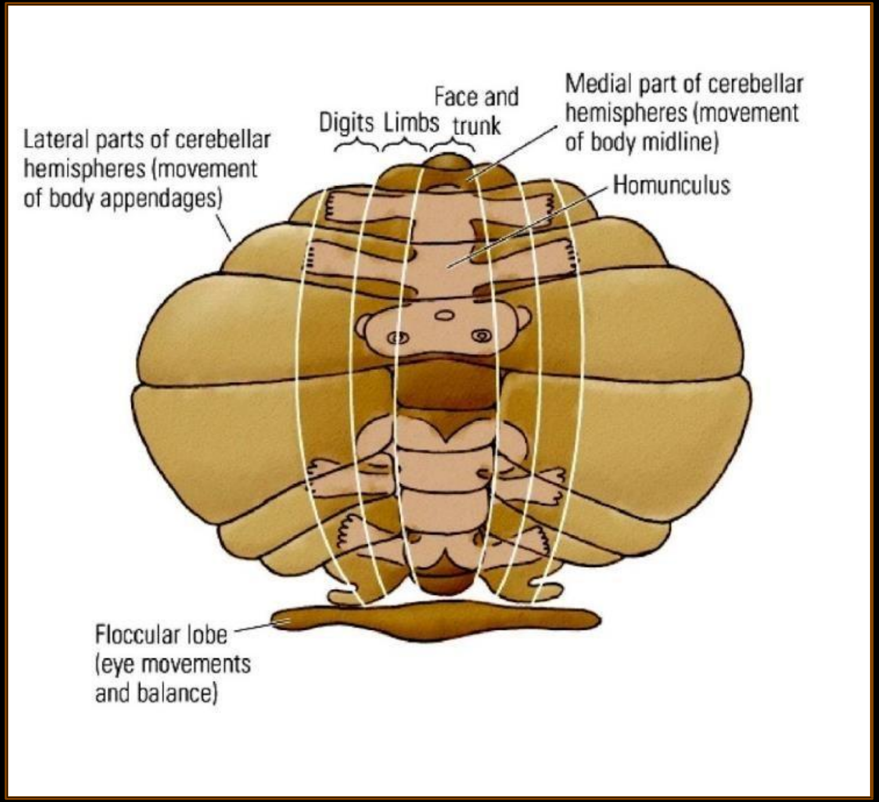
The Cerebellar Contribution to Vision: Clinically Applying the New Neurologic Research with Advanced Eye Movement Techniques

- **Cerebellum, eye motor control and attention center**
- **Areas of clinical interest: the triads**
- **Applying neuro-mechanisms for better clinical outcomes**

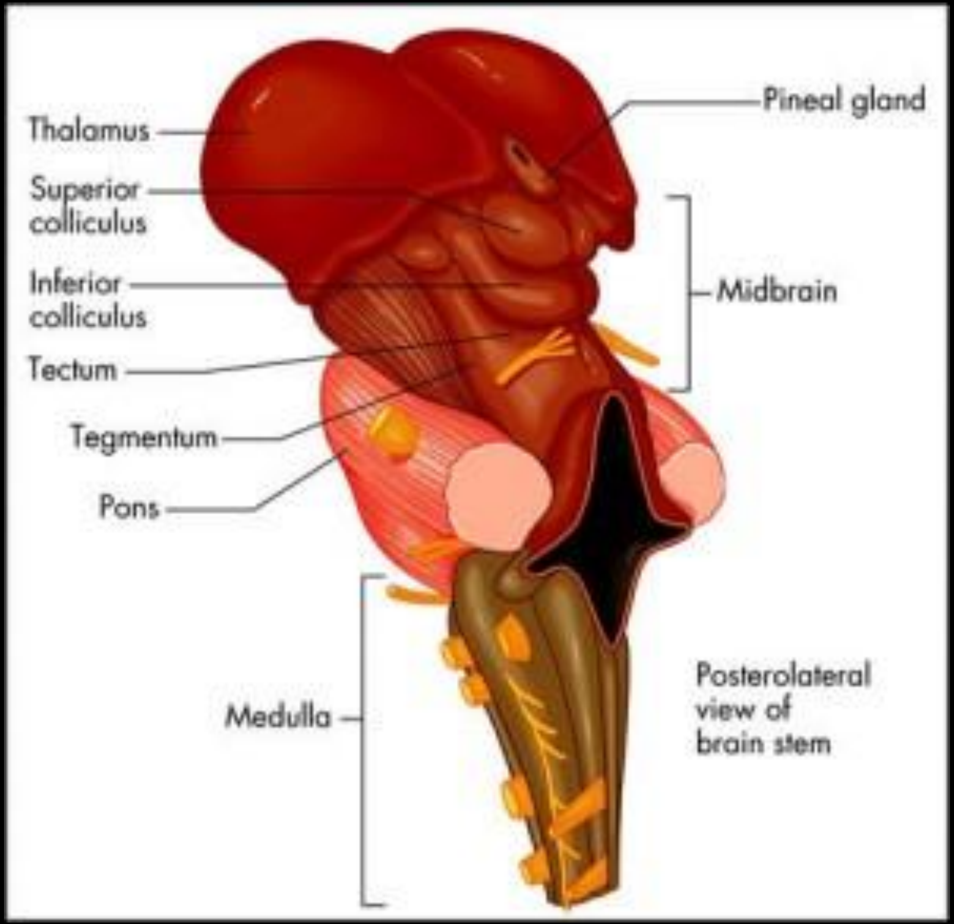
Doug Major OD, FAAO FCOVD ABO CCHP

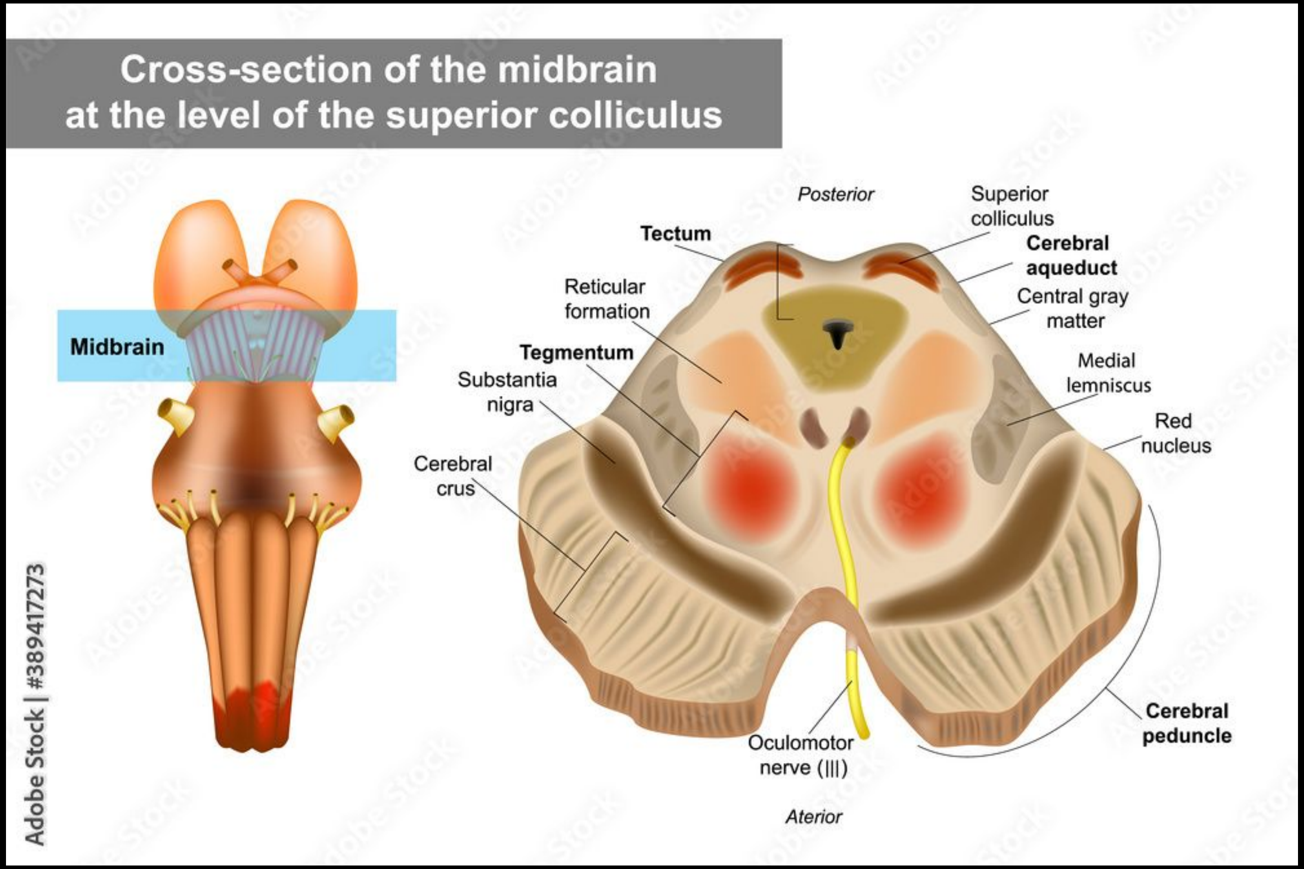


Primary Movement Findings

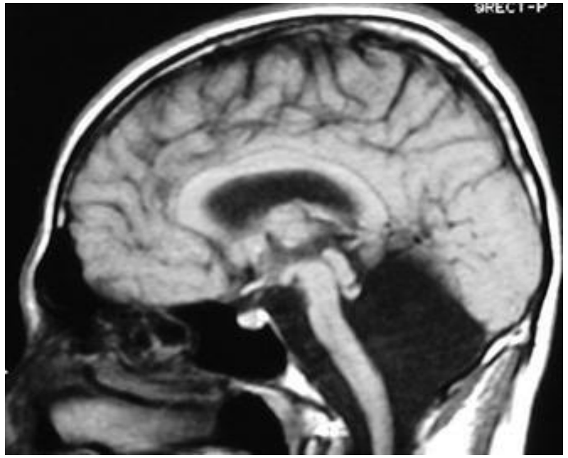
1. Accuracy
2. Balance
3. Coordinatio
n

The Cerebellum was always cut away or hidden behind the PONS in Neuro Anatomy Class!





Cerebellar agenesis is an extremely rare condition. Cerebellar agenesis is a descriptive term implying complete absence of the cerebellum. Living, but with profound neurologic disfunction.



- Damage to the cerebellum can lead to: 1) **loss of coordination of motor movement (a Synergia)**, 2) the inability to judge distance and when to stop (dysmetria), 3) the inability to perform rapid alternating movements (adiadochokinesia), 4) movement tremors (intention tremor), 5) staggering, wide based walking (ataxic gait)

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

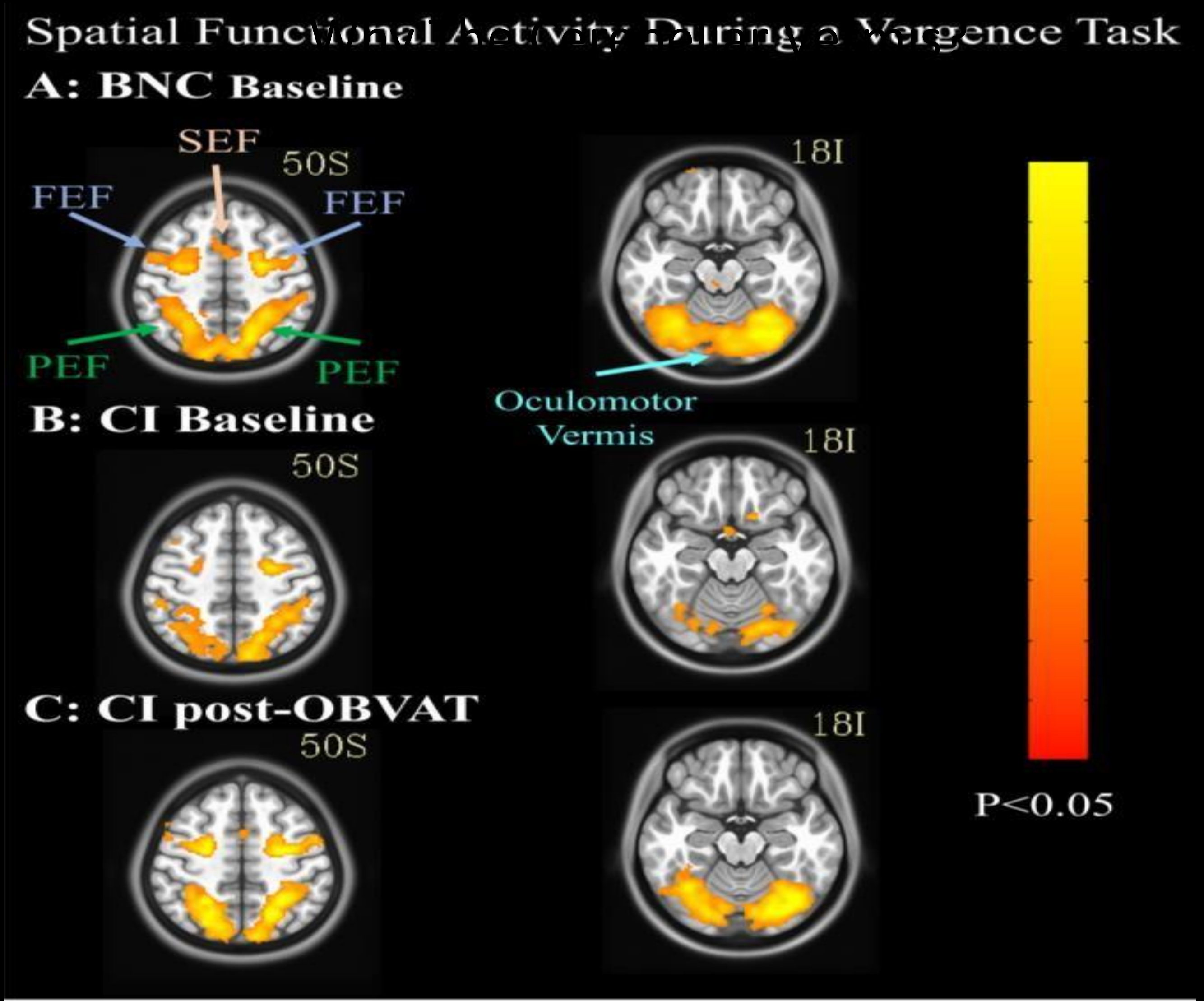


Figure 5: Group-level spatial activation of frontal eye fields (FEF), supplementary eye field (SEF), parietal eye fields (PEF) from axial slice 50S and oculomotor vermis from axial slice 18I using one sample *t*-test of BOLD signal and canonical waveform of experimental design. Data from 25 BNC (plots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

