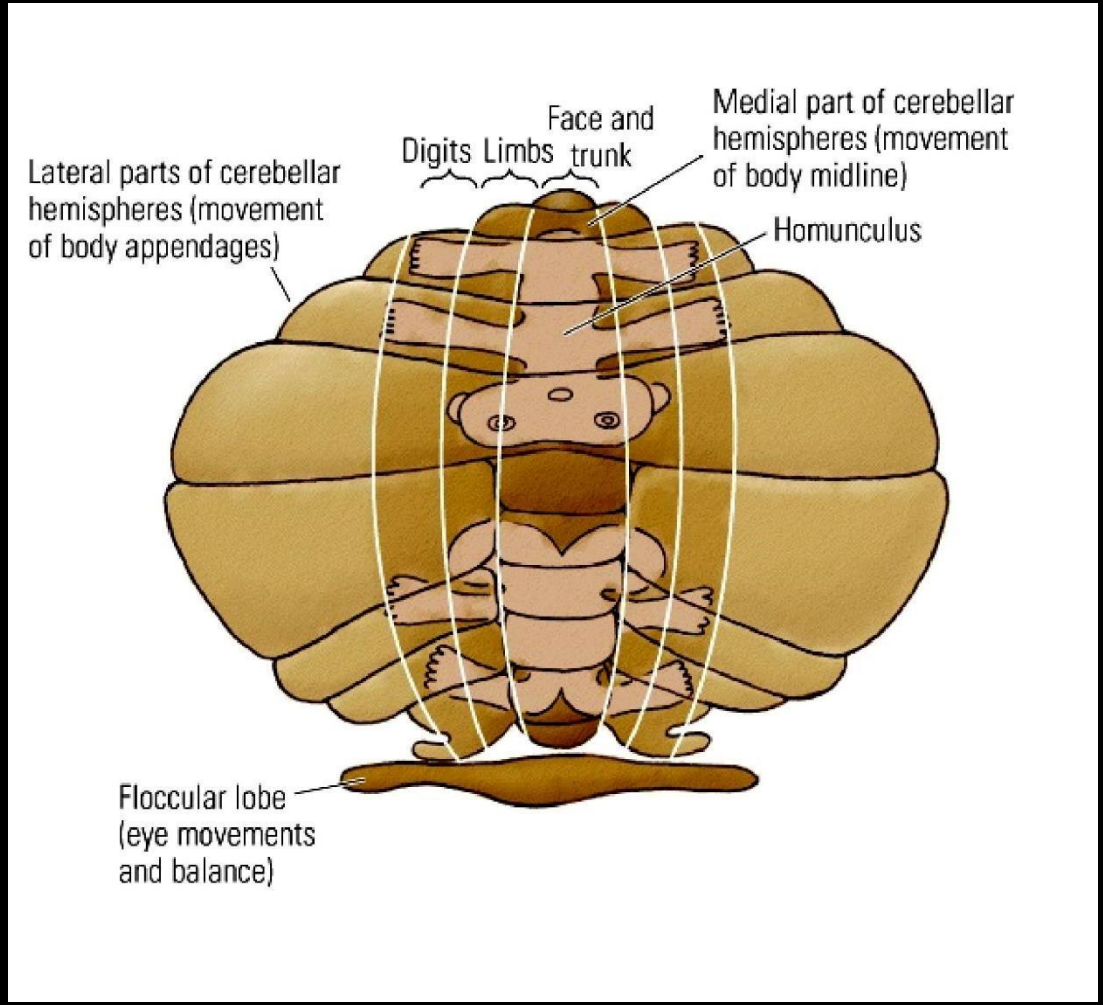
"Our series highlights that diplopia secondary to a comitant esotropia may be the presenting feature of cerebellar dysfunction. In all cases this was initially misdiagnosed as unilateral or bilateral lateral rectus paresis."

"This preliminary report highlights the importance of examining for cerebellar eye signs in patients who present with new-onset esotropia. All patients presenting with lateral rectus under-action without spontaneous recovery or demonstrating progression should raise the index of suspicion for possible cerebellar dysfunction, and a careful examination looking for cerebellar eye signs should be carried out."

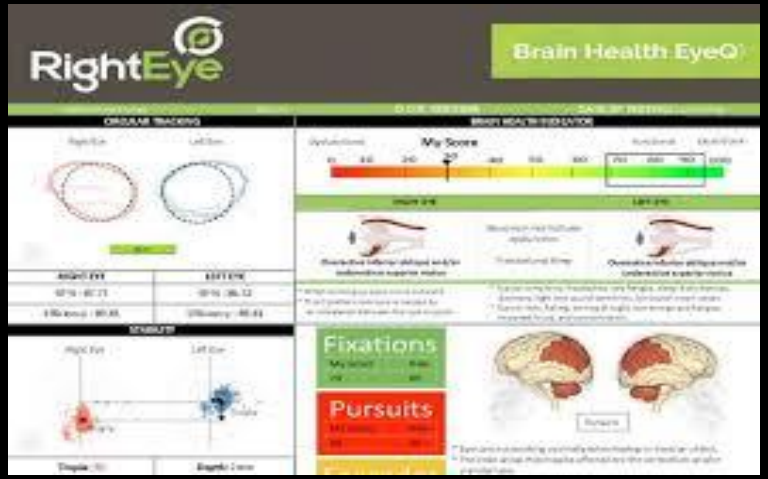
Wong, Sui H, et al. 2015. "Acquired Esotropia in Cerebellar Disease: A Case Series Illustrating Misdiagnosis as Isolated Rectus Paresis and Progression Over Time." *Neuroophthalmology* 39 (2): 59–63.

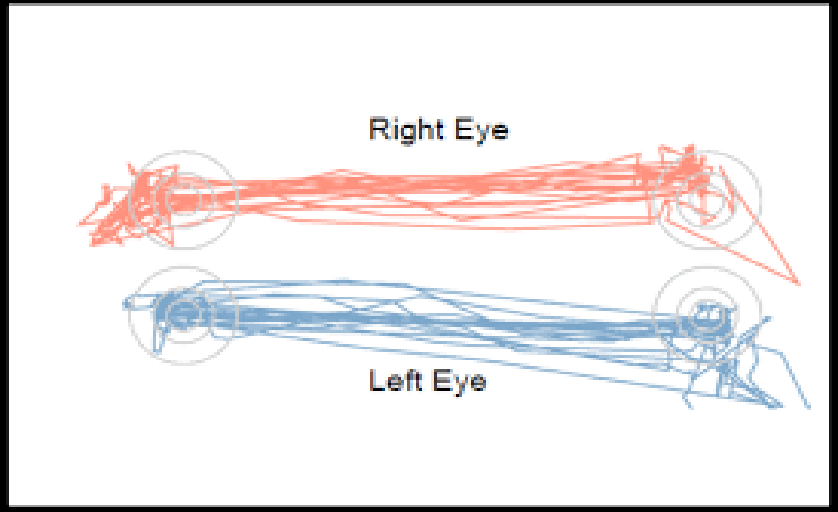
Cerebellar Assessments

1. Roberg's
2. Romberg's with Perturbation
3. Gait
4. Dysmetria (Finger-Nose)
5. Dyssynergia (Tapping)
6. Dysdiadochokinesia (RAPS)
7. Oculomotor Testing
8. Vestibular Testing
9. Spinal and Proximal Extensors
10. Pronator Drift
11. Rebound Testing



RightEye's Brain Health Eye-Q Assesses Cerebellar Functions Hypermetric Eye Movements IS a sign of a dysregulated Cerebellum





Cerebellar Contributions to Eye Movements

Cerebellar Contributions to Eye Movements

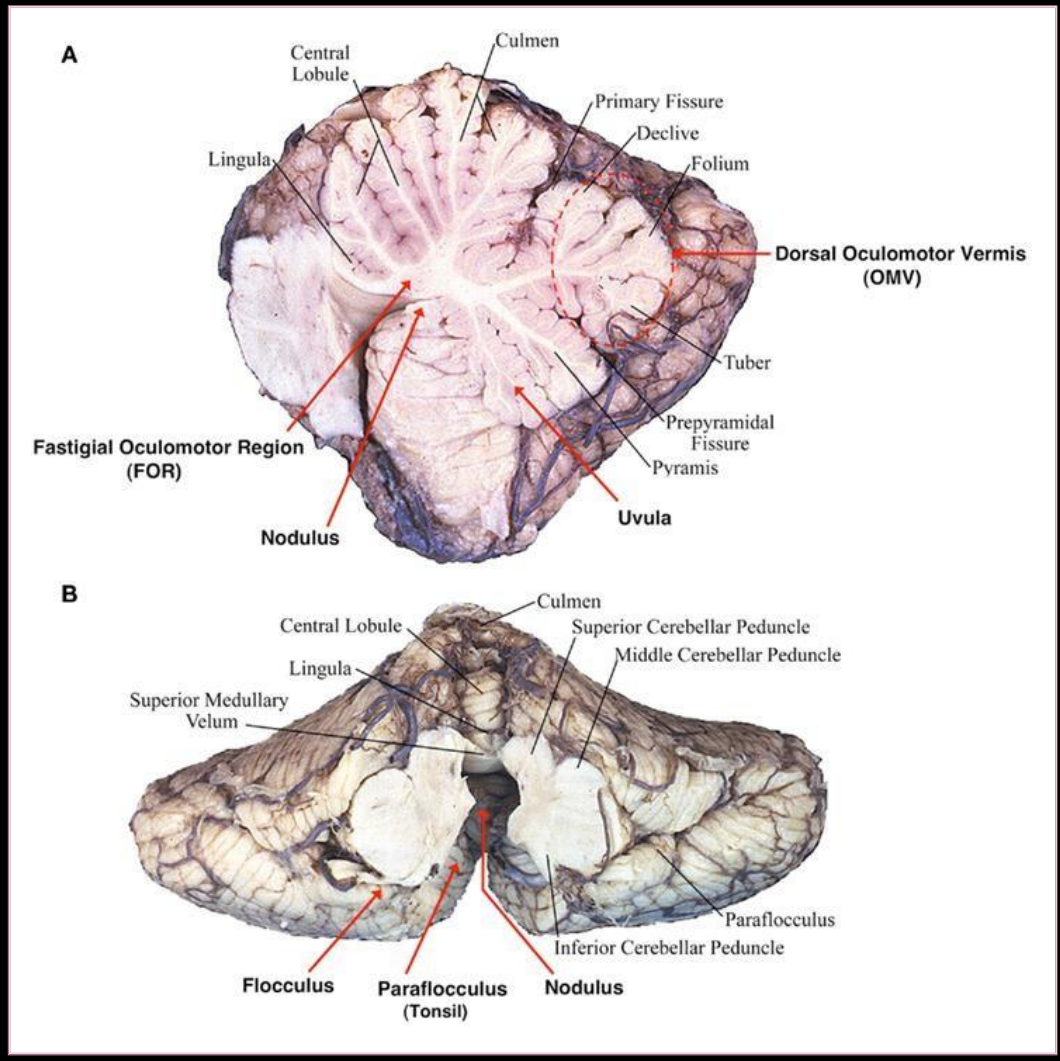
The cerebellum's core function in the visuomotor system is to optimize oculomotor performance. It fine-tunes all types of eye movements and helps coordinate them with each other and with head and body positions.

The cerebellum is intimately involved in the real-time, immediate modulation of gaze-shifting and gaze-stabilizing, as well as the long-term calibration and adaptation of those skills. These two contributions help make each individual eye movement accurate.

Cerebellar Contributions to Eye Movements

Cerebellar Areas of Interest

* Fastigial Oculomotor Region
* Flocculus and Paraflocculus
* Nodulus and Uvula



Cerebellar Contributions to Eye Movements

Fastigial Oculomotor Region

- Most active during the initial acceleration and final deceleration of smooth pursuits
- Primary cerebellar area responsible for ensuring the accuracy of saccades

Flocculus and Paraflocculus

- Essential for holding eccentric gaze fixations
- More significant role in pursuit maintenance than starting and stopping
- Modifies the strength, or gain, of the angular/rotational VOR

Nodulus and Uvula

- Responsible for generating and maintaining the linear/translational VOR
- Controls the velocity storage mechanism, a form of vestibular memory

Cerebellar Contributions to Eye Movements– Which Direction to Upregulate?