Oculomotor Vermis CHANGES with VT

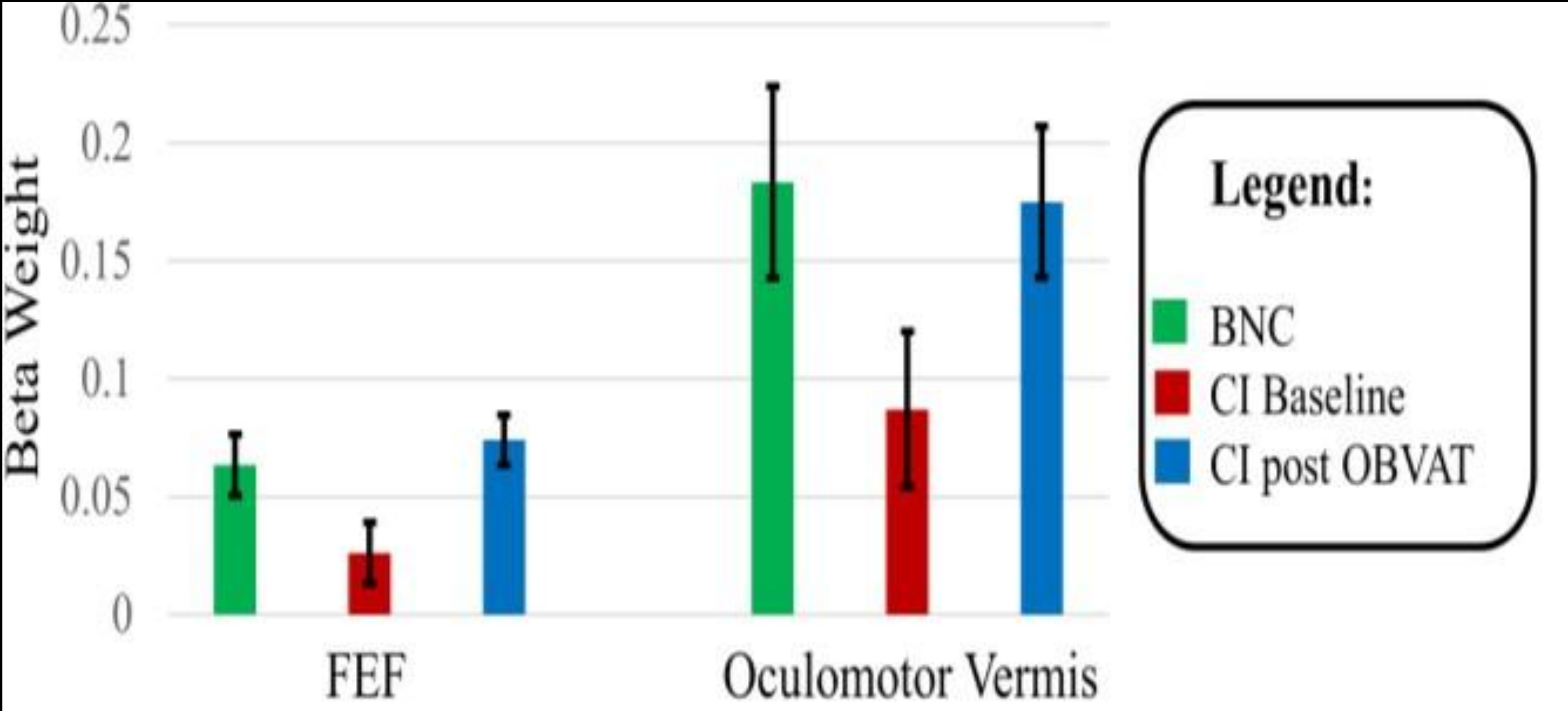
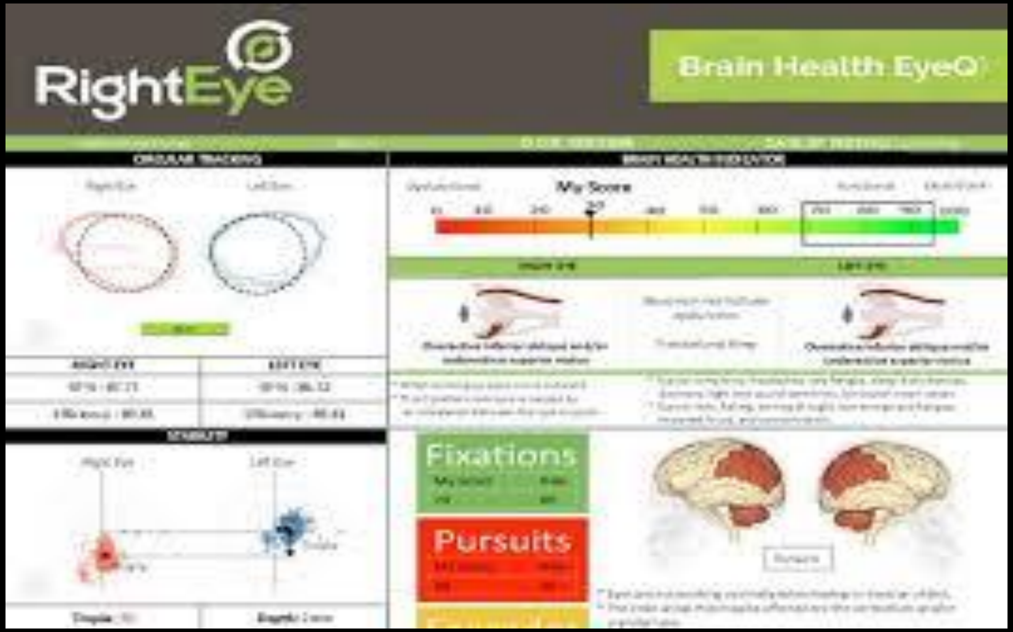
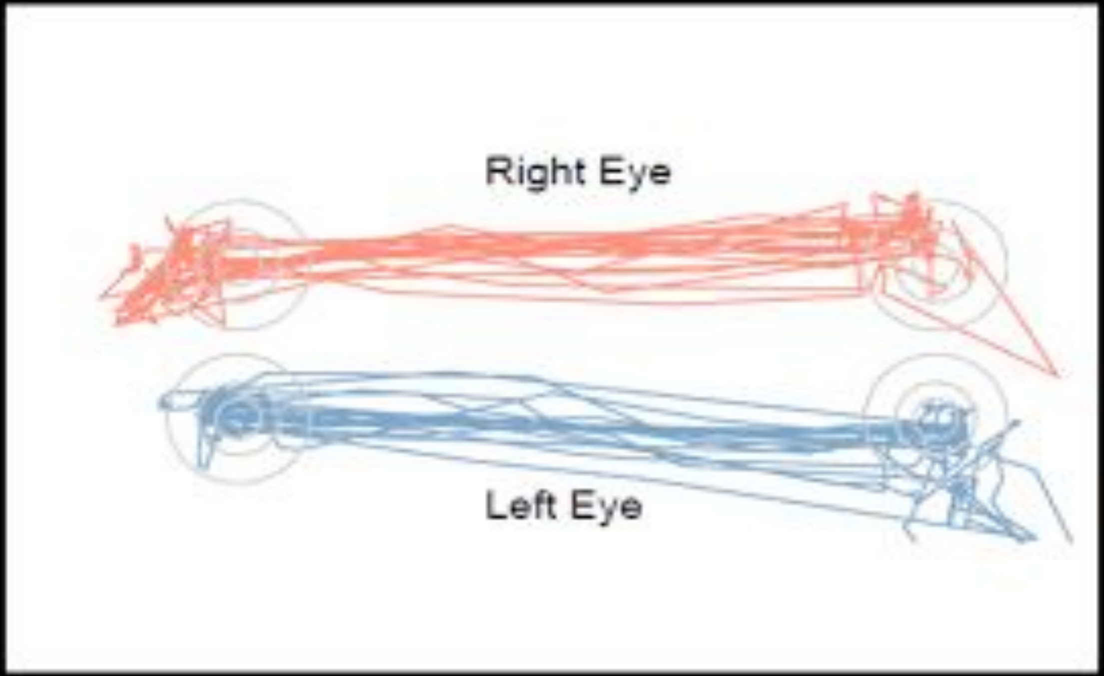


Figure 6: Functional activity mean beta weight ± standard error of mean (SEM) from a 7 mm sphere within Right FEF [MNI (in mm): 26R 8A 52S] and Functional activity mean beta weight ± SEM from a 5 mm sphere within Left Cerebellar Declive called Oculomotor Vermis [MNI: 26L 69P 17I].

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





PERSPECTIVE

A Discussion of Attention Impairments and the Science of Oculomotor Metrics: Concussion and Beyond

Jamshid Ghajar, MD, PhD, FACS
Stanford Brain Performance Center Clinical Professor of Neurosurgery

Doug Major, OD, FAAO, FCOVD, CCHP
Clinical Practice in Paso Robles and Los Osos California
Corresponding Author/Interviewer

EDITOR'S NOTE

This is a compilation of questions and answers directed toward neuro optometric practitioners, based in part on Dr. Ghajar's presentation on "The Eyes Have It: Modern Diagnosis & Treatment of Concussion using Advanced AR/VR platforms" at the 51st Annual Meeting of the College of Optometrists in Vision Development in 2022.

covd.org. https://doi.org/10.31707/ VDR2022.8.4.p225-33.

Ghajar J, Major D. A discussion of attention impairments and the science of oculomotor metrics: concussion and beyond. Vision Dev & Rehab 2022; 8(4):22533.

Jamshid Ghajar, MD, PhD, FACS

Stanford Brain Performance Center Clinical Professor of Neurosurgery

- Founder, SyncThink

SYNCTHINK®

- Consultant, Abbott

Abbott

- President Emeritus,
Brain Trauma Foundation

Brain Trauma FOUNDATION

Disrupted white matter microstructure of the cerebellar peduncles in scholastic athletes with concussion

Jacob M. Mallott[1], Eva M. Palacios[1], Jun Maruta[2,3], Jamshid Ghajar[3,4], Pratik Mukherjee[1,5]*

University of California San Francisco, Icahn School of Medicine at Mount Sinai, Brain Trauma Foundation, Stanford University School of Medicine

Regional Difference in DTI parameters of scholastic athletes with mTBI

Frontiers Neurology 2019

Conclusion:
The prevalence of white matter abnormality in cerebellar tracts lends credence to the hypothesis that post-concussive symptoms are caused by shearing of axons within an attention network mediated by the cerebellum,

and warrant further study of the correlation between cerebellar DTI findings and clinical, neurocognitive, oculomotor and vestibular outcomes in mTBI patients.

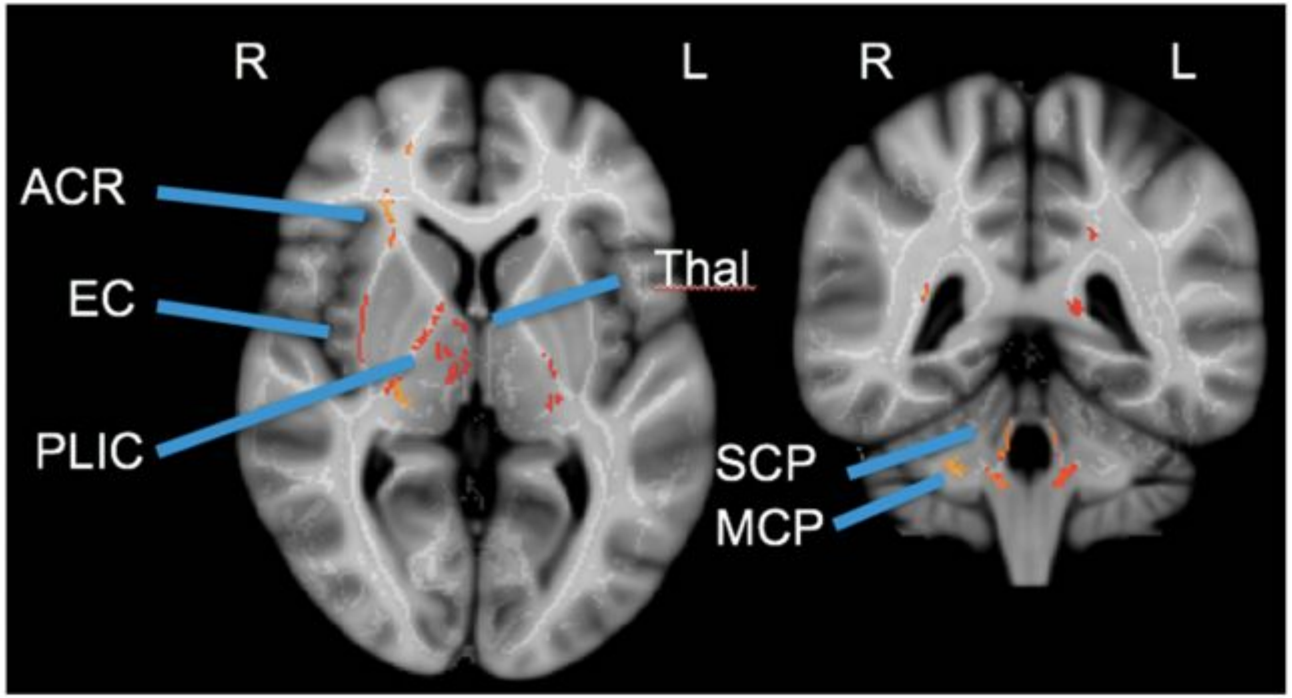
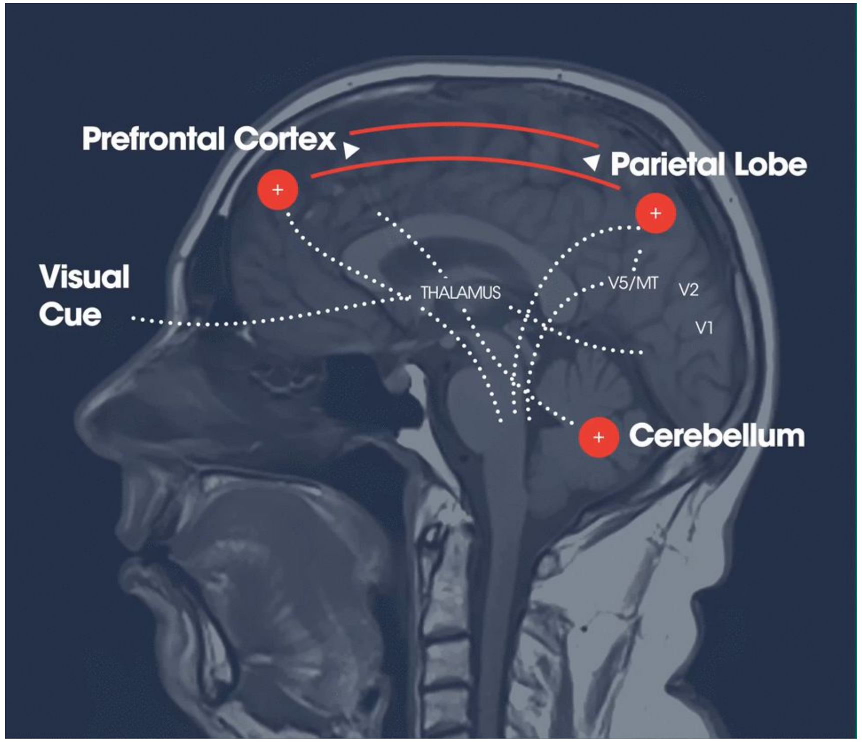


Figure 2. *Cross-Sectional Voxel-wise Comparison: Control > Patient Axial Diffusivity.* Two cross-sections illustrating regions of significant decrease in athlete AD (acute post-injury time point)

- **The Science of Prediction (attention)**
  - Brain in the past
  - Cerebellum
  - Development

- **Sensori-motor variance is the key metric**
  - Ocular-motor: best variance detector
  - XR goggle technology
  - neuro-optometry will lead

- **Clinical applications**
  - Concussion
  - ADHD
  - CNS degenerative
  - Optimization



Major Problem:

The Brain’s Present
is
The Present’s Past

Solution: Prediction

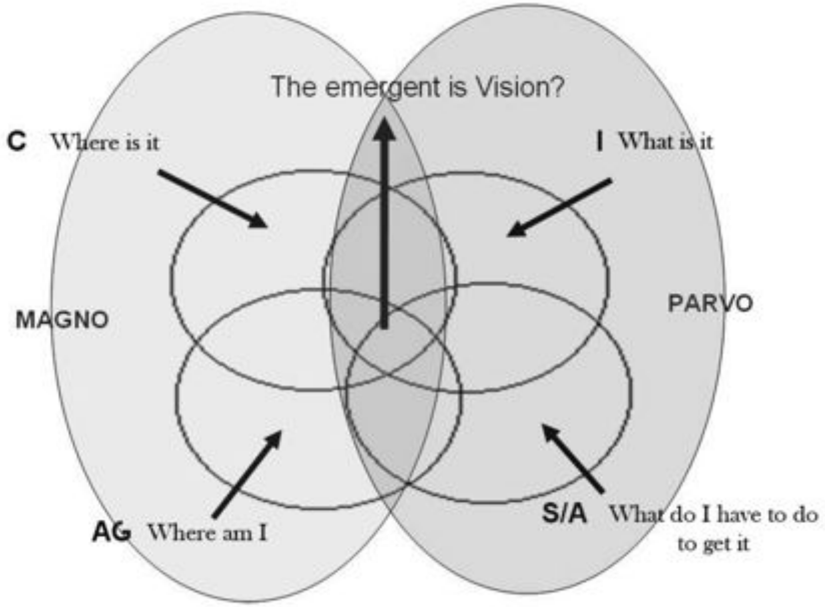
The Brain Has a Hard Problem

It is impossible to be in the Present

You **predict** the **Future**

(To **interact** in the **Present**)

And **experience** the **Past**



Where **What**

A. M. Skeffington, O.D.

Attention: the brain's window to the world

- Spatial (where): Parietal
- Temporal (When): Cerebellum

Processor: Interaction with outside world

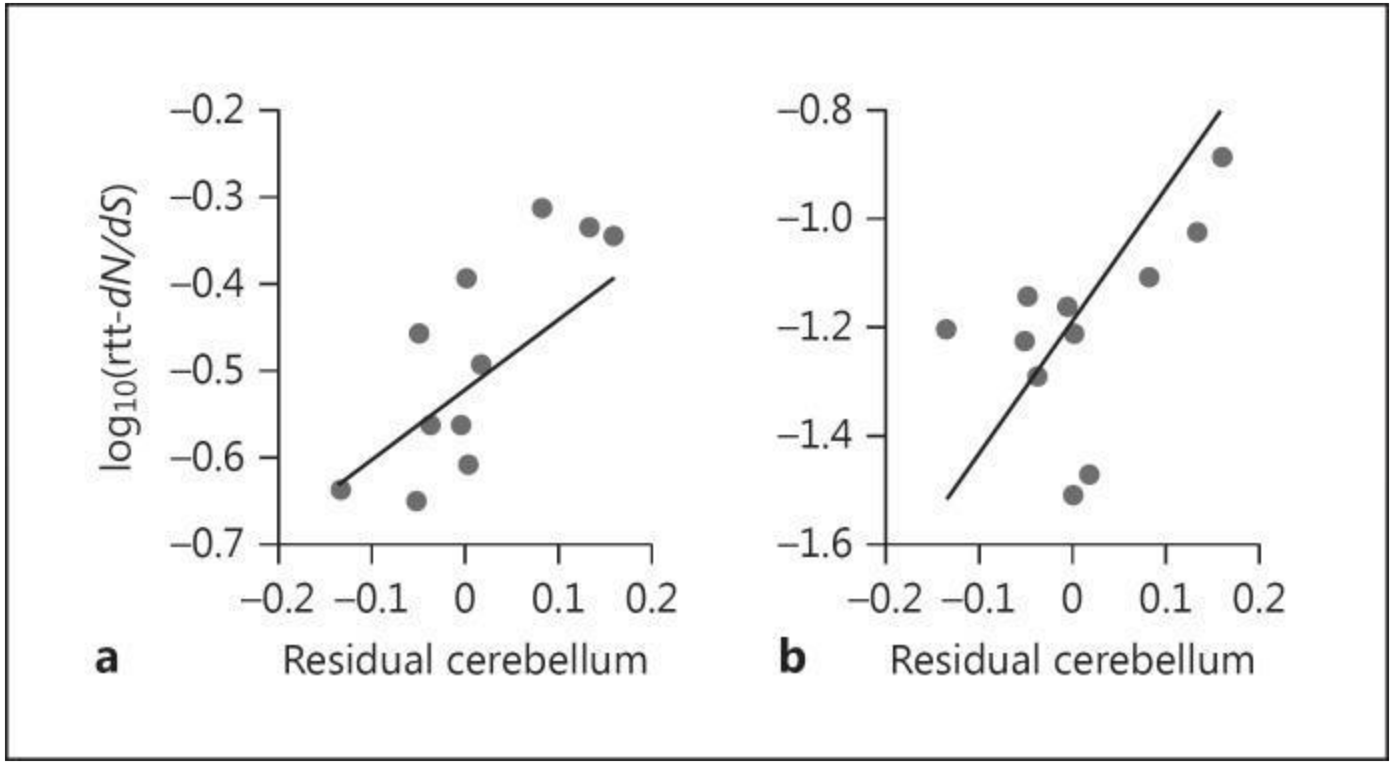
- Cognitive (What): Prefrontal cortex
- Motor: Motor cortex

When?

In humans, the cerebellum contains about 70 billion neurons—four times more than in the neocortex. The cerebellum seems to be particularly involved in the temporal organization of complex behavioral sequences.

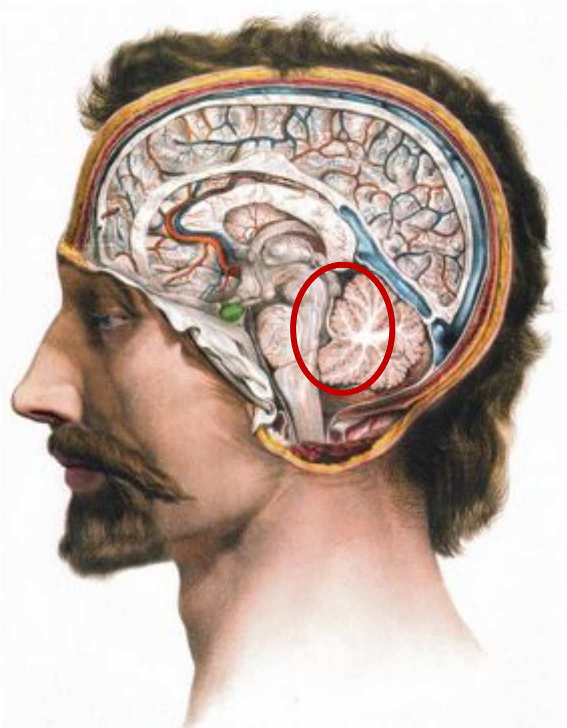
While the neocortex of the brain has been called "the crowning achievement of evolution and the biological substrate of human mental prowess," newly reported evolutionary rate comparisons show that the cerebellum expanded up to six times faster than anticipated throughout the evolution of apes, including humans. *Current Biology* Barton et al. 2014: "Rapid evolution of the cerebellum in humans and other great apes."

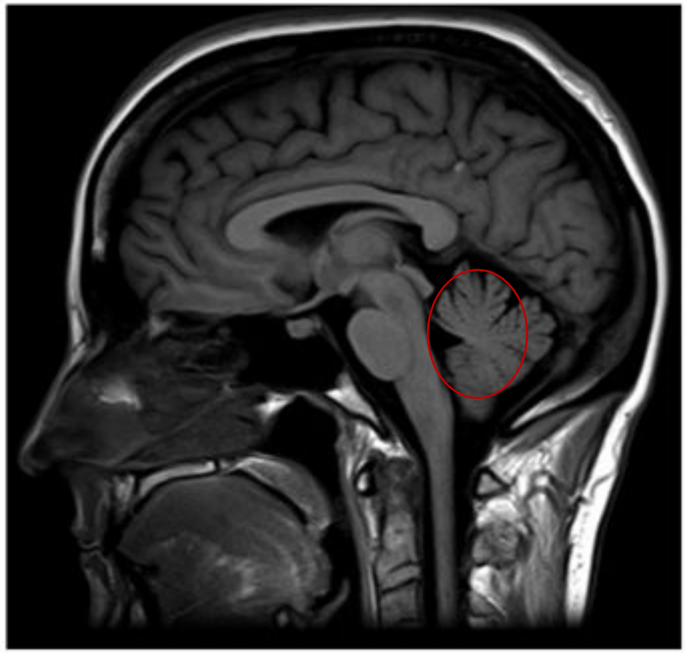
Evolutionary rate comparisons show that the cerebellum expanded up to six times faster than anticipated. Cerebellar prediction frees the neocortex from always being in the "NOW".