Directional Specificity

Fastigial Oculomotor Region

* The majority of smooth pursuit neurons in the FOR discharge most strongly when initiating pursuits and accelerating the eyes in a contraversive and/or downward direction

* Most of the remaining pursuit neurons activate with a preference for decelerating and terminating ipsiversive and/or upward movements

Flocculus and Paraflocculus

* Horizontal smooth pursuit cells in the flocculus and paraflocculus are most sensitive to maintaining ipsiversive pursuits and fixations

* Vertical smooth pursuit cells in the flocculus and paraflocculus are most sensitive to maintaining diagonally contraversive and downward pursuits and fixations

* Torsional smooth pursuit cells in the flocculus and paraflocculus are most sensitive to pursuits that extort the ipsilateral eye

Gaze Fixations: A Staring Contest
Neurologic Training based on Cerebellar function anatomy

Purpose:

- Foundational element of all other eye movements
- Allow us too see objects clearly
- Sample the visual scene to create perception

- Dysfunction: Cerebellum, Basal Ganglia, Lateral Prefrontal Cortex

Smooth Pursuits: Keeping Your Eye On the Ball
Neurologic Training based on Cerebellar function anatomy

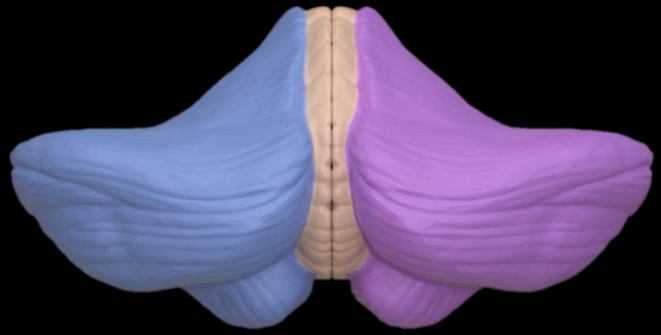
Purpose:

- Foveate moving isolate targets
- VOR-Cancellation

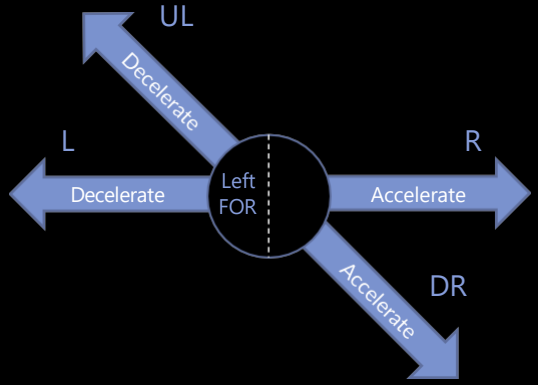
Dysfunction:

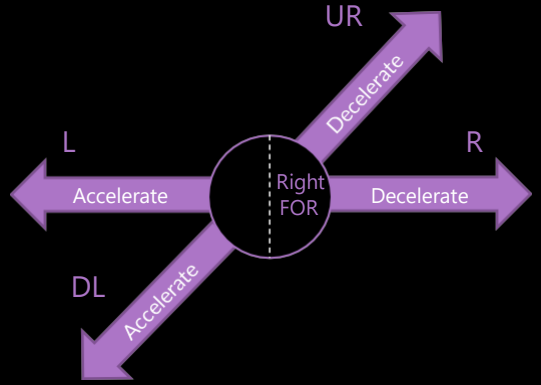
- Ipsilateral Parietal
- Cerebellum

Cerebellar Contributions to Eye Movements

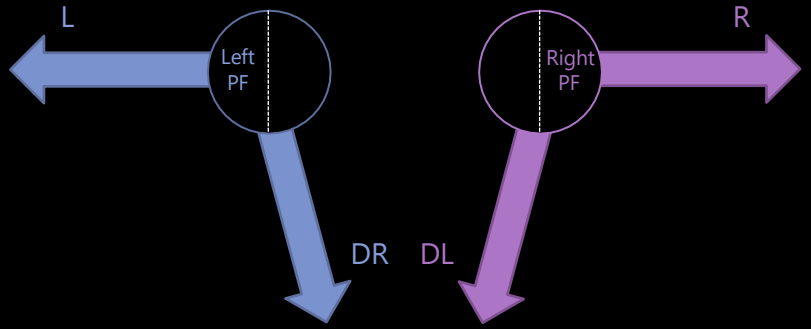


Laterality for the FOR

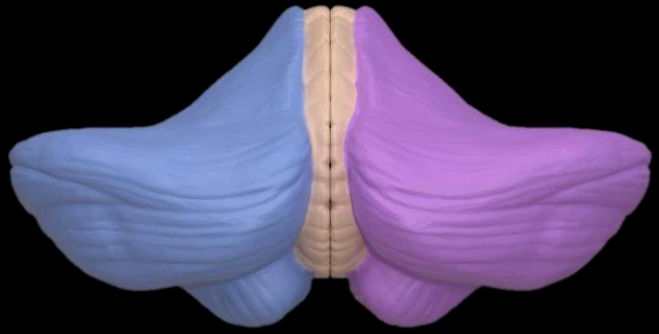




Laterality for the FL/PF

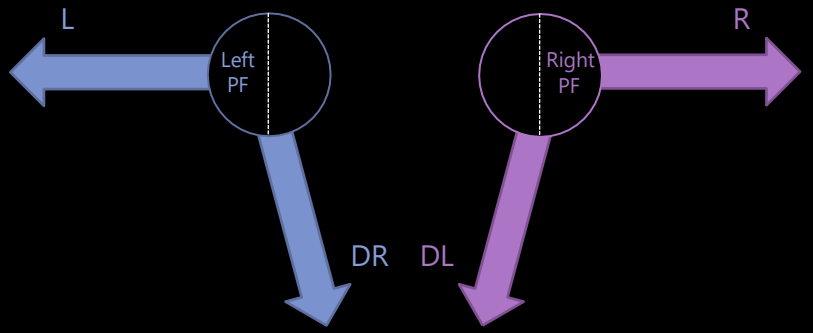


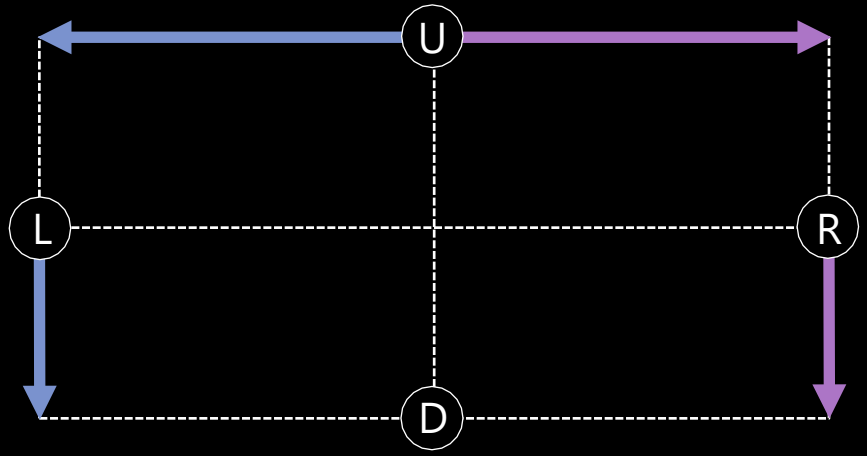
Cerebellar Contributions to Eye Movements



L R

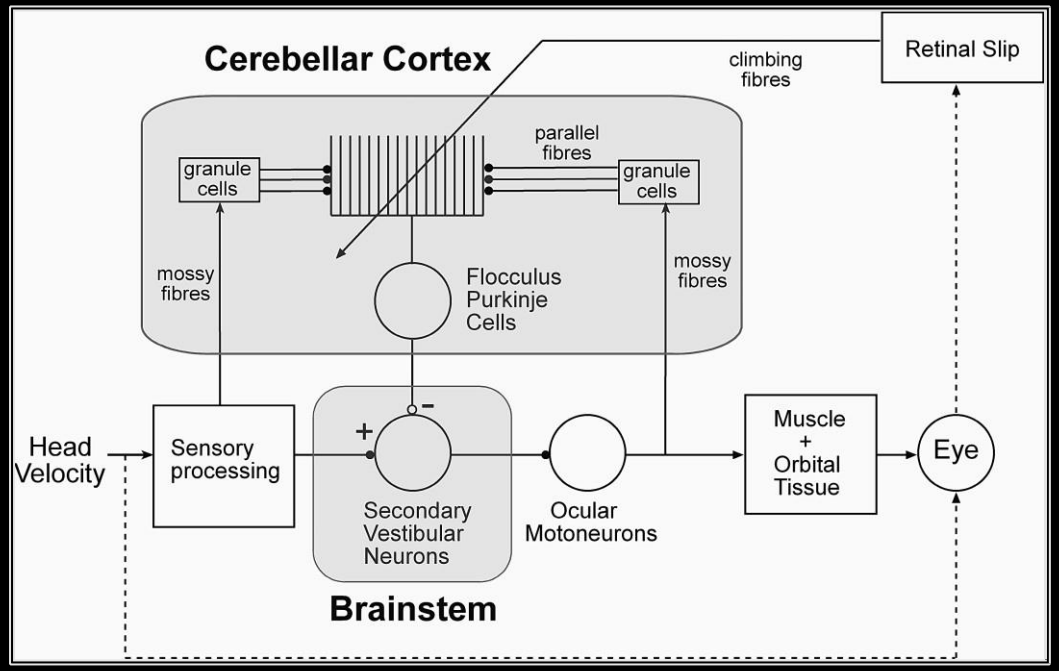
Laterality for the FL/PF





The Flocculus and Paraflocculus will be our most common cerebellar areas of interest for smooth pursuits, fixations, and aVOR's.

Cerebellar Contributions to Eye Movements



Flocculus and Parafloccculus

The foremost function of the floccular/parafloccular complex is to provide an inhibitory influence on the ipsilateral medial and superior vestibular nuclei. Purkinje cells in the flocculus and paraflocculus inhibit neurons in these nuclei that excite the ocular motor neurons associated with the horizontal and anterior semicircular canals on that side.

To simplify:

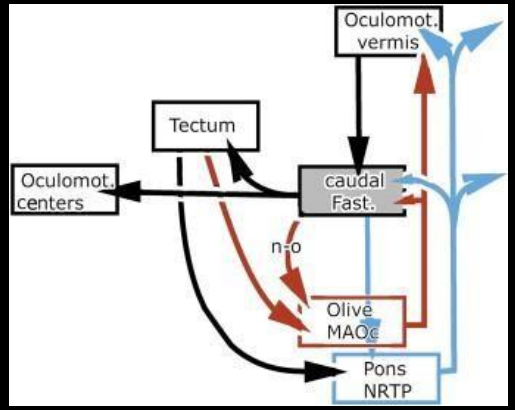
For fixations and smooth pursuits, the flocculus and paraflocculus help the eyes move in the opposite direction of the ipsilateral horizontal and anterior canal VOR's.