More Brain Cells = Better Prediction

About 75% of all brain cells are granule cells in the cerebellum

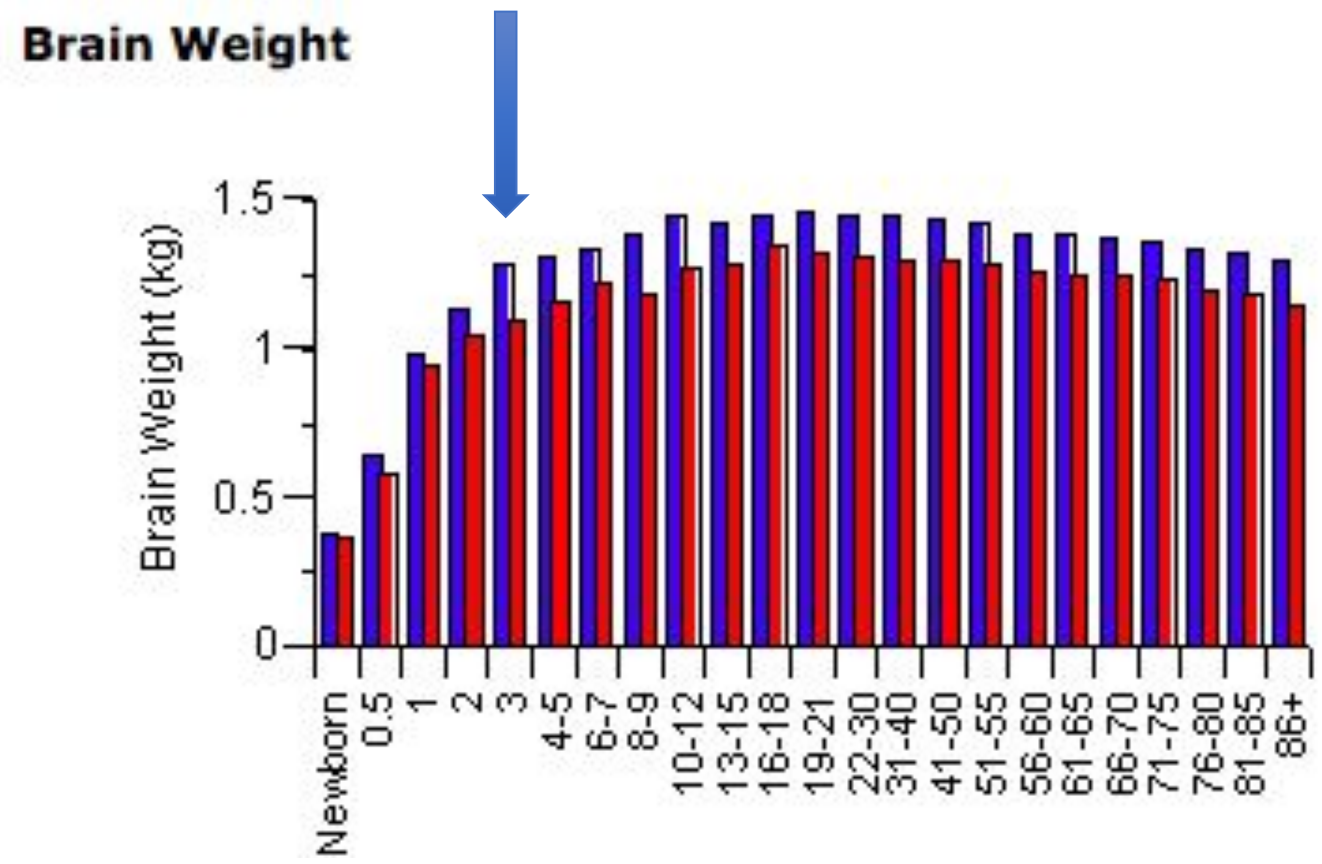




Timing

Brain Growth Over Time

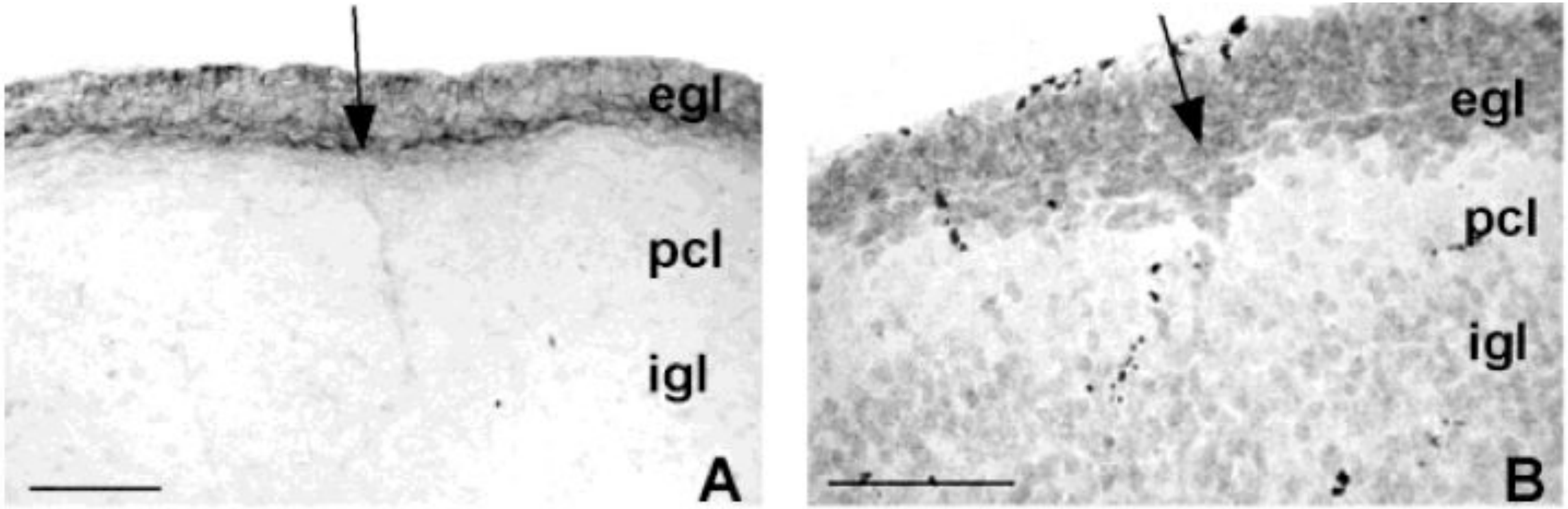
The increase in brain volume during the first year of life is greatest in the cerebellum, which increases in volume by an impressive **88% in the first year**, 15% in the second year, and then more modestly but steadily thereafter.



Critical Age 0-7

Granule Cells Make Connections During Spatial/Temporal Exploration
Age 0-7
Myelination or maybe we should focus on Granulization!

Cells descending into cerebellum



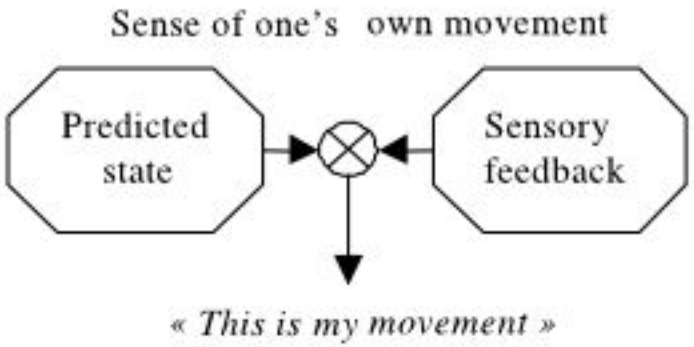
Play is an adaptive neurobiological drive to establish
predictive timing in interactions
that will serve as the timing construct in learning

“Who” Produces Predictive Timing?

The development of SELF

-Toward the end of the second year children develop a sense of self

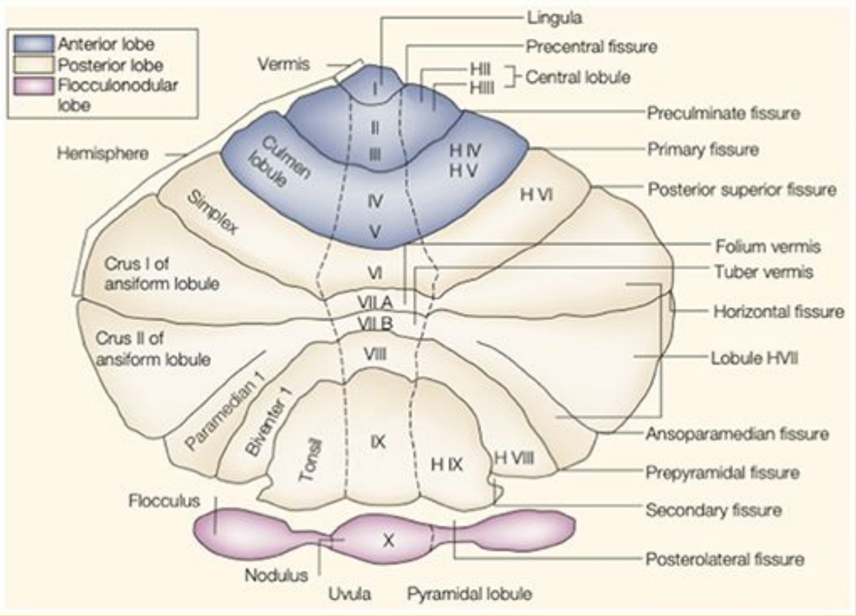
-This is the same time as the appearance of prediction



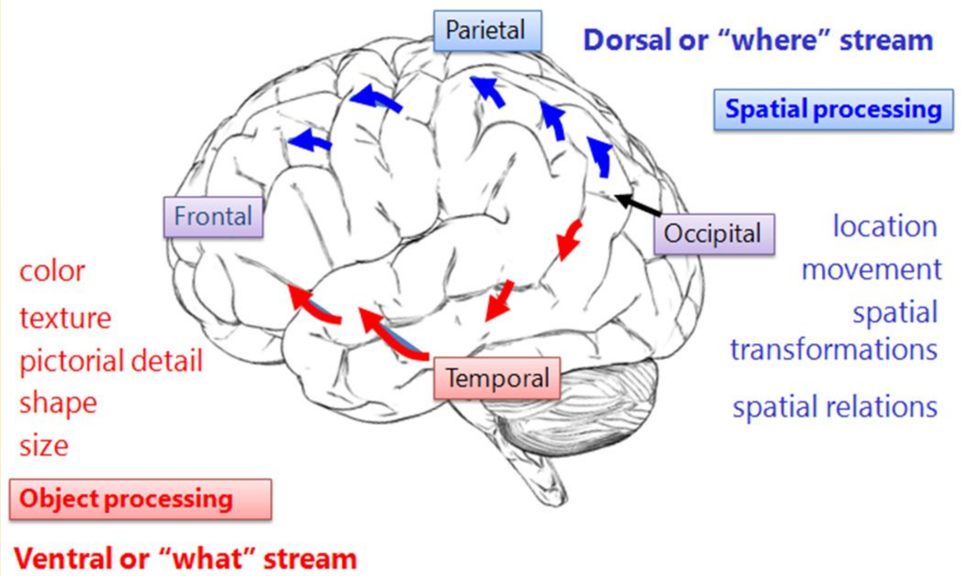
Cerebellar Influence on Visual Processing

- The first evidence in humans for a cerebellar involvement in visual processes derives from work undertaken by Ivry and Diener, who found that cerebellar patients were impaired in making judgments of the velocity of moving stimuli, whereas elementary visual functions (such as visual acuity) remained intact
- Dr. Schmahmann study revealed cerebellar connections were found for dorsal visual stream areas, but not in the ventral visual stream areas.
- Sokolov's study had patients with tumors to the left cerebellum showed that damage to the lateral lobules VIIB, VIIIA, and crus I and II substantially affects visual sensitivity to biological motion.
- Baumann used High field MRI where identified vermal lobule VI and right-hemispheric lobule X (nodulus) as two structures that are significantly more active during visual stimulation than during auditory stimulation
- neuroimaging evidence for direct interaction between the cerebellum and temporal areas involved in visual motion processing and body motion processing (MT/MST and STS), as presented by Drs. Baumann, Mattingley, Pavlova and Sokolov
- No functional link was found in these studies between cerebellum and primary visual cortex

- **WE are the Where and When Vision Care Providers!**

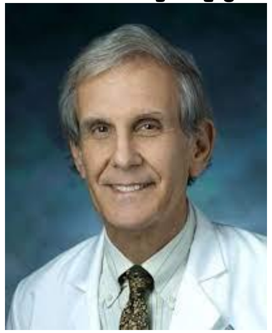


Manni E, Petrosini L. A century of cerebellar somatotopy: a debated representation. Nat Rev Neurosci. (2004) 5:241–9. doi: 10.1038/nrn1347



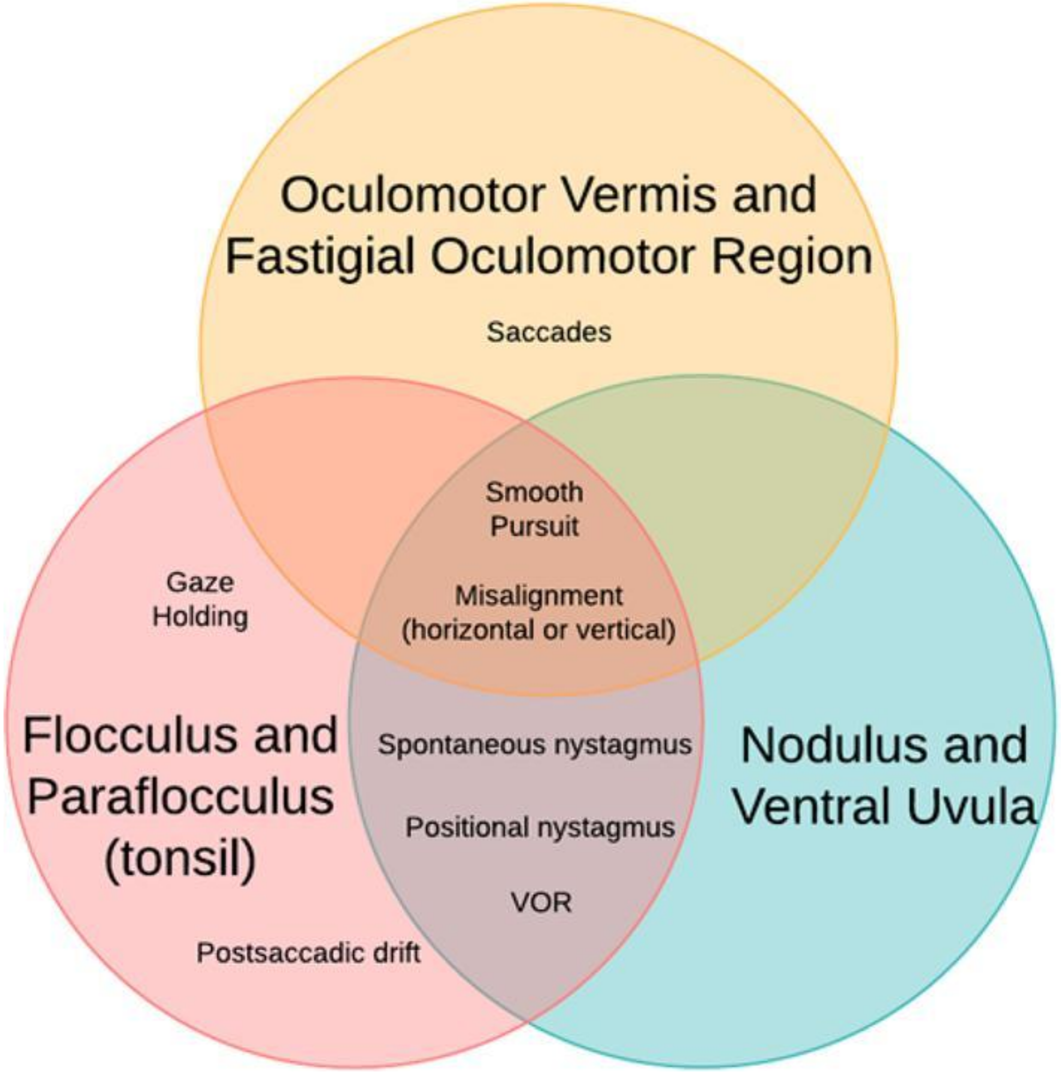
https://www.google.com/url?sa=i&url=https%3A%2F%2Fvisionhelp.wordpress.com

Eye Movement Disorders and the Cerebellum Ari A. Shemesh and David S. Zee (J Clin Neurophysiol 2019;36: 405–414)



- Summary: The cerebellum works as a network hub for optimizing eye movements through its mutual connections with the brainstem and beyond. Here, we review three key areas in the cerebellum that are related to the control of eye movements:
- (1) the flocculus/paraflocculus (TONSIL) complex, primarily for high-frequency, transient vestibular responses, and also for smooth pursuit maintenance and steady gaze holding;
- (2) the nodulus/ventral uvula, primarily for low-frequency, sustained vestibular responses (UVULA)
- (3) the dorsal vermis (OVM)/ posterior fastigial nucleus (FOR), primarily for the accuracy of saccades. (HARD PALETE)
- Although there is no absolute compartmentalization of function within the three major ocular motor areas in the cerebellum, the structural–functional approach provides a framework for assessing ocular motor performance in patients with disease that involves the cerebellum or the brainstem.
- (J Clin Neurophysiol 2019;36: 405–414)

OVERLAPPING OCULAR MOTOR FUNCTIONS AND ABNORMALITIES IN THE CEREBELLUM



The question "What is a cerebellar eye sign?" has always been complicated by the unique features of the connectivity and function of the cerebellum.

First, precise localization to the cerebellum can be confounded by the intimate afferent and efferent connections of the cerebellum with the brainstem, the thalamus and beyond Second, the cerebellum has a fundamental role in maintaining accurate and precisely calibrated motor performance, showing a robust adaptive capability that promptly responds to the changes required in the face of normal development and aging and also disease and trauma. Unless you see a patient within seconds of the onset of a neurologic insult, any abnormalities will reflect not only the immediate damage but also the attempt of the cerebellum to "repair" the problem. In other words, a previously repaired imperfection may be revealed when there is a new damage to the cerebellum. Furthermore, more than one area in the cerebellum may participate in the same function, though perhaps not to the same degree. Thus, one part of the cerebellum can attempt to substitute (and hide a defect)

TAKE HOME Messages/"Plasticity on Steroids in the CBell"

- **Eye movements abnormalities are easy to observe clinically and to measure and quantify**, making them excellent markers for assessing diseases that involve the cerebellum.
- Lesions in the flocculus and paraflocculus (tonsil) lead to spontaneous downbeat nystagmus, defects in eccentric gaze holding, impaired smooth pursuit, and abnormalities of high-frequency, high-velocity brief head rotations (head impulses).
- Lesions in the nodulus and ventral uvula lead to spontaneous downbeat nystagmus, periodic alternating nystagmus, and changes in the response to low-frequency, sustained head rotations.
- Lesions in the dorsal vermis and underlying fastigial nuclei lead to inaccurate saccades: hypermetria with bilateral fastigial nucleus lesions and hypometria with bilateral dorsal vermis lesions.
- There is no absolute compartmentalization of function within the three major ocular motor areas in the cerebellum; however, this redundancy is beneficial as part of the essential role that the cerebellum plays in maintaining movements accurate in the face of disease, trauma, natural development and aging.
- New technology – for example, quantitative bedside video-oculography, high-resolution structural and functional imaging, and transcranial direct current stimulation– enables better localization and characterization of cerebellar deficits. This informtiaon **will assist in developing better diagnostic algorithms, and novel treatments,** including medications and **rehabilitation programs** that can **take advantage of the central role of the cerebellum in monitoring and adjusting movements to keep them accurate**.

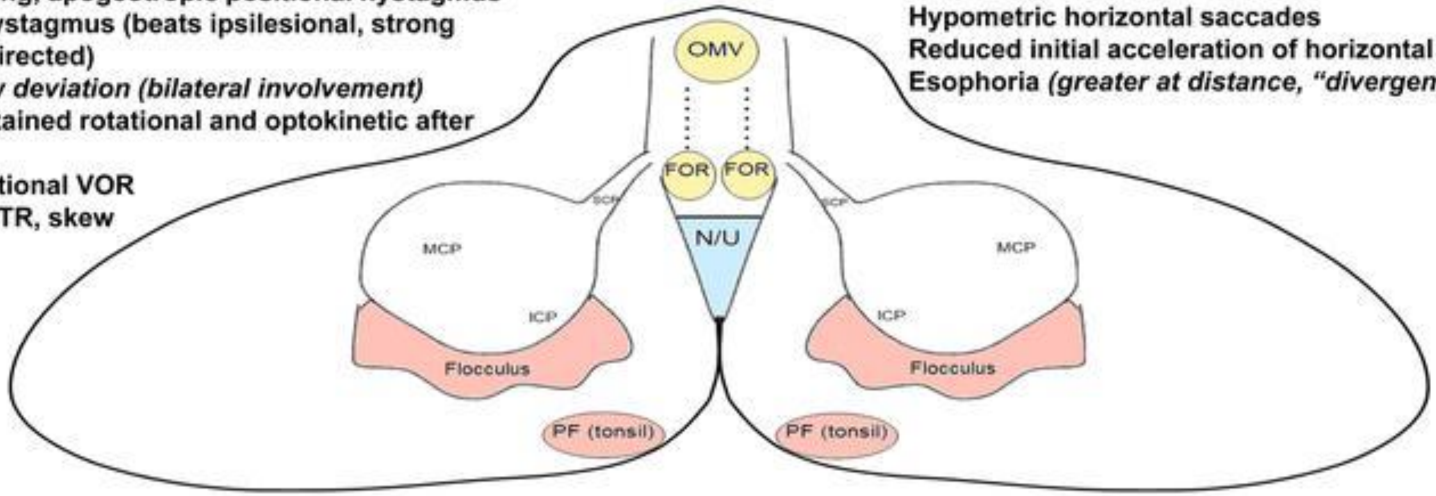
Topical Localization in the Cerebellum

(Italics, provisional localization)

NODULUS AND VENTRAL UVULA
Prolonged horizontal rotational VOR
Periodic alternating nystagmus (PAN)
Impaired habituation of VOR
Loss of tilt suppression of post-rotatory nystagmus
Downbeat nystagmus
Impaired vertical (up-down asymmetry) pursuit
Direction changing, apogeotropic positional nystagmus
Head-shaking nystagmus (beats ipsilesional, strong reversal or misdirected)
Alternating skew deviation (bilateral involvement)
Misdirected sustained rotational and optokinetic after nystagmus.
Impaired translational VOR
Contraversive OTR, skew

OCULAR MOTOR VERMIS (V,VI,VII)
Unilateral:
- Hypermetric contraversive saccades.
- Hypometric ipsiversive saccades
- Reduced initial acceleration of ipsilateral pursuit

Bilateral:
- Hypometric horizontal saccades
- Reduced initial acceleration of horizontal pursuit
- Esophoria *(greater at distance, "divergence paralysis")*



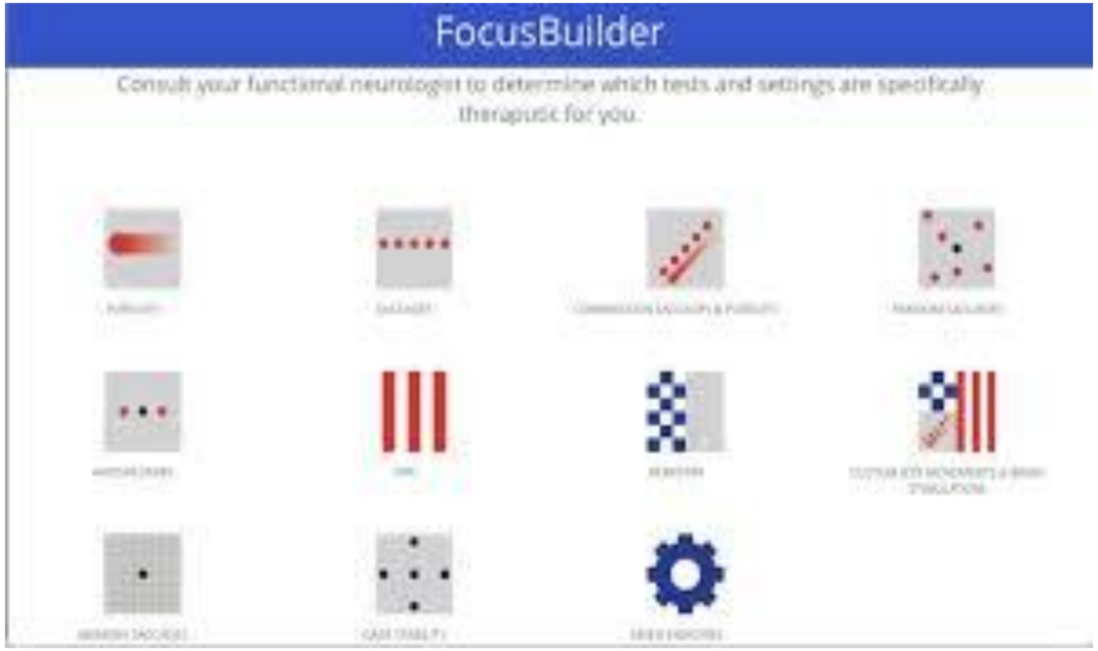
OMV – Oculomotor Vermis; FOR – Fastigial Oculomotor Region; PF – Paraflocculus; N/U – Nodulus and Ventral Uvula; SCP – Superior Cerebellar Peduncle; MCP – Middle Cerebellar Peduncle; ICP – Inferior Cerebellar Peduncle.

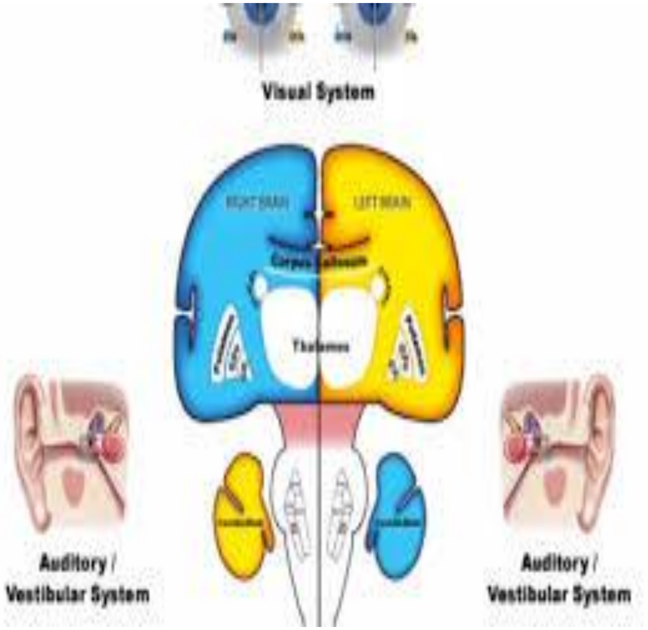
FLOCCULUS/PARAFLOCCULUS (TONSIL)
Downbeat, gaze-evoked, rebound, centripetal nystagmus
Impaired horizontal and vertical (up-down asymmetry) smooth pursuit
Impaired cancellation of VOR in passive combined eye-head movement
Abnormal amplitude (more robust contralesional) and direction of head impulse response
Contraversive OTR
Alternating skew deviation (bilateral injury)
Abnormal torsion with vertical pursuit (brachium pontis)
Direction changing, geotropic positional nystagmus
Impaired VOR adaptation

FASTIGIAL OCULOMOTOR REGION
Unilateral:
- Hypermetric ipsiversive saccades.
- Hypometric contraversive saccades
- Reduced contralateral initial acceleration of pursuit and gain
- Downward pursuit gain is reduced

Bilateral:
- Hypermetric horizontal and vertical saccades
- Macrosaccadic oscillations
- *Normal pursuit*
- Exophoria
- *Saccade intrusions (square wave jerks)*

(Globose/Emboliform – *esophoria, downward saccades dysmetria)*





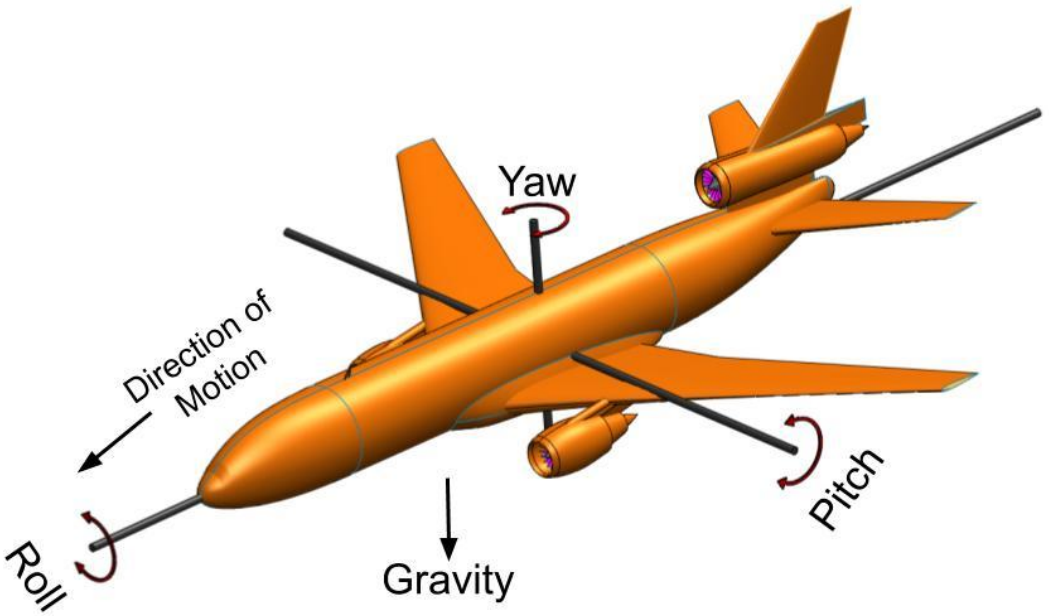
FOCUS BUILDERS, Cedrick Noel, DC and Jason Whittiker,DC