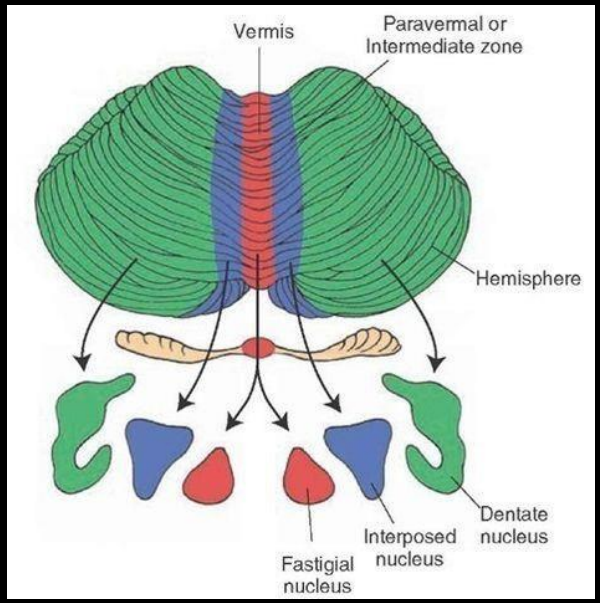
Cerebellar Contributions to Eye Movements

Fastigial Oculomotor Region

The FOR is traditionally more associated with saccades, but it also plays a role in smooth pursuits and fixations. For smooth pursuits, as in saccades, the FOR accelerates the eyes for contraversive eye movements and decelerates them for ipsiversive movements.

For fixational eye movements, the FOR is involved in refining microsaccades and encoding the target position for those saccades.



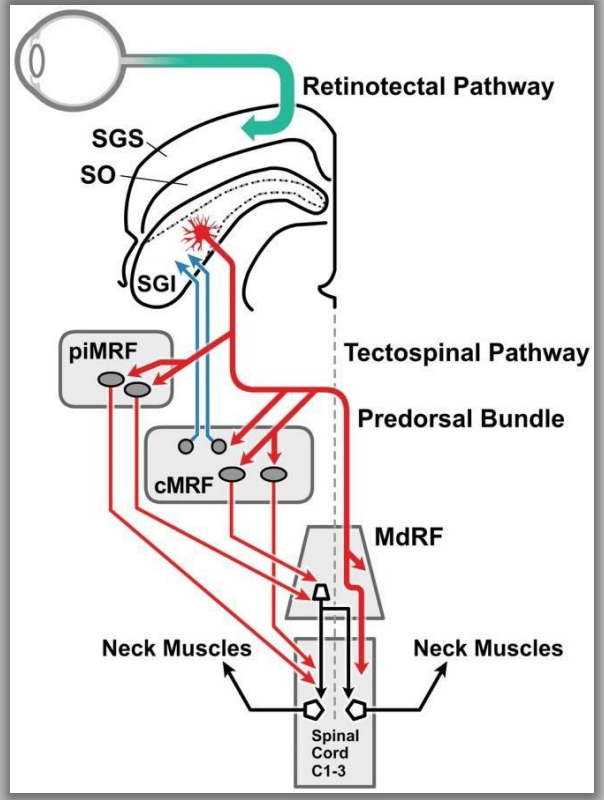


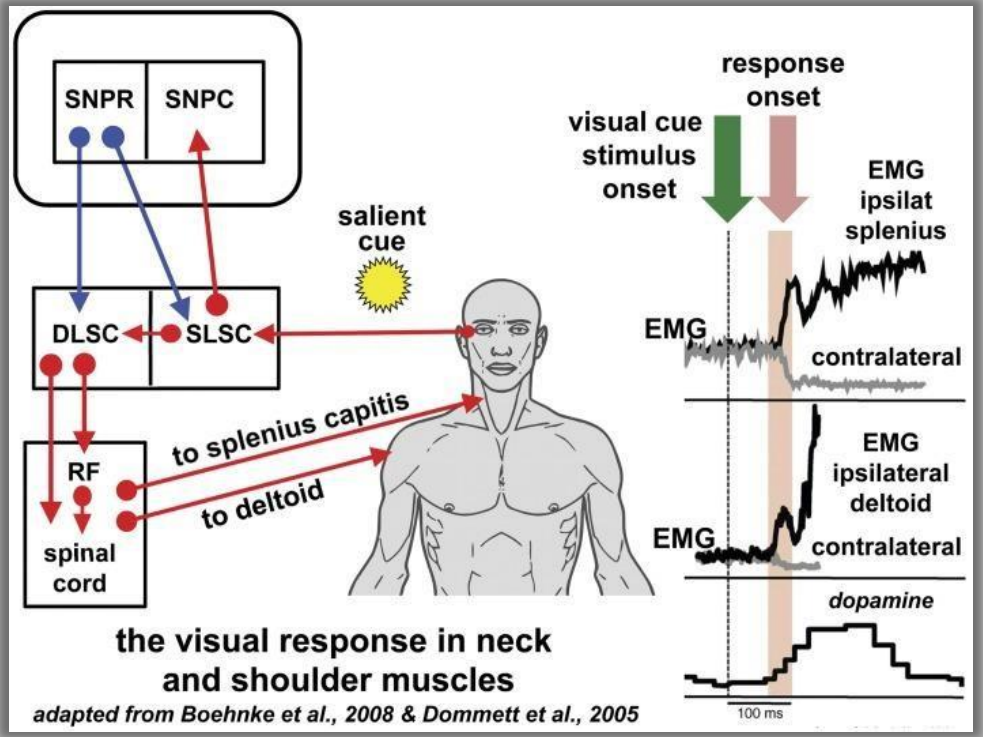
To simplify:

The fastigial oculomotor region speeds up eye movements going to the opposite side and slows down eye movements coming toward it.

Fastigial Oculomotor Region	Flocculus and Parafloccullus	Nodulus and Uvula
Initial acceleration of smooth pursuits	Maintaining fixations and pursuits	Integrating canal and otolith information
Terminal deceleration of smooth pursuits	Adjusting and adapting the aVOR	Adjusting and adapting the tVOR
Less predictable smooth pursuits	More predictable smooth pursuits	Controls the velocity storage mechanism
Speed adaptation	Directional adaptation	
Go/No-Go decisions for pursuits		
Faster pursuits ❼ more activation	Faster pursuits, aVOR ❼ more activation	Faster tVOR and slower, more sustained aVOR ❼ more activation
Also strongly associated with saccades	Also strongly associated with VOR-C	Also strongly associated with downward smooth pursuits
Left FOR:	***Left FL/PF:***	***Left nodulus and uvula:***
* Accelerate Right and Down/Right * Decelerate Left and Up/Left	* Fix and SP Left and Down/Right * aVOR for the left canals and left eye	* Slow aVOR for the left canals * tVOR for the left utricle
Right FOR:	***Right FL/PF:***	***Right nodulus and uvula:***
* Accelerate Left and Down/Left * Decelerate Right and Up/Right	* Fix and SP Right and Down/Left * aVOR for the right canals and right eye	* Slow aVOR for the right canals * tVOR for the right utricle

Oculomotor Reflexes- SHOULDERS-EYES and the PEPPER TEST "IS THERE NEUROLOGY?"

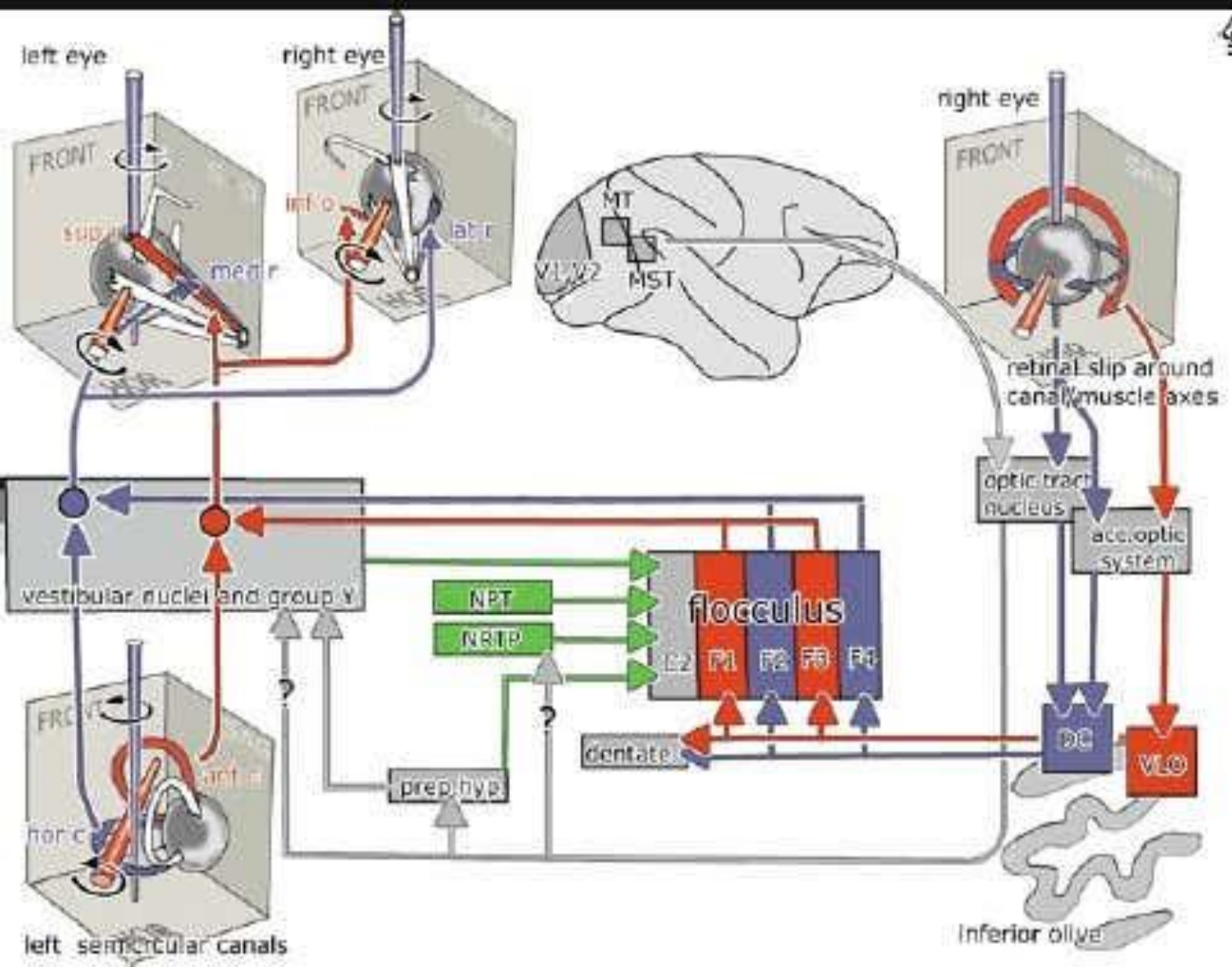




Hutchinson, Michael et al. 2014. "Cervical Dystonia: A Disorder of the Midbrain Network for Covert Attentional Orienting." *Frontiers in Neurology* 5: 54.

Tonic Neck Reflexes

- Ellis, Michael D. et al. 2012. "Neck rotation modulates flexion synergy torques, indicating an ipsilateral reticulospinal source for impairment in stroke." *Journal of Neurophysiology* 108 (11): 3096–104.
  - "In brief, cervical spine joint receptors and/or muscle spindle afferents from perivertebral muscles are excited from head rotation. These neck receptors project rostrally onto and result in the activation of, among others, the gigantocellular reticular nucleus (origin of lateral/medullary reticulospinal tract). . . . Completing the reflex loop, descending projections from motor nuclei in the reticular formation then project bilaterally to spinal motor neurons and interneurons."
- Le Pellec, A. and B. Maton. 1996. "Influence of tonic neck reflexes on the upper limb stretch reflex in man." *Journal of Electromyography and Kinesiology* 6 (2): 73–82.
  - "Vidal et al. and Roucoux et al. have reported that the neck muscles showed an EMG activity linked to the position of the eyes within the orbit in the cat. This EMG activity was preferentially evoked in those muscles ipsilateral to the direction of the eye rotation. A great deviation of the eye was used to provide an optimal effect. . . . Therefore, the influences of the head and eye positions on the excitability of elbow extensor motoneurons interact."