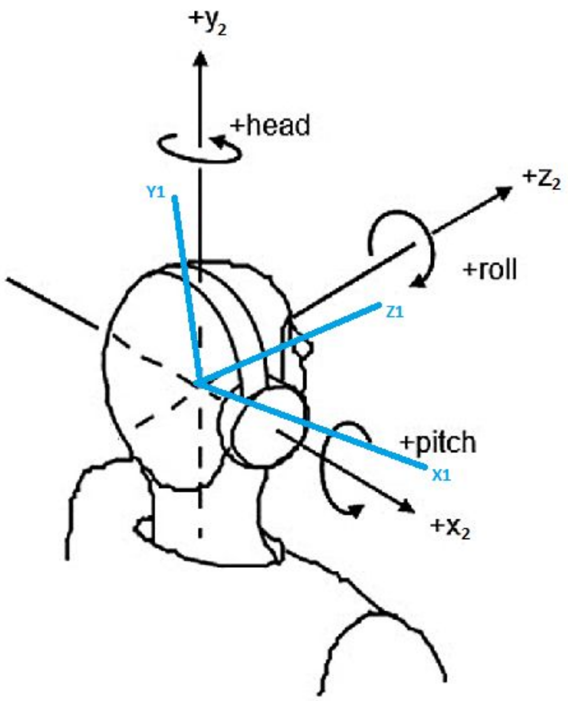
Semi Circular Canals activation TRIAD

Pitch YES YES YES

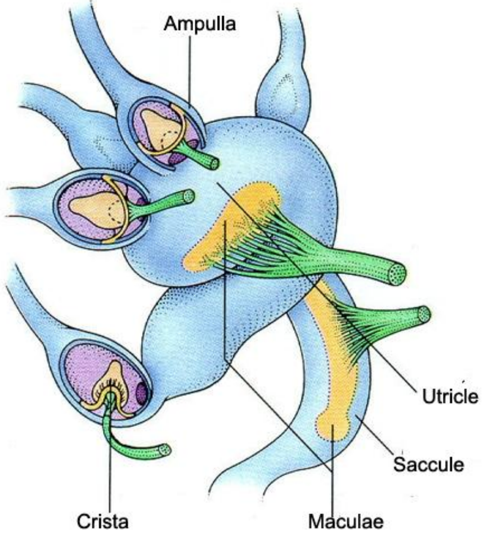
Yaw NO NO NO

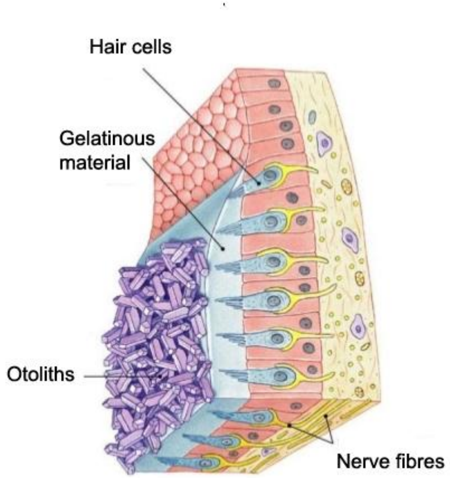
Roll EAR EAR EAR

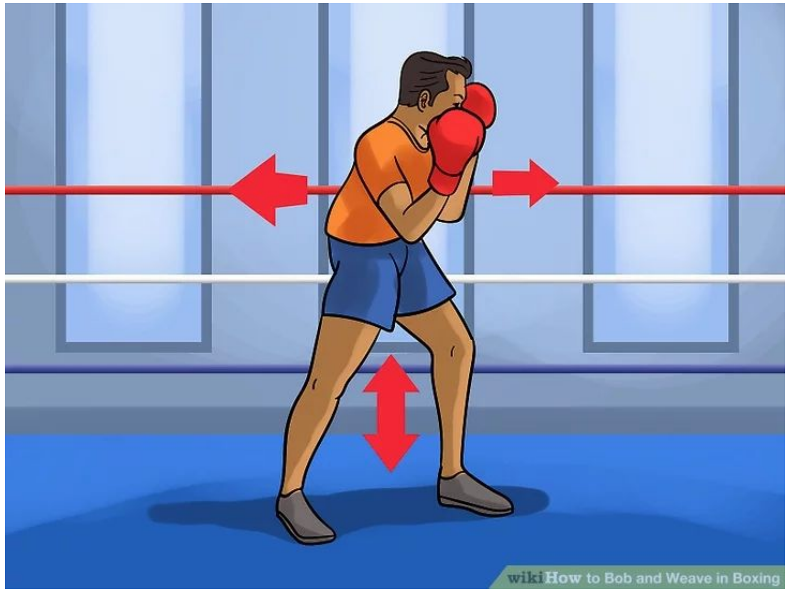


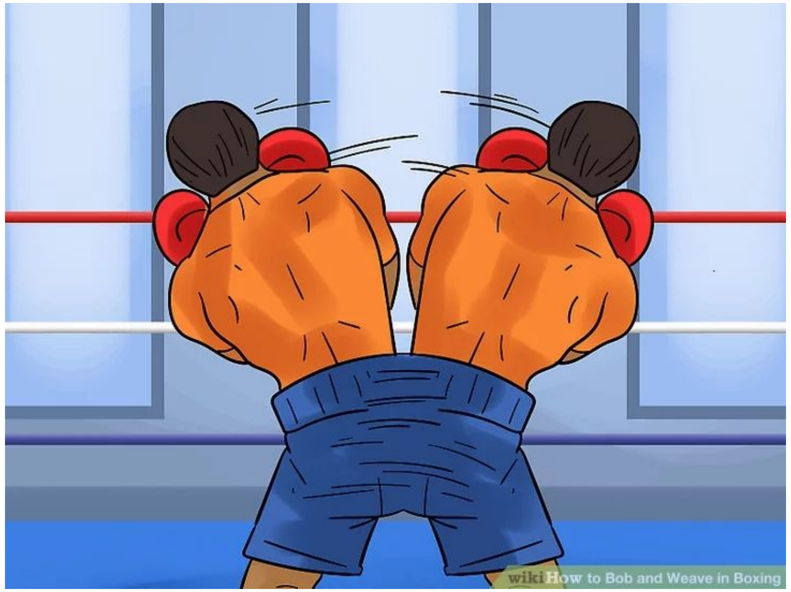


Otolith Translational Triad: Body ROCKS
Bob: Up-Down-Up (Pepper!)
Weave: side-straight-side
Lounge: forward-back-forward







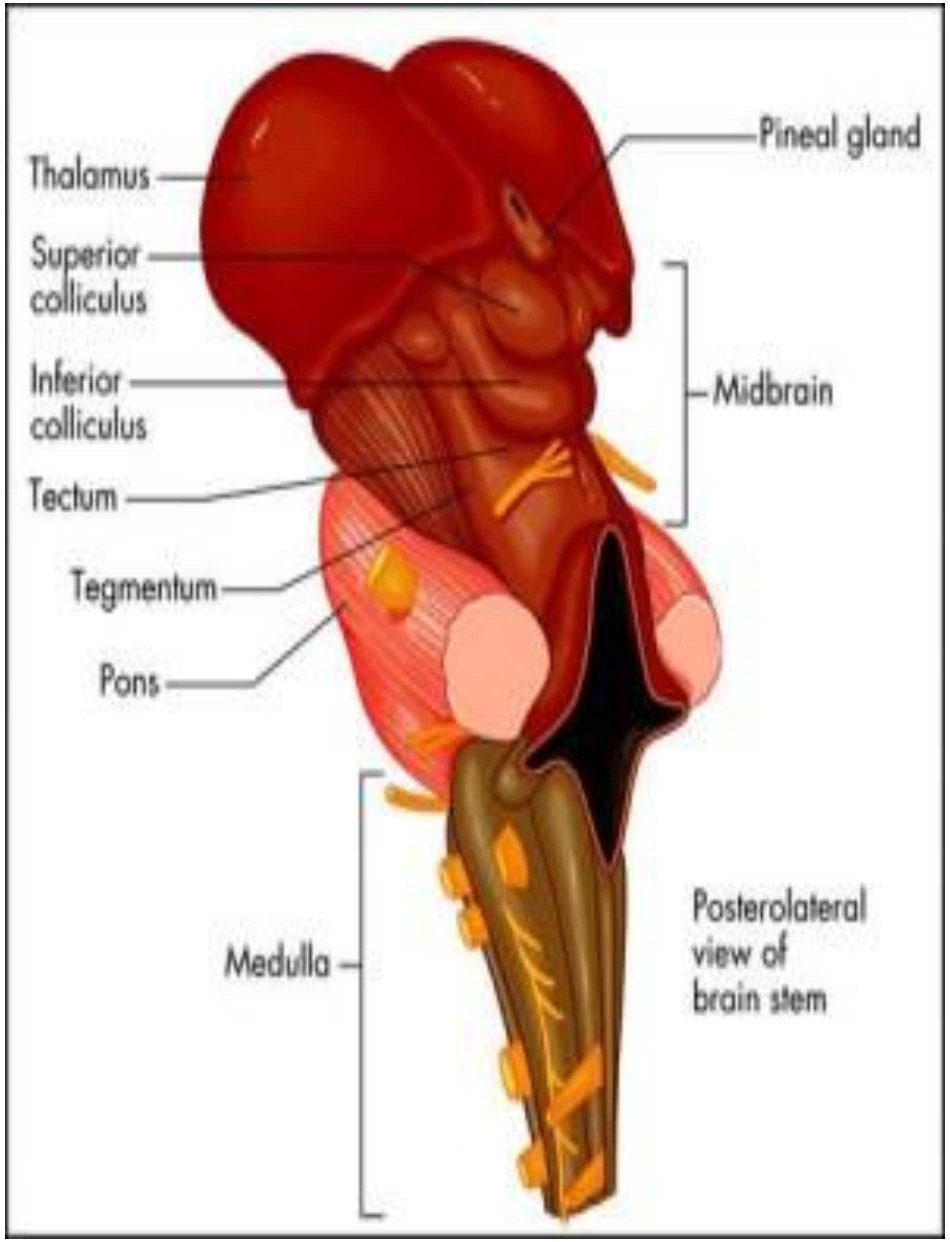


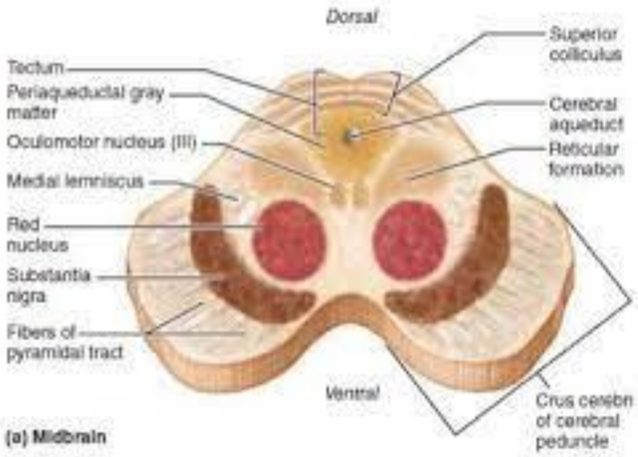
Perceptual World Mapping Triad

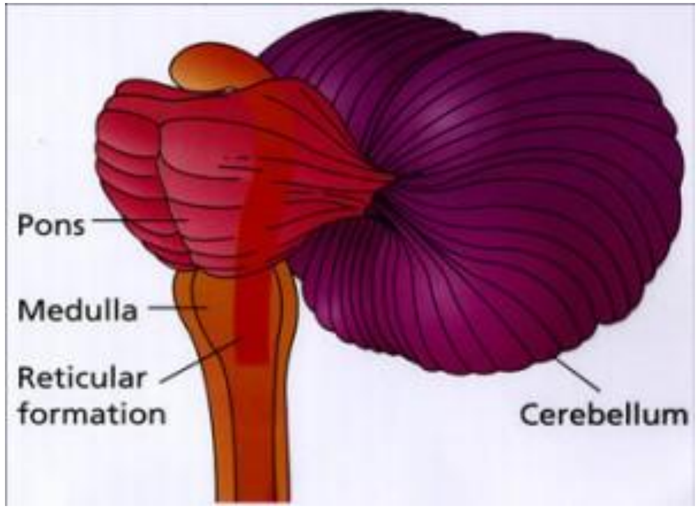
Superior Colliculus: Visual world map

Inferior Colliculus: Auditory and Anti-gravity map

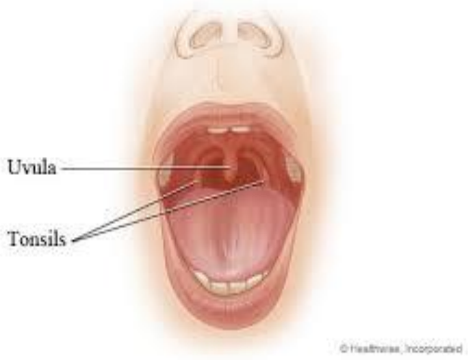
Cerebellum: Attention to all the inputs and calculation of the possible timeline of the predictive future