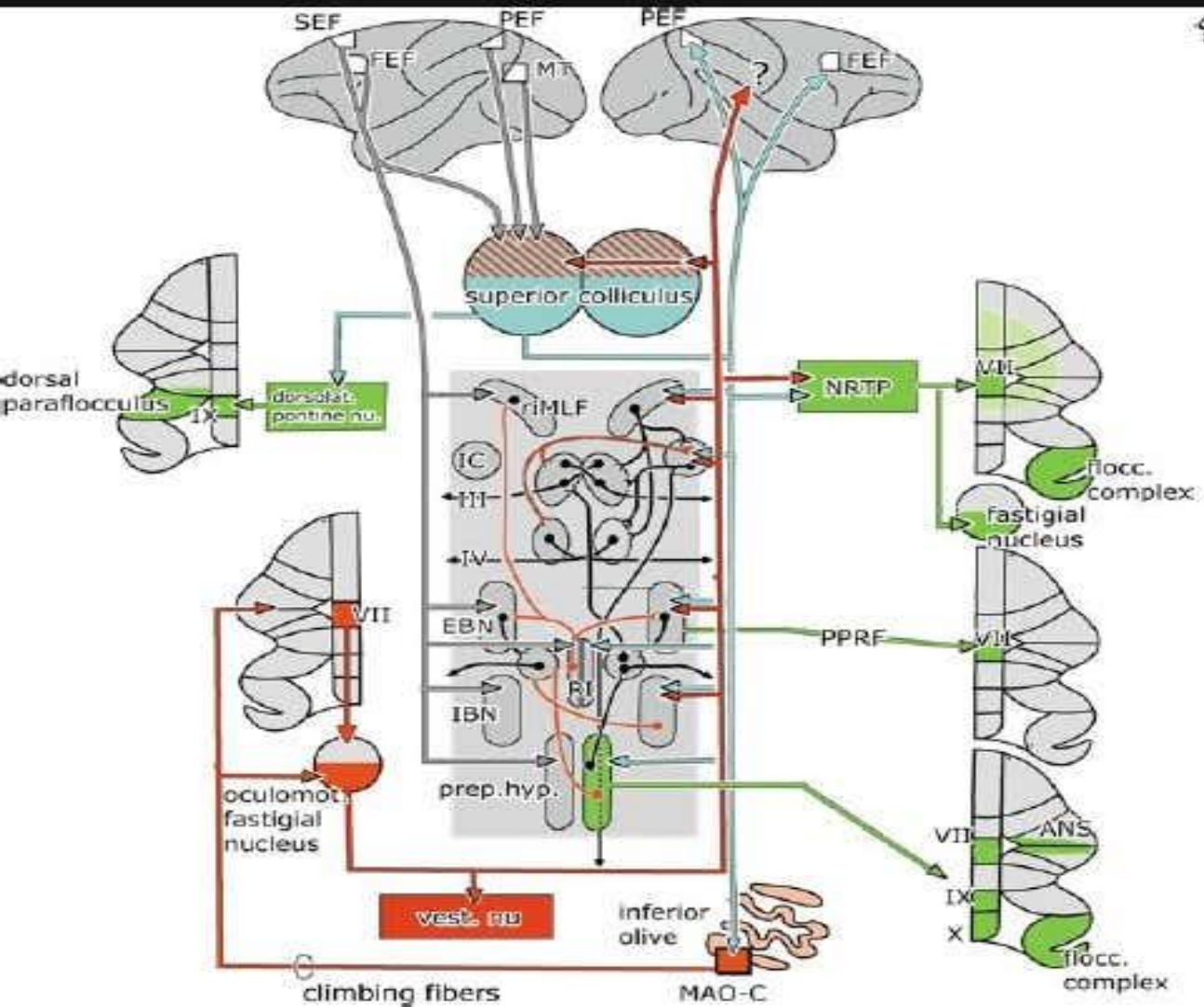

left eye
right eye
FRONT
MT
MST
V1,V2
right eye
retinal slip around canal/muscle axes
optic tract nucleus
acc.optic system
vestibular nuclei and group y
NPT
NRTP
flocculus
L2
P1
P2
P3
P4
dentate
DC
VLO
prep hyp
?
?
left semicircular canals
Inferior olive

Superior Colliculus and Eye Alignment

"Our finding of SC misalignment-related cells places the SC within a vergence and accommodation circuit that is potentially disrupted in strabismus."

"Motivated by the evidence in normal monkeys and humans, we recently investigated the SC in strabismic monkeys using electrical stimulation techniques and showed that low current electrical stimulation within mostly the rostral part of the SC of strabismic monkeys resulted in a change in strabismus angle. Depending on the site of stimulation, we elicited either convergent or divergent change of strabismus angle."

Upadhyaya, Suraj and Vallabh E. Das. 2019. "Response Properties of Cells Within the Rostral Superior Colliculus of Strabismic Monkeys." *Investigative Ophthalmology & Visual Science* 60:4292–4302.


SEF
PEF
FEF
MT
PEF
?
FEF
superior colliculus
dorsal paraflocculus
IX
dorsolat. pontine nu.
riMLF
IC
III
IV
NRTP
VII
flocc. complex
fastigial nucleus
VII
EBN
PPRF
VIII
RI
IBN
prep.hyp.
oculomot. fastigial nucleus
VII
ANS
IX
X
flocc. complex
vest. nu
inferior olive
climbing fibers
MAO-C

Amer Al Saif, J Phys Ther Sci. 2015 Jan;27(1)

Determine the effect of neck muscle fatigue on dynamic visual acuity in healthy young adults.

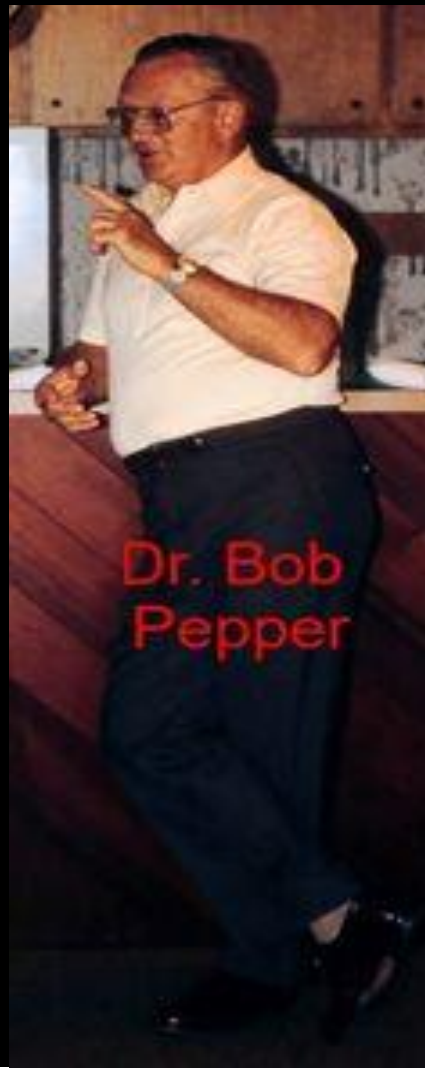
The results of this study suggest that neck fatigue negatively impacts dynamic visual acuity and diminished cervical spine proprioception as measured by joint positional error.

Anat Bechar Zipoi, PloS One. 2018; 13 (10)

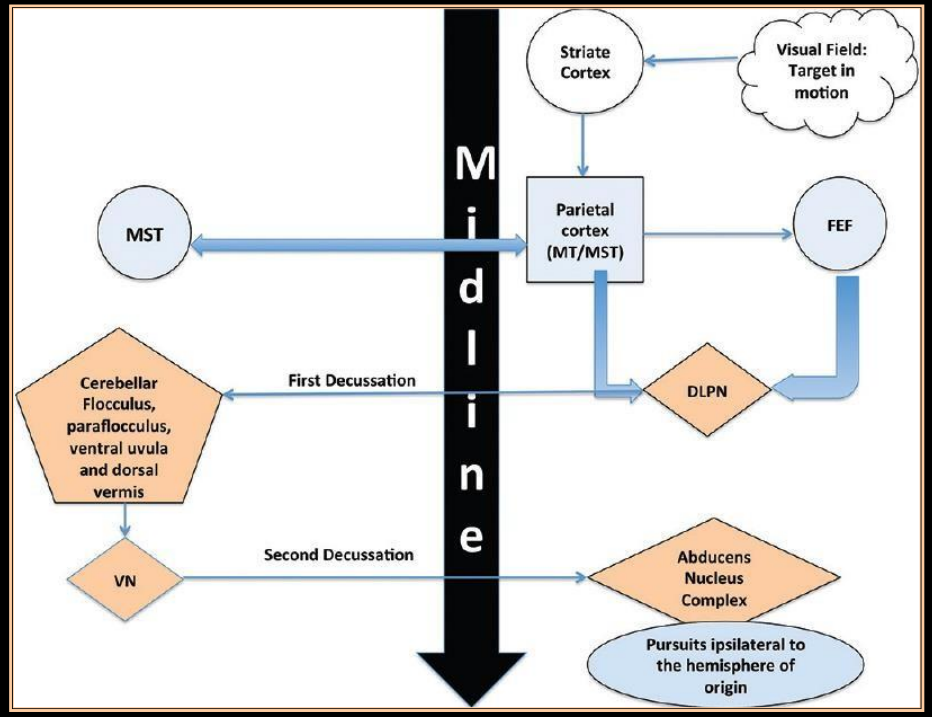
Postural stability and visual impairment: Assessing balance in children with strabismus and amblyopia

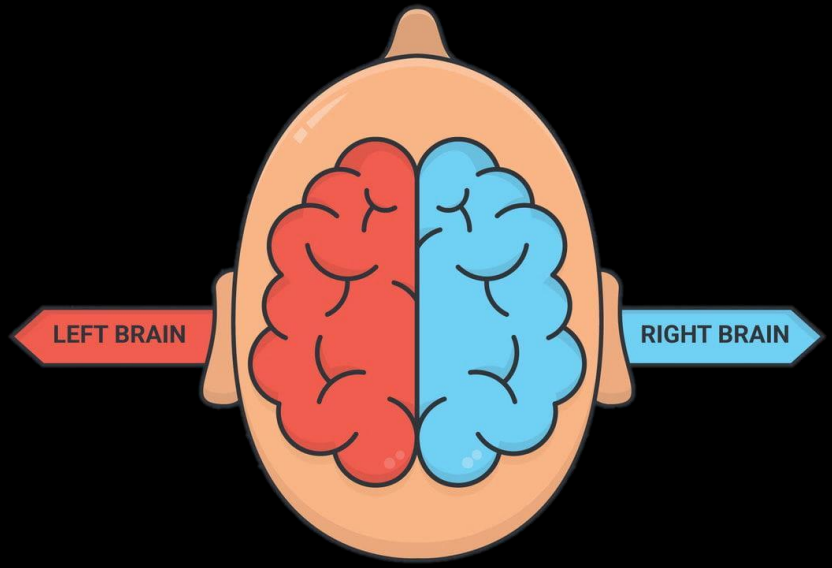
Finding suggest that binocular vision plays an important role in development and maintenance of balance control in children. Balance was reduced in strabismic and amblyopic children equally. Even mild cases of intermittent strabismus and phorias, if present in early life, can lead to postural instability.

Dr Bob Pepper's clinical observations and practices now have a strong Neurological evidence and support!

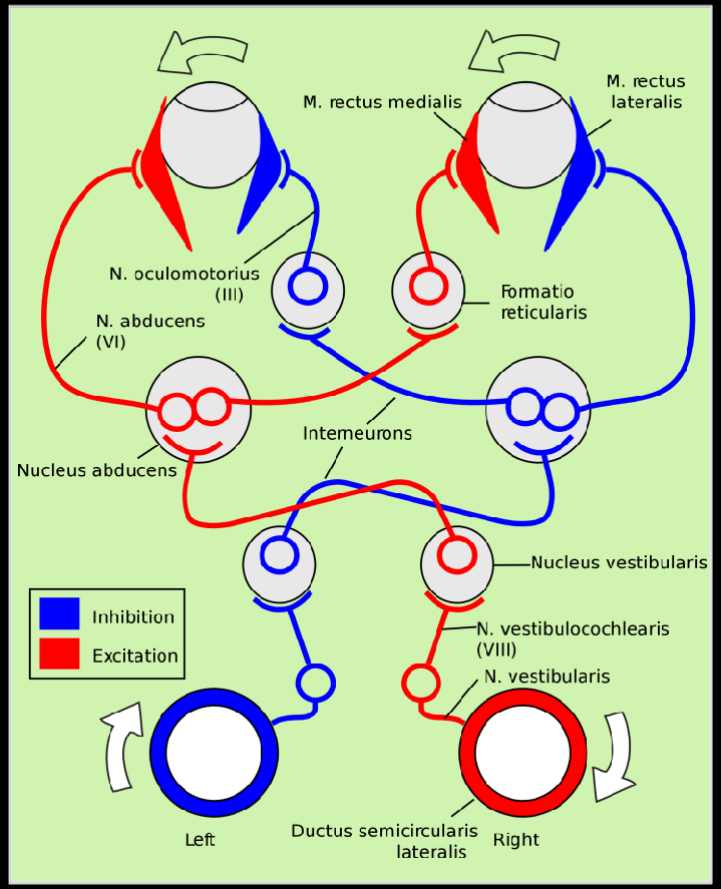


Cortical Control of Smooth Pursuits





The 3 Major Vestibular Reflexes



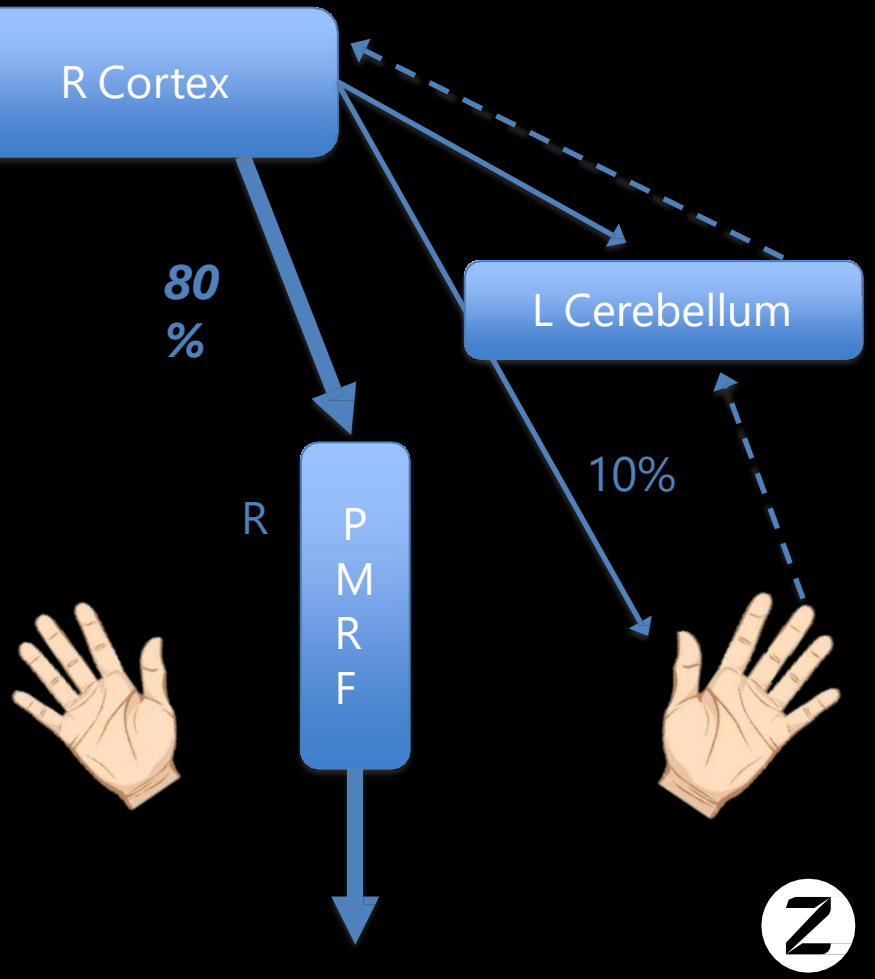
1. Vestibuloocular Reflex (VOR): Keeps the eyes still in space when the head moves.

2. Vestibulocollic Reflex (VCR): Keeps the head still in space or on a level plane when you walk.

3. Vestibulospinal Reflex (VSR): Adjusts posture for rapid changes in position.

Understanding the Neurology of Movement

1. Frontal Lobe decides to create voluntary movement
2. FL sends copy of movement to contralateral Cerebellum
3. FL sends motor command to contralateral musculature
4. FL sends stability command to ipsilateral PMRF to pass on to muscles
5. Joint mechanoreceptors send afferent signals to CB
6. CB communicates with FL regarding accuracy, balance, & coordination



I-Phase Neurology Rules:

Cortical Activation Drills

- **Contralateral Complex Movements**
- **Contralateral Sensory Stimulus (with focus!)**
- **Contralateral VOR Canals**
- **Ipsilateral Smooth Pursuits**

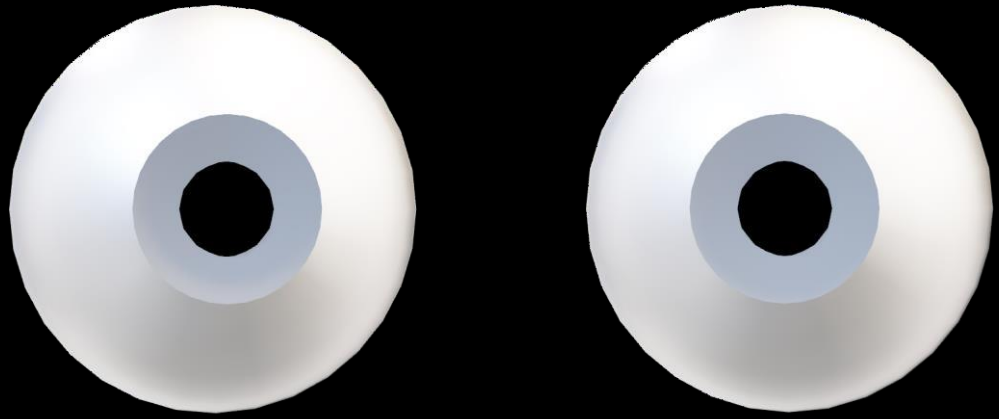
Cerebellar Activation Drills

- **Ipsilateral Complex Movements**
- **Ipsilateral VOR Canals**
- **Cerebellar Fixation and Smooth Pursuit Directions**