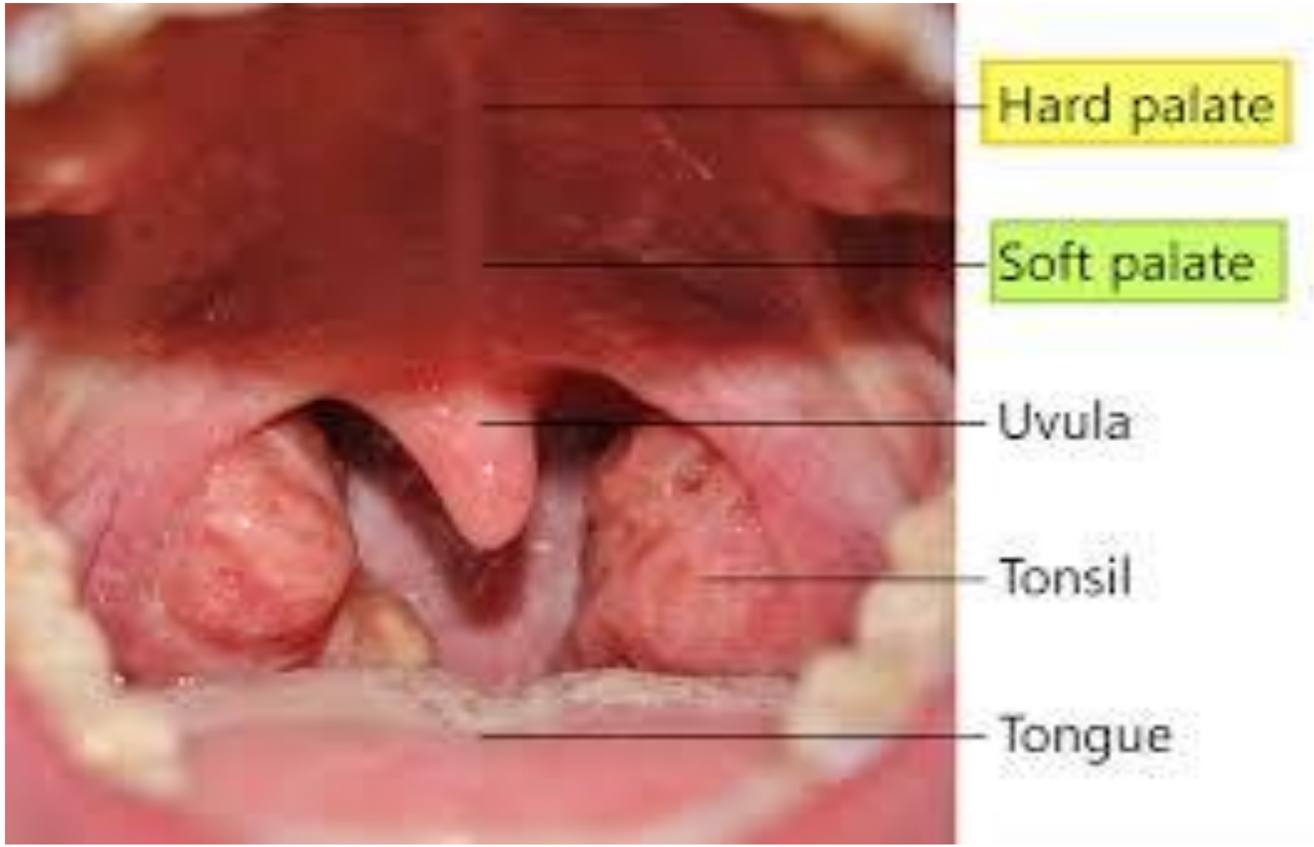




Triad of Interest, Embodiment descriptors of the Cerebellum



Vermis/Tonsils/Uvula



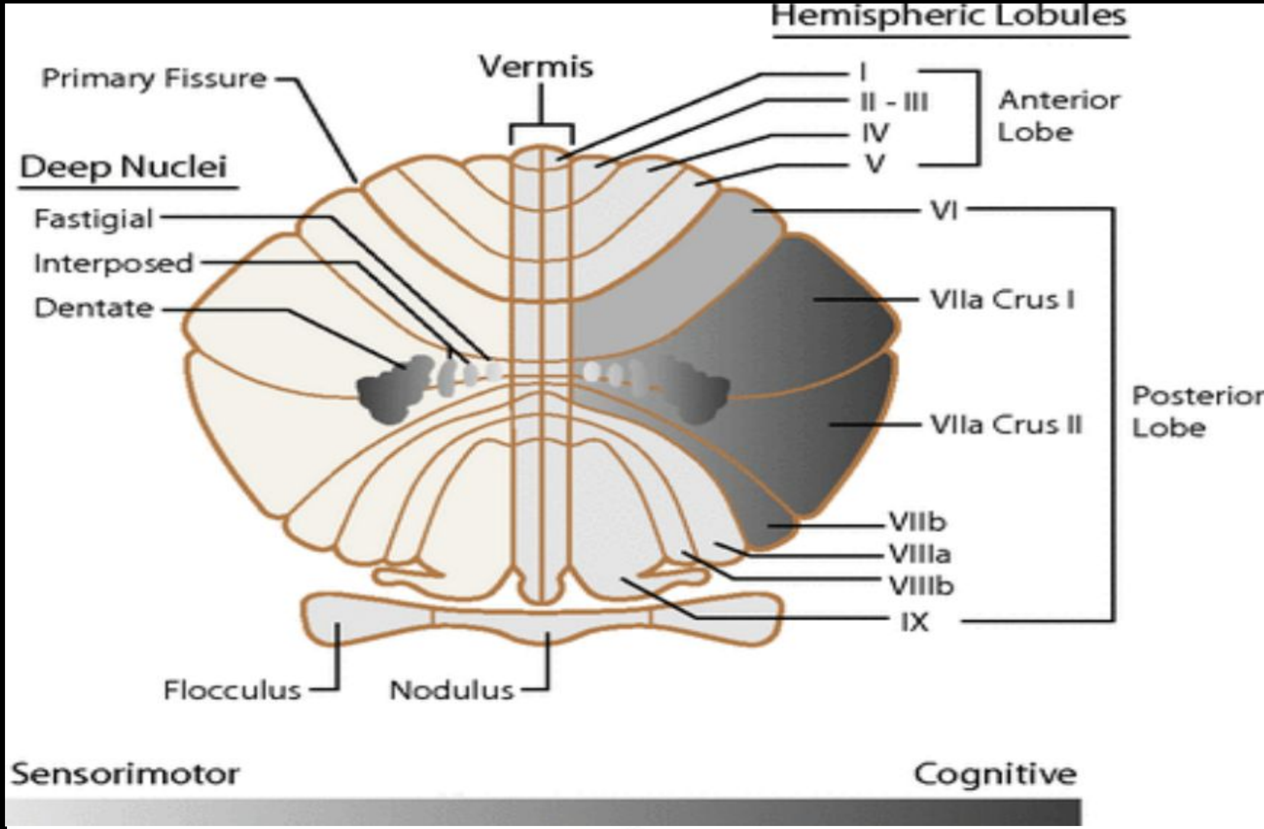
Cerebellar Contributions to Eye Movements

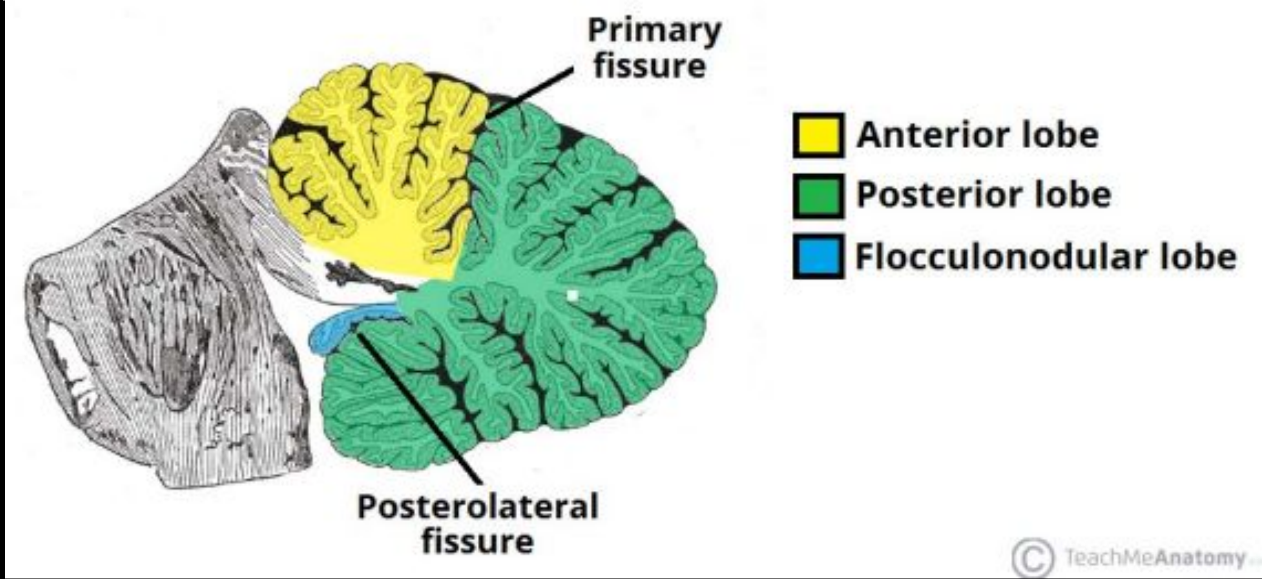
Cerebellar Areas of Interest

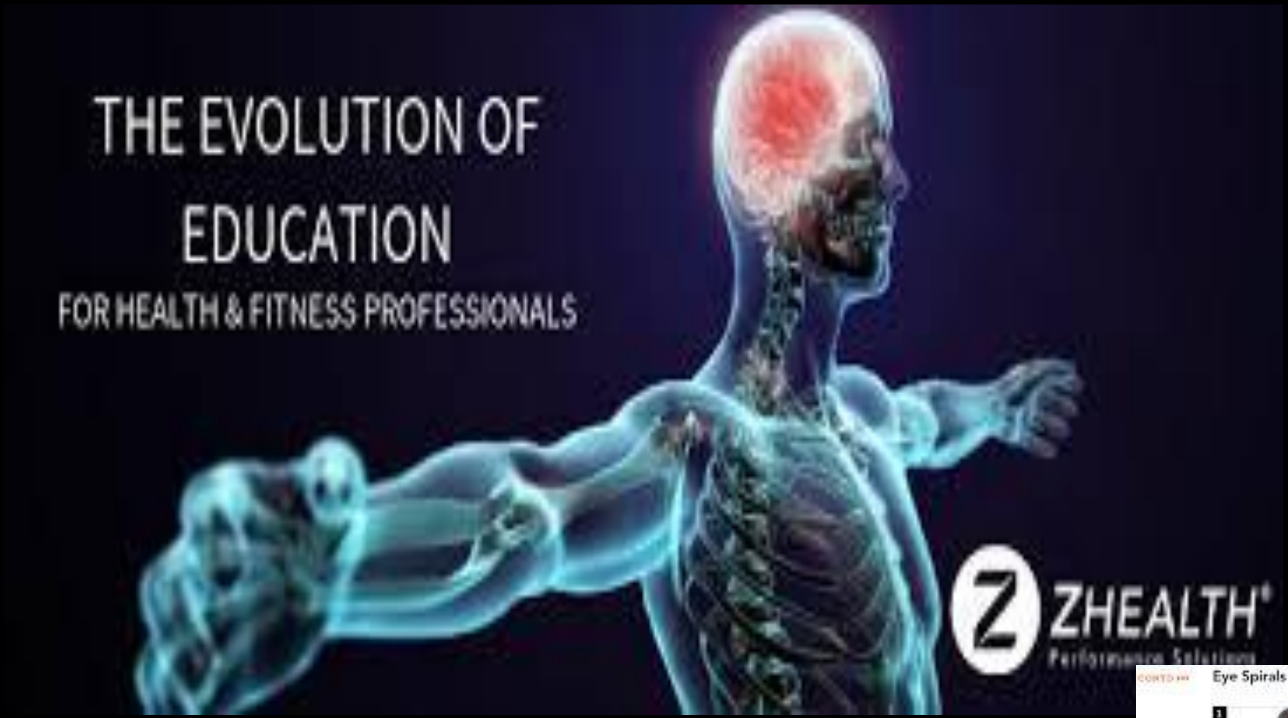
* HARD PALATE
  Fastigial Oculomotor Region (FOR) and Oculomotor Vermis (OMV)

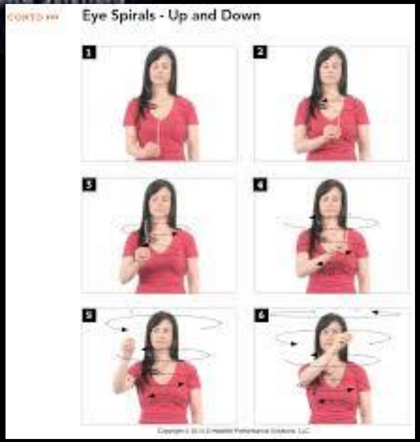
* TONSIL
  Flocculus and Paraflocculus

* UVULA Nodulus and Uvula









Eric Cobb, DC, and Michael Golden
Z Health University. 10,000+ Athletic Trainers/therapist

#1. Your patient is complaining of muscular strain around his eyes while performing smooth pursuits diagonally down and left, so you decide to activate the associated extraocular muscles with reflexive eye movements instead of voluntary ones. Which of the following therapy would best accomplish this goal?

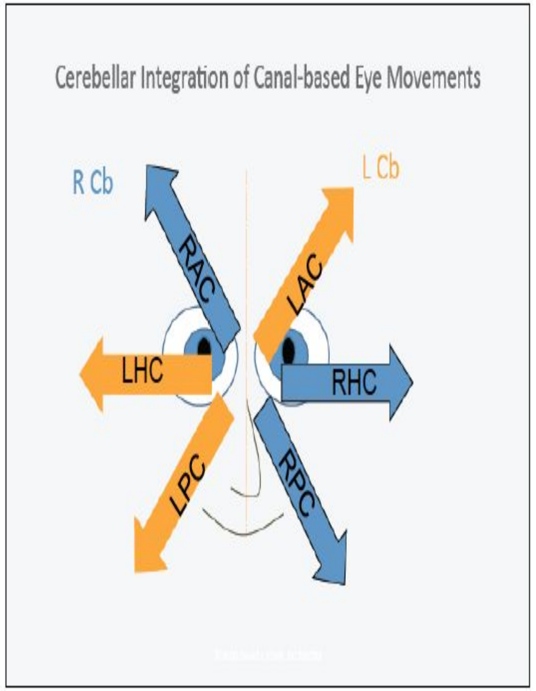
1. **An aVOR drill for the patient's right posterior semicircular canal**

2. **An aVOR drill for the patient's right horizontal semicircular canal**

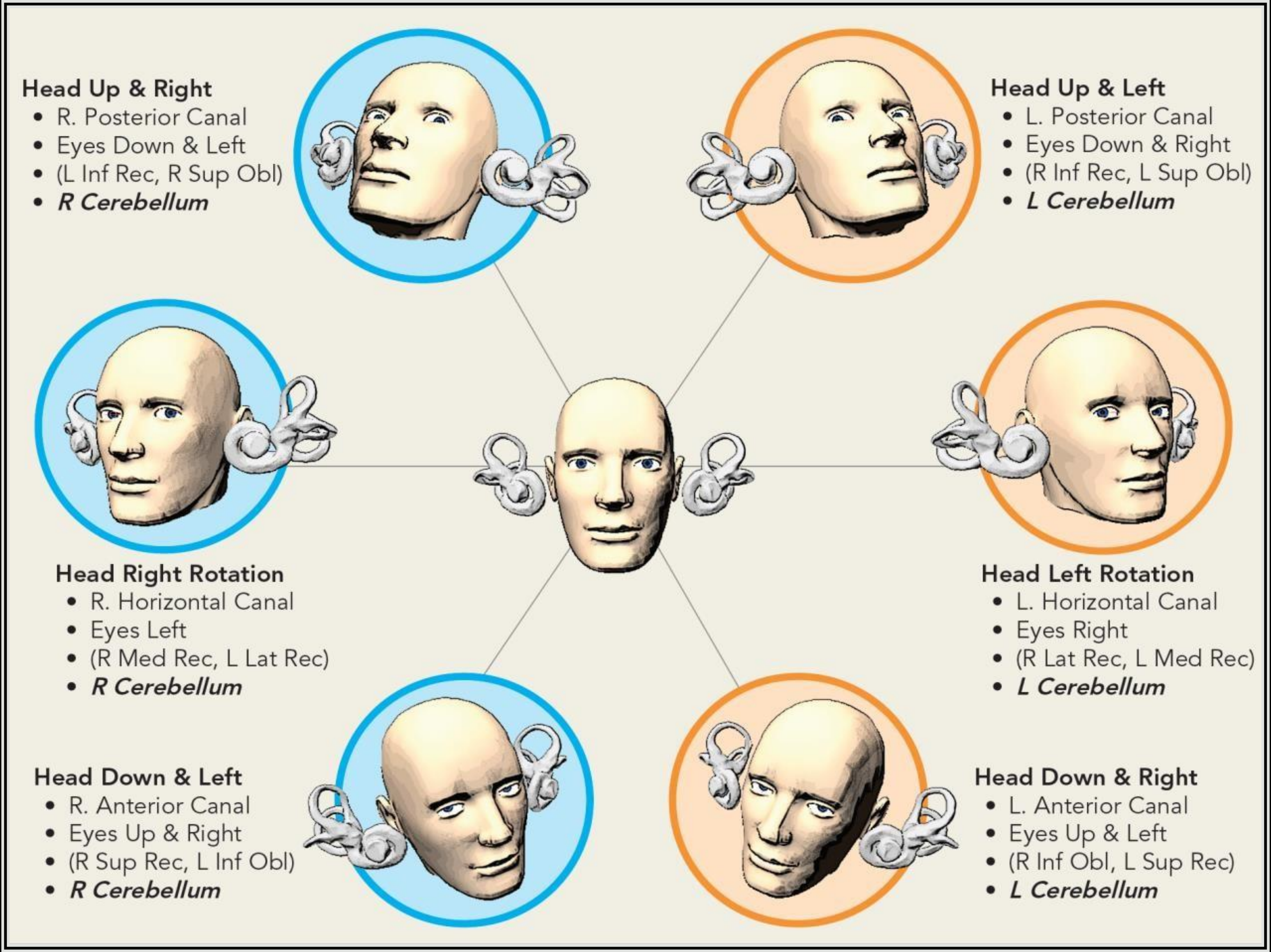
3. **A VOR-Cancellation drill for the patients left posterior semicircular canal**

4. **A gaze fixation drill while the patient's eyes are diagonally down and left**

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



#2. The vestibulo-ocular reflex from the right anterior semicircular canal would best excite which of the following extraocular muscles?