Vestibular Influence on Eye Muscles

Right Horizontal Canal

Left Horizontal Canal



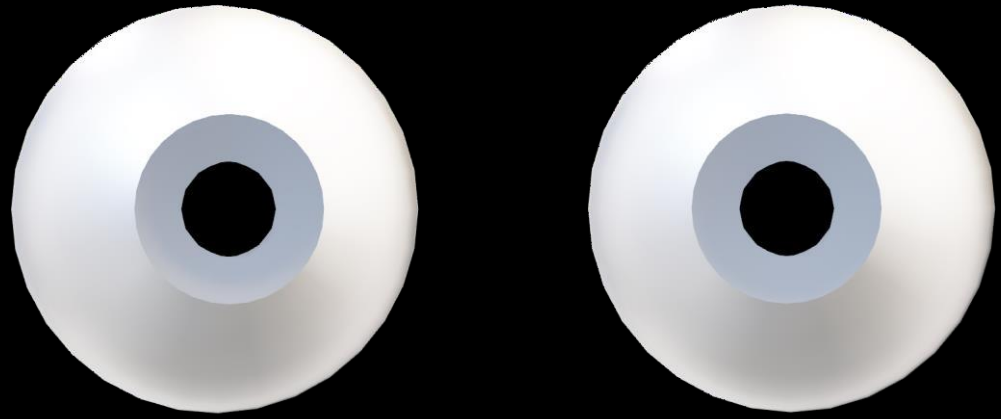
R

L

Vestibular Influence on Eye Muscles

Right Horizontal Canal

Left Horizontal Canal



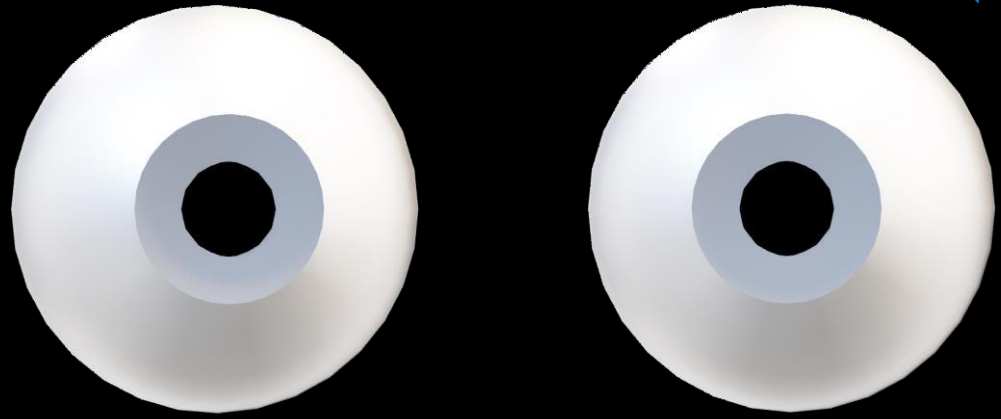
R

L

Vestibular Influence on Eye Muscles

Right Horizontal Canal

Left Horizontal Canal



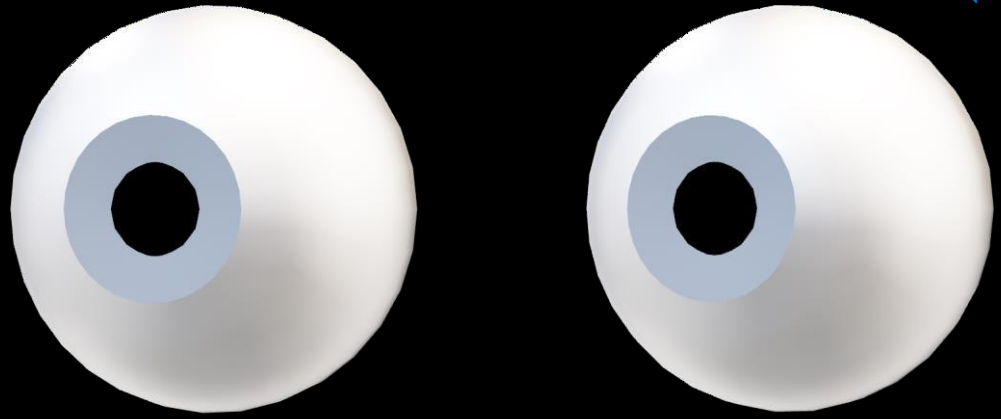
R

L

Vestibular Influence on Eye Muscles

Right Horizontal Canal

Left Horizontal Canal

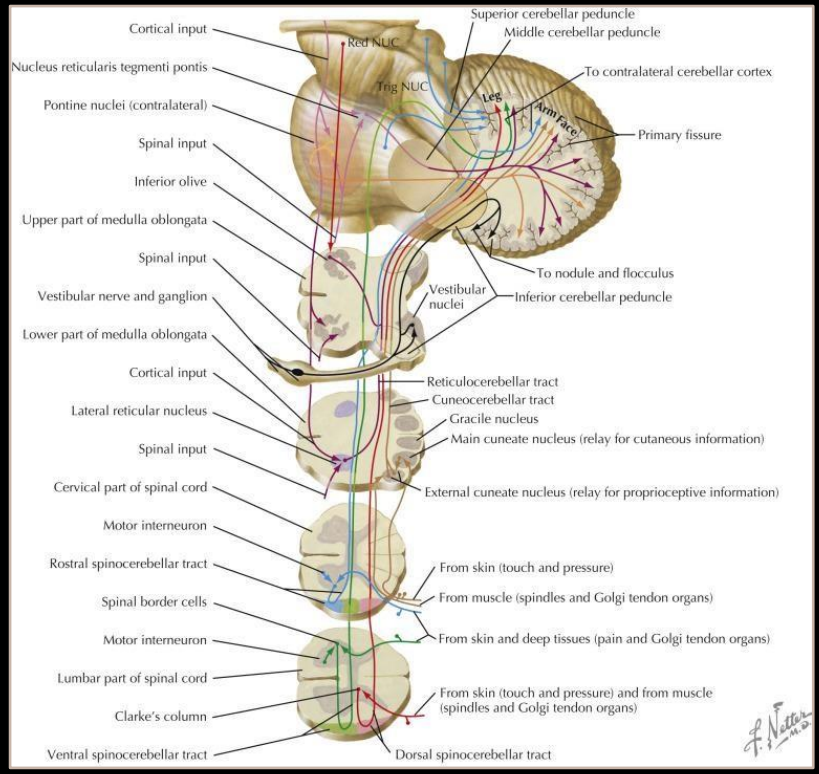


R

L

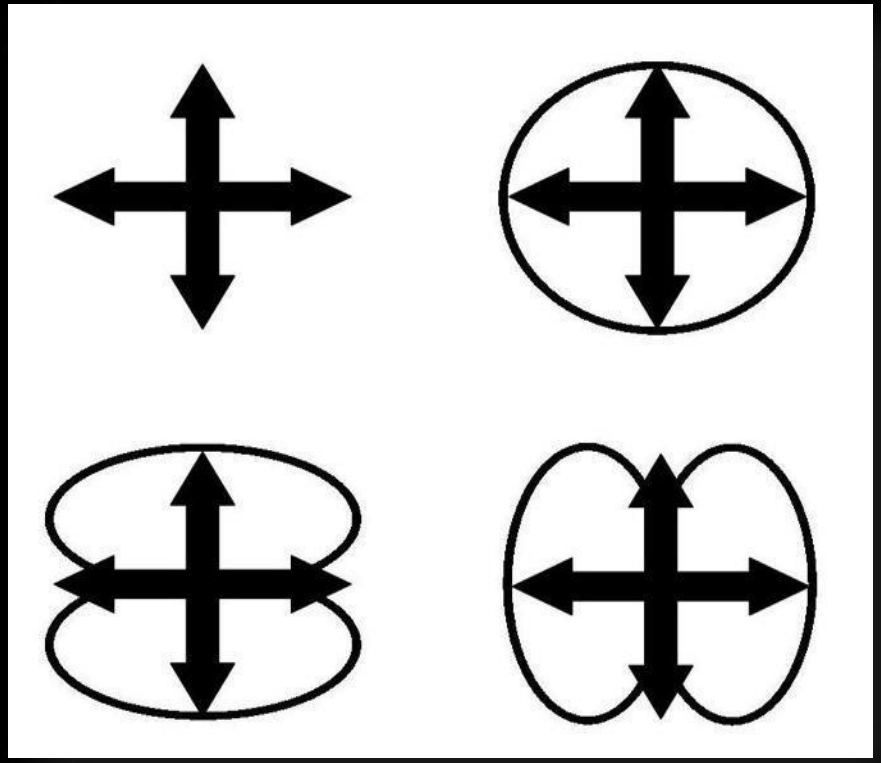
The Cerebellum

1. Integrates (and simplifies) the complex data generated by all our body systems and cognition.
2. Coordinates complex movements ipsilaterally.
3. Eliminates all unwanted movement by ensuring Accuracy, Balance, and Coordination



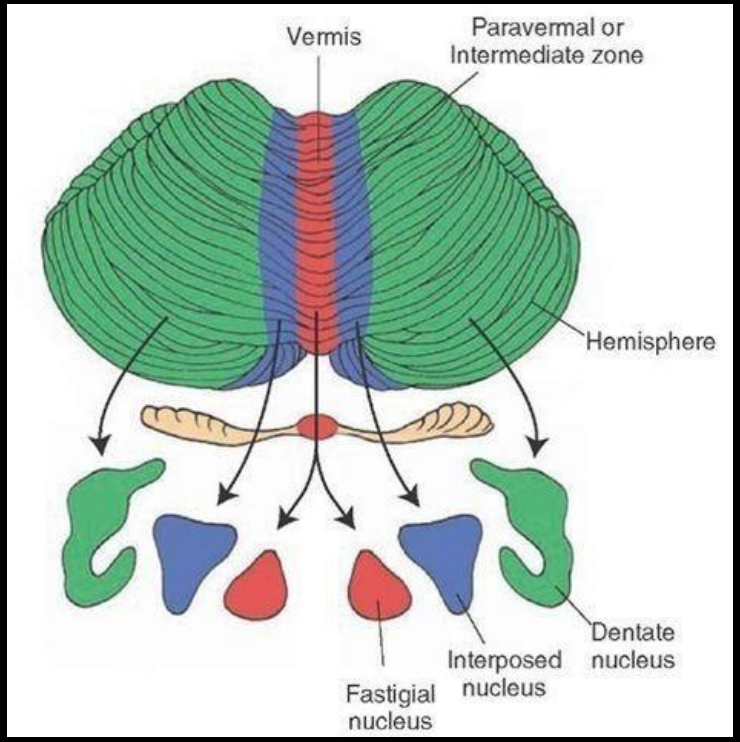
4. Directly stimulates the contralateral cerebral cortex (frontal lobe)
5. Is in direct communication with the ipsilateral vestibular system.

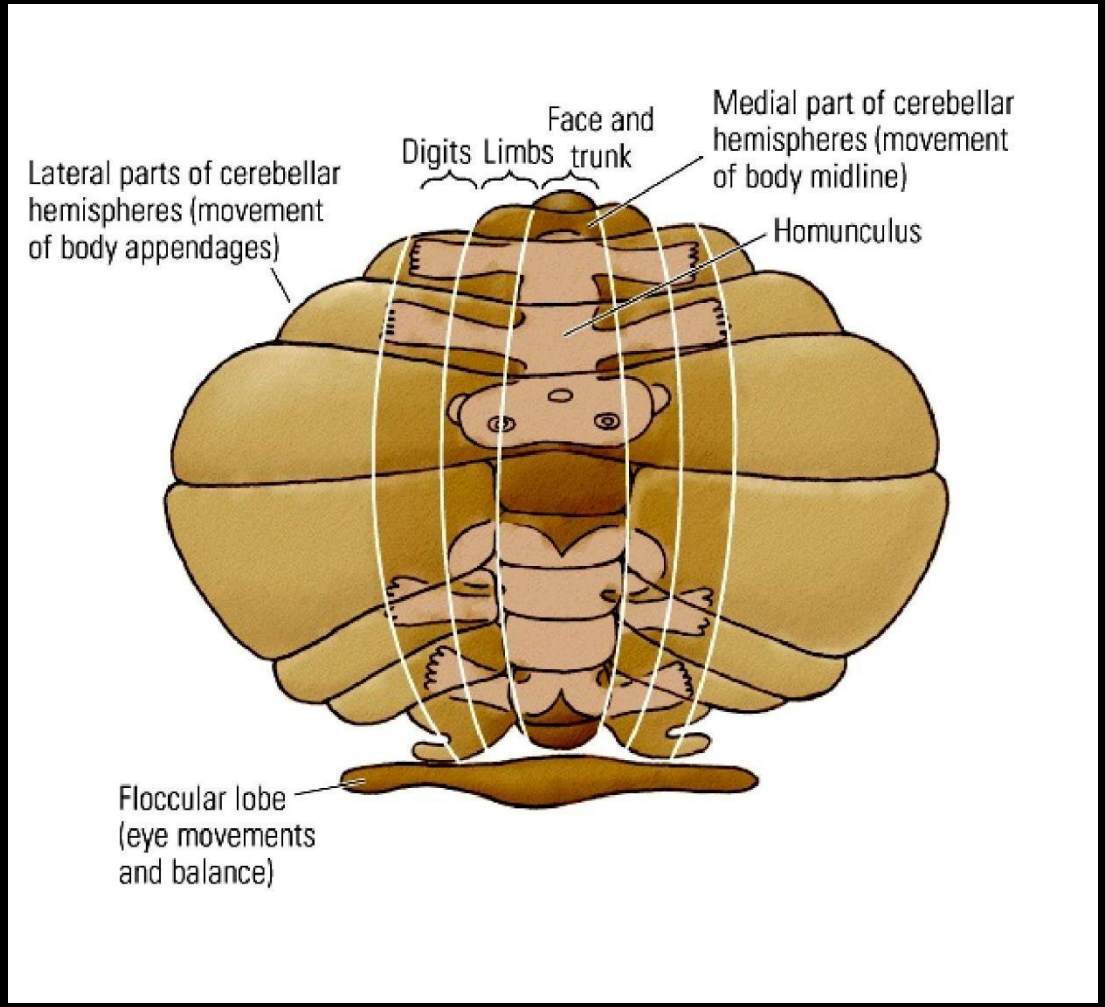
Continuum of Cerebellar Activation



1. Mechanoreceptor stimulation
   - Joint-rich areas
   - Full ranges of motion
   - Speed and load
2. Novelty
3. Complexity
4. Error correction/unpredictability
5. Accuracy
6. Timing/Rhythm/Sequencing
7. Balance
8. Proximal extensor tone
9. Vision, vestib, auditory, olfactory

Cerebellar Assessments

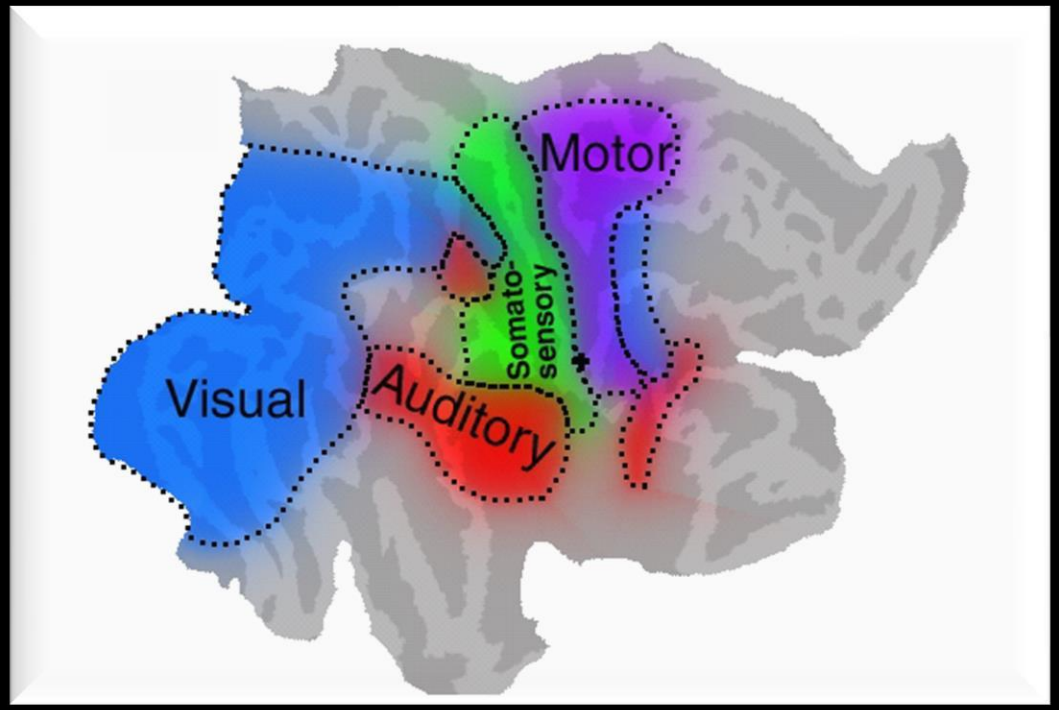




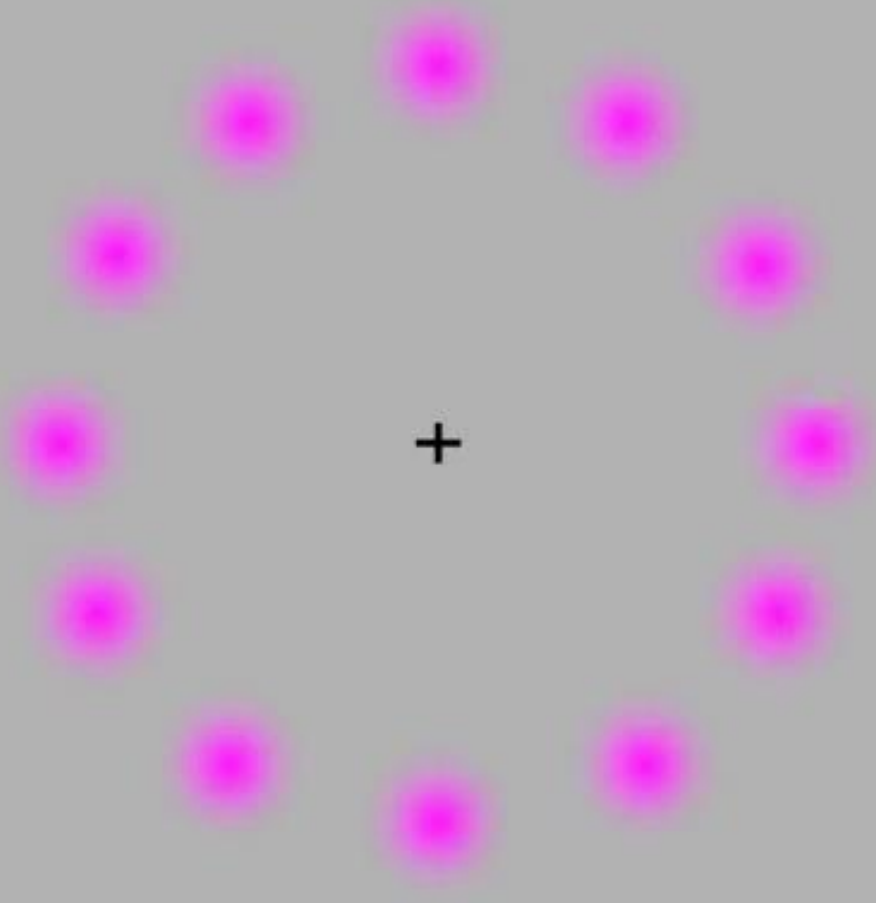
Sharpened Romberg's Test

- Screening Test for Athletes (Which means everyone)
- More athletically challenging.
- If they fail, you don't necessarily need to refer out, but use care before adding load.
- Use to show progress in developing their balance.
- Common ways to "cheat" the test:
  1. Not fully heel to toe.
  2. Flaring the feet

The Visual System



Your Dominant
Sensory System



The Vestibular System – Where It Lives

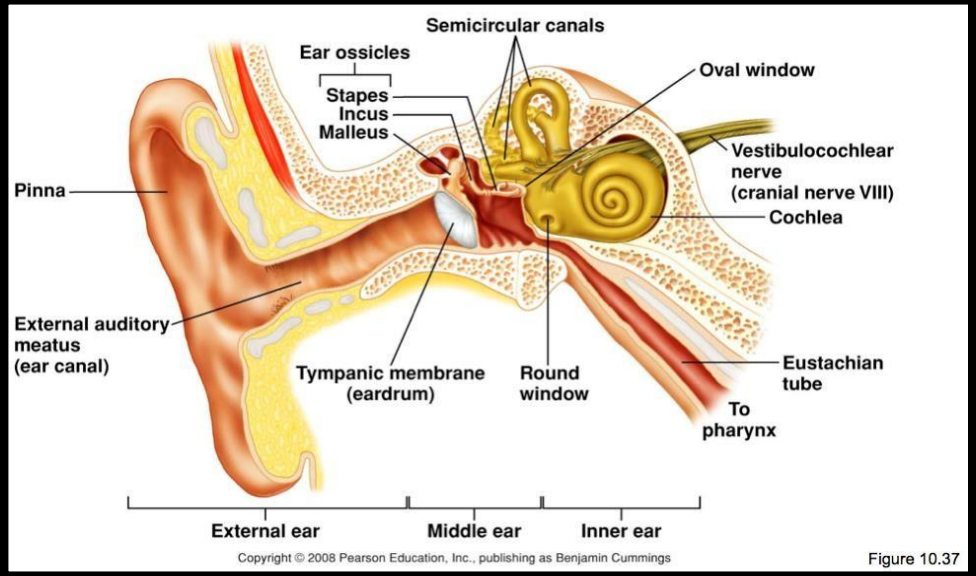
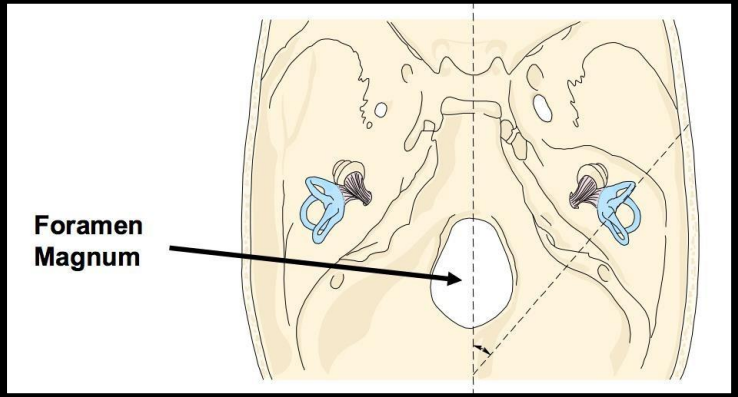
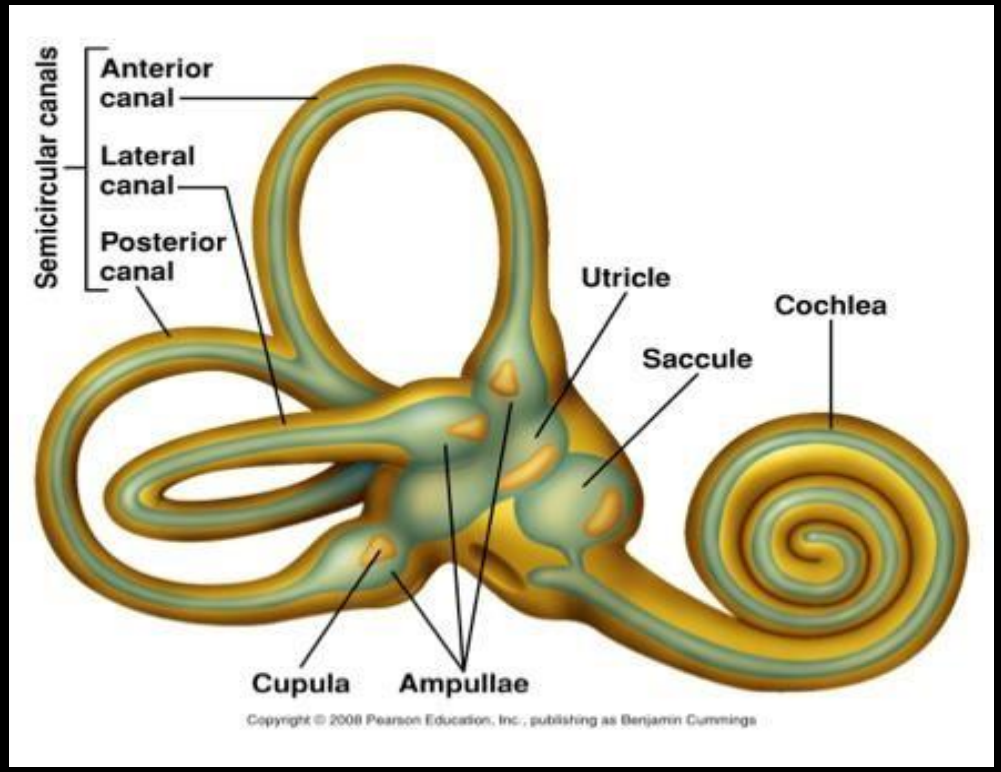


Figure 10.37

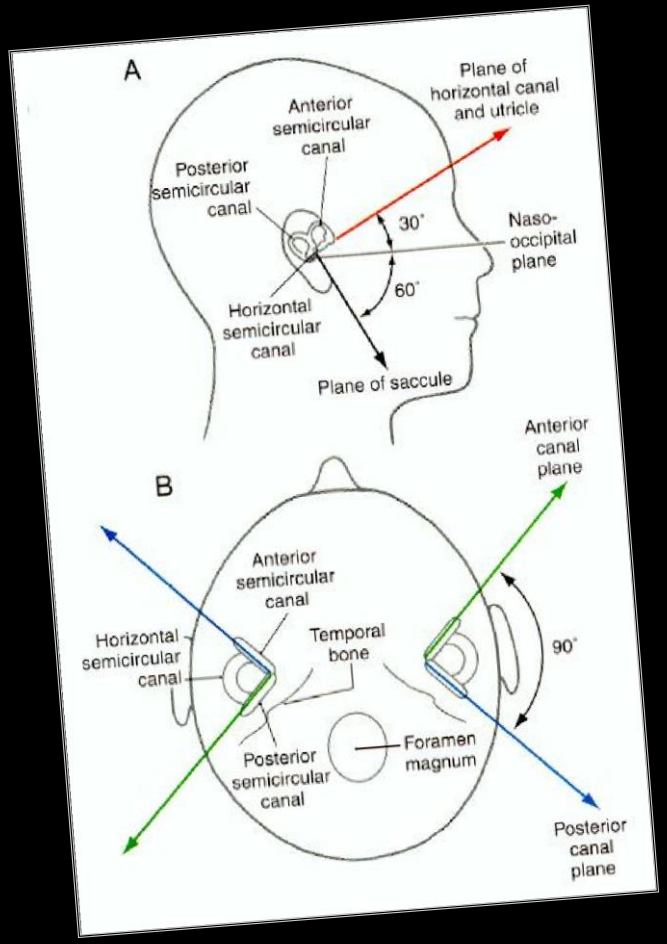


The Vestibular System Parts



- 3 Semicircular Canals
  - Anterior,
    AKA Superior
  - Lateral,
    AKA Horizontal
  - Posterior
- 2 Otolith Organs
  - Utricle
  - Saccule

The Semicircular Canals – Pairings



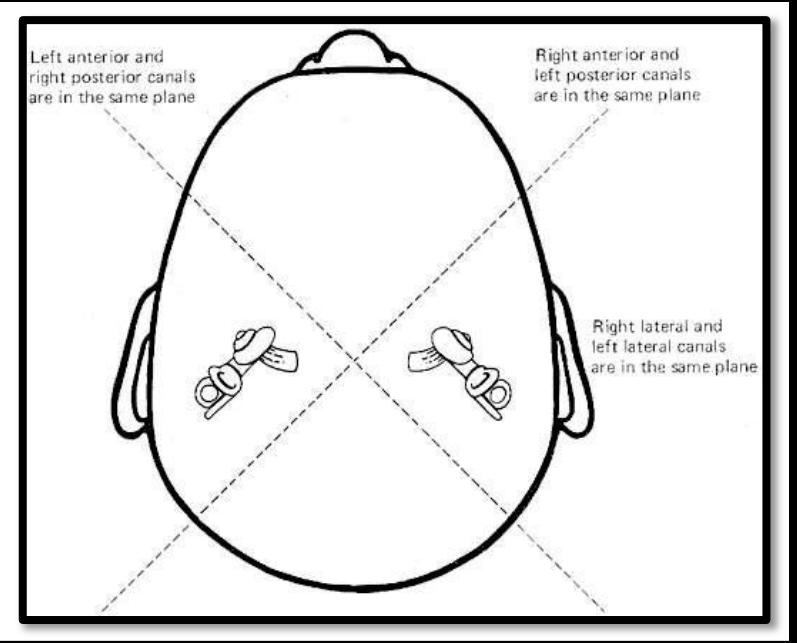
The semicircular canals are <u>functionally paired</u> and sense rotation, or angular acceleration.

- Horizontal Canals: Rotation in the horizontal plane
- Left Anterior and Right Posterior Canals (LARP): Rotation in the vertical plane skewed 45 anteriorly to the left.
- Right Anterior and Left Posterior Canals (RALP): Rotation in the vertical plane skewed 45 anteriorly to the right.

The Semicircular Canals and Eye Muscles

The semicircular canals lie in roughly the same planes as the extraocular muscles:

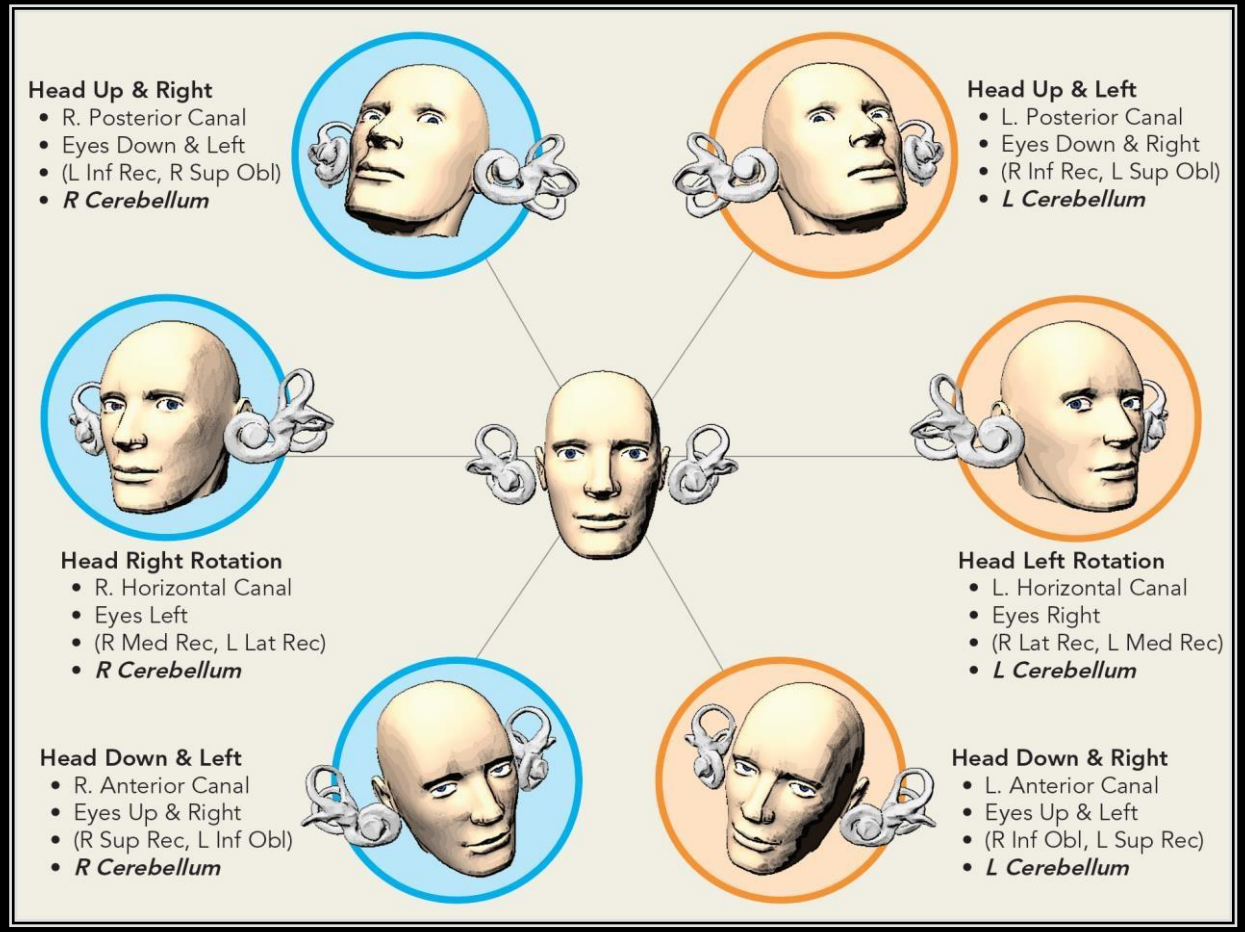
- Horizontal Canals: lateral and medial recti.
- LARP: left vertical recti, right obliques.
- RALP: right vertical recti, left obliques.
- Each canal excites a pair of muscles and inhibits a pair of muscles in its plane.
- Its partner excites the muscles it inhibits, and vice versa.



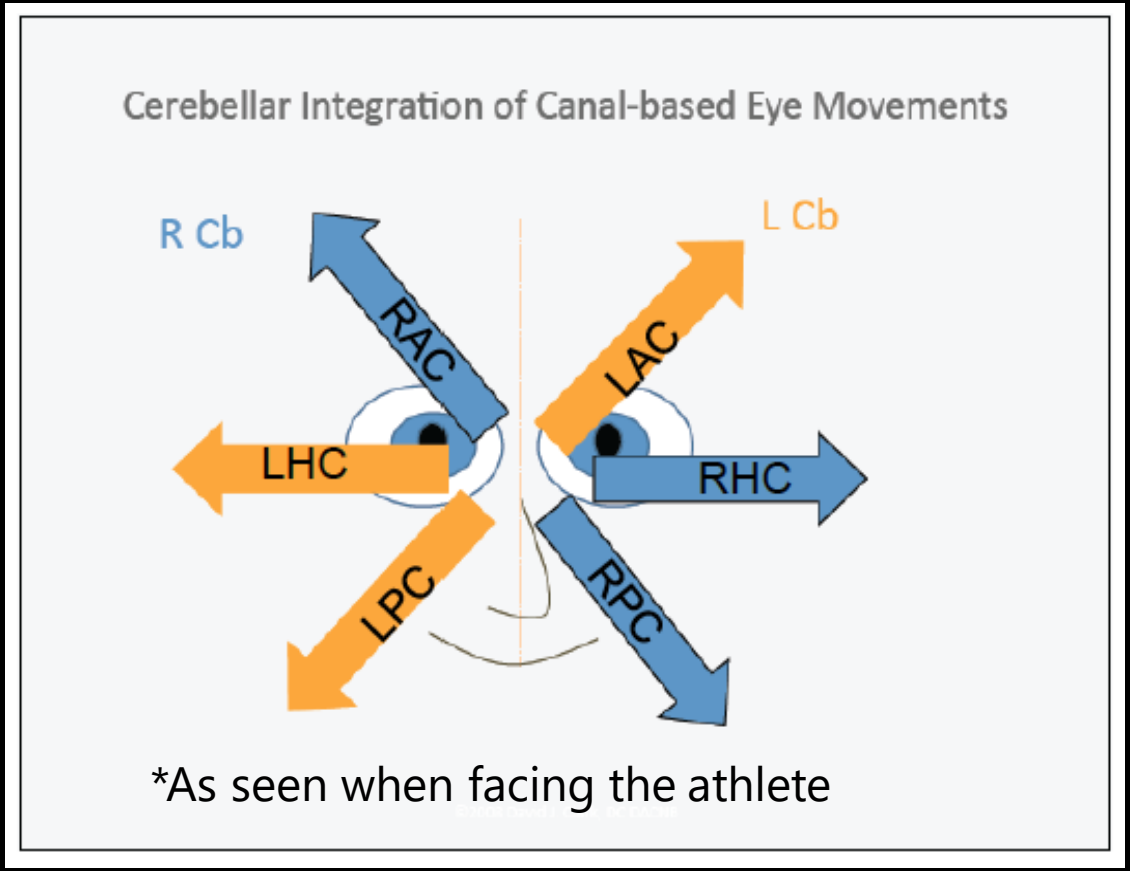
Eye Muscle Connections to Semicircular Canals (VOR)

Movement =	Canal =	Eye Muscles =	Eye Position =
Nose Right	R Horizontal	R Med Rectus, L Lat Rectus	Eyes Left
Nose Left	L Horizontal	L Med Rectus, R Lat Rectus	Eyes Right
Nose Down & Left	R Anterior	R Sup Rectus, L Inf Oblique	Eyes Up & Right
Nose Down & Right	L Anterior	L Sup Rectus, R Inf Oblique	Eyes Up & Left
Nose Up & Right	R Posterior	R Sup Oblique, L Inf Rectus	Eyes Down & Left
Nose Up & Left	L Posterior	L Sup Oblique, R Inf Rectus	Eyes Down & Right

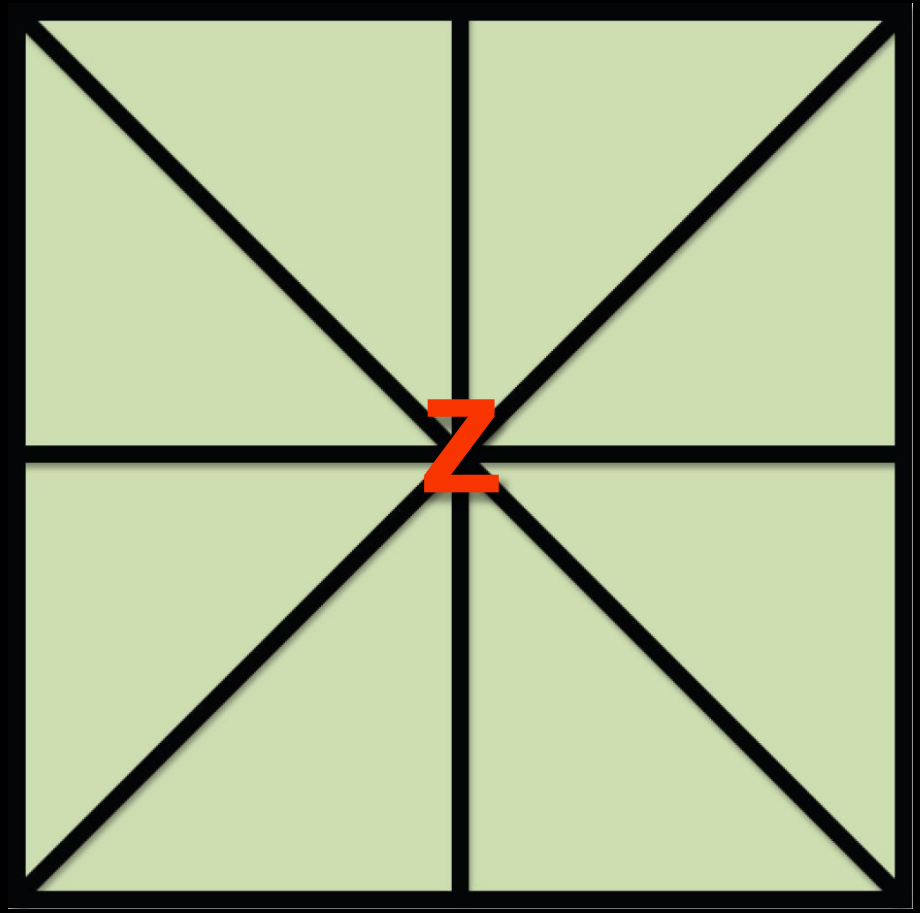
The Vestibulo-Ocular Reflex



Canal-Based Eye Movements (VOR)



Practical VOR Training



Create a BASIC “VOR” Template
for clients to take home.
8 Compass Directions with a centered visual target

Referral – The Professional Approach

Recommended members of your referral network:

1. Z-Health® Trainer
2. General Physician
3. Chiropractic Physician
4. Orthopedic Surgeon
5. Neurologist
6. Pain Management Specialist
7. Behavioral Optometrist (FCOVD)