1. Left lateral rectus

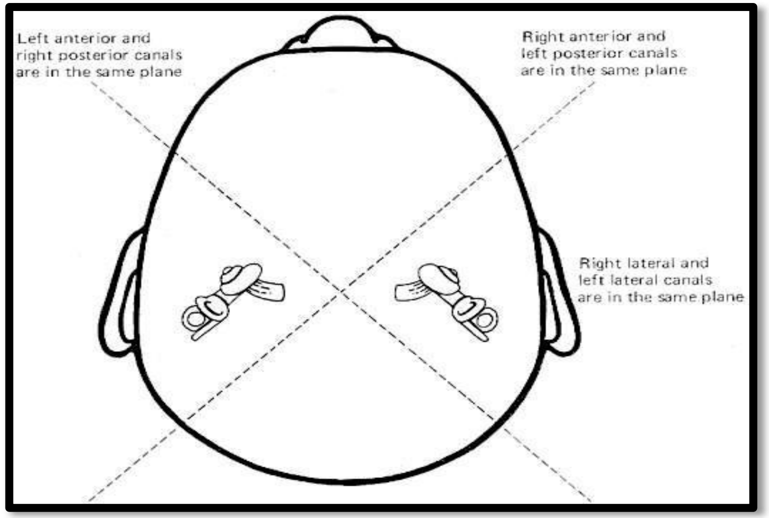
2. Right medial rectus

3. Right superior rectus

4. Left inferior oblique

5. Left inferior rectus

6. Right superior oblique



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.

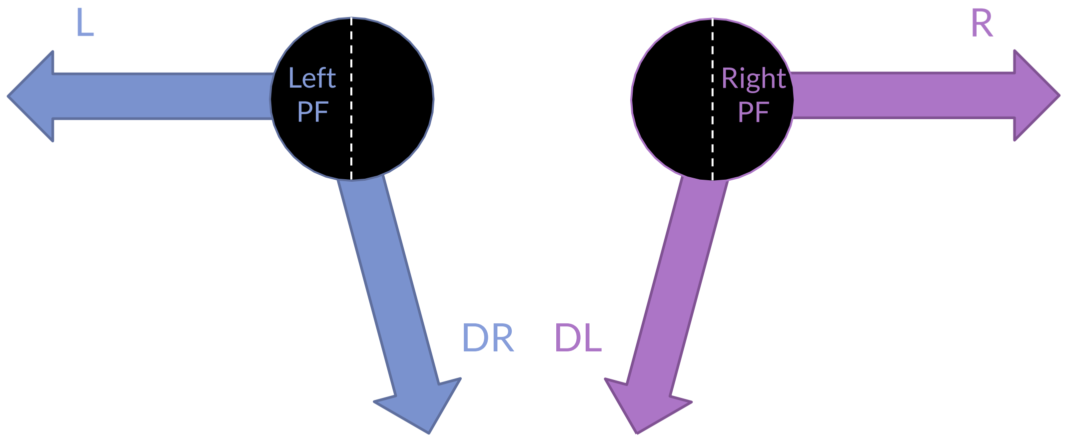
#3. Which of the following directions of gaze fixations would be most stimulating for the right half of the cerebellum?

1. Eyes diagonally down and left

2. Eyes up

3. Eyes diagonally up and left

4. Eyes left



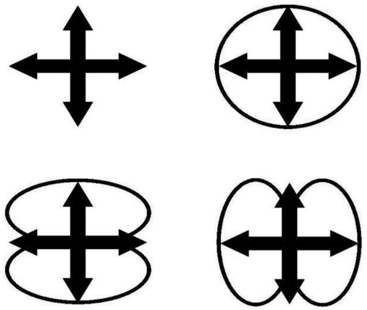
#4. After observing that your patient is walking with his left shoulder and left hip internally rotated, you decide use some motor stimulation stacked with oculomotor input to help provide corrective activation for this neurological gait pattern. Which of the following combinations would be most stimulating for the brain structure of interest?

1. Complex, non-linear body movements on her left side while fixating on a visual target in an eyes left position

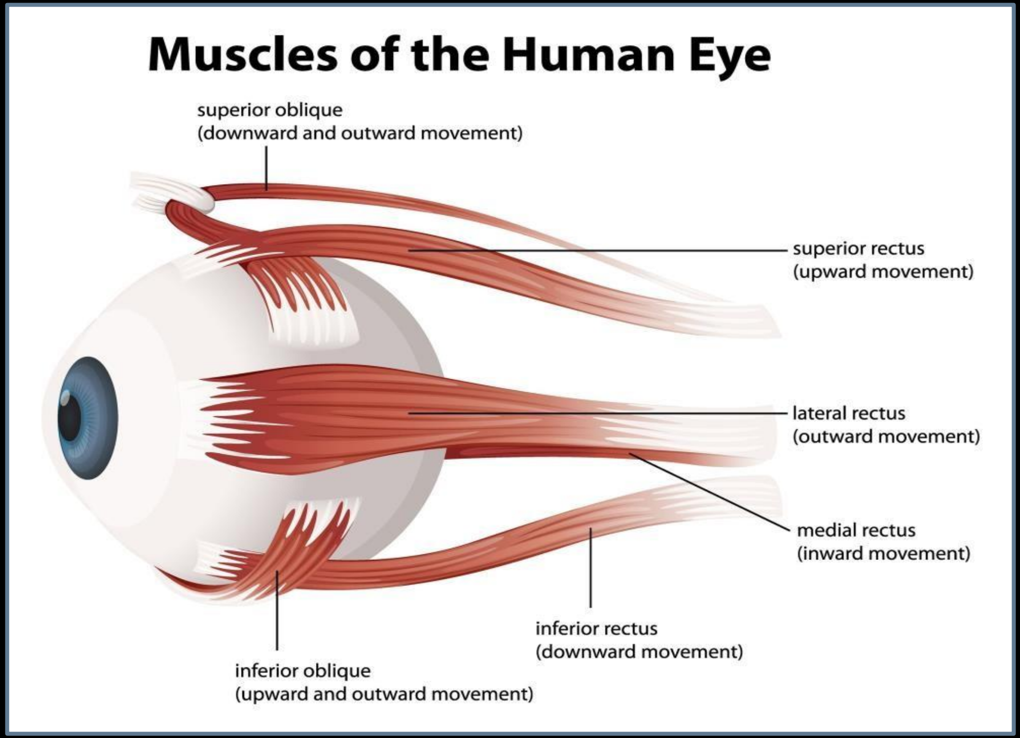
2. Complex, non-linear body movements on her left side while fixating on a visual target in an eyes right position

3. Complex, non-linear body movements on her right side while fixating on a visual target in an eyes left position

4. Simple, uniplanar body movements on her left side while fixating on a visual target in an eyes right position



Oculomotor Reflexes



- Eyes Up: Facilitates Extension (also out)
- Eyes Down: Facilitates Flexion (also in)
- Eyes Right: Facilitates Right Rotation, Right Extension, Left Flexion
- Eyes Left: Facilitates Left Rotation, Left Extension, Right Flexion

Cranial Nerve Insertions Stacking
Why do we have three for EOM control?

III. Oculomotor FLEXOR

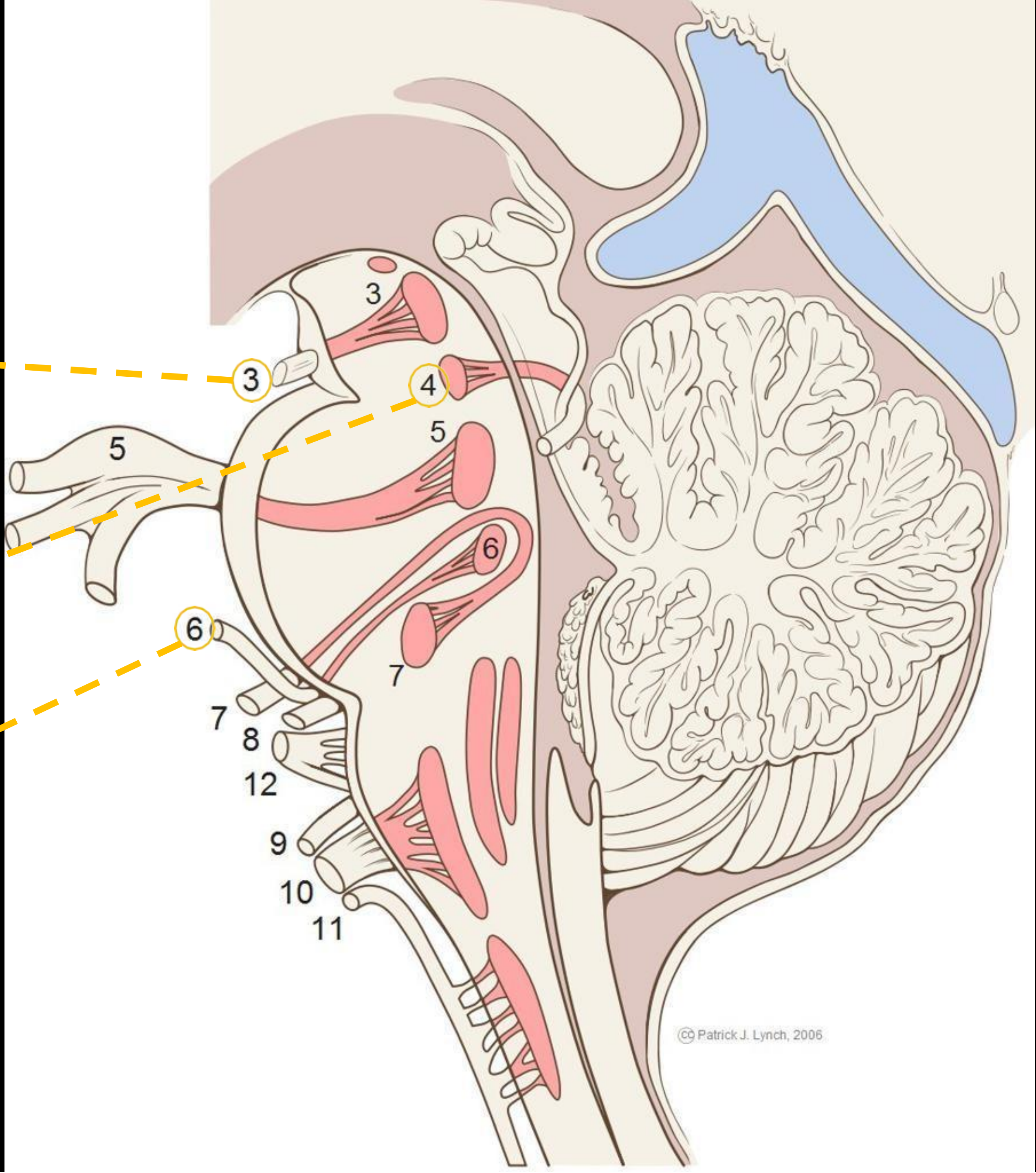
Inferior Rectus Inferior Oblique Medial Rectus Superior Rectus

IV. Trochlear FLEXOR

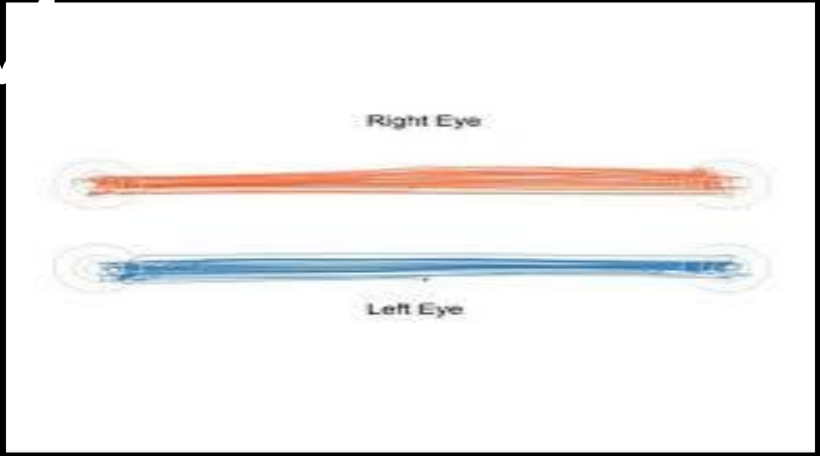
Superior Oblique*

VI. Abducens EXTENSOR

Lateral Rectus (also the Cerebellum)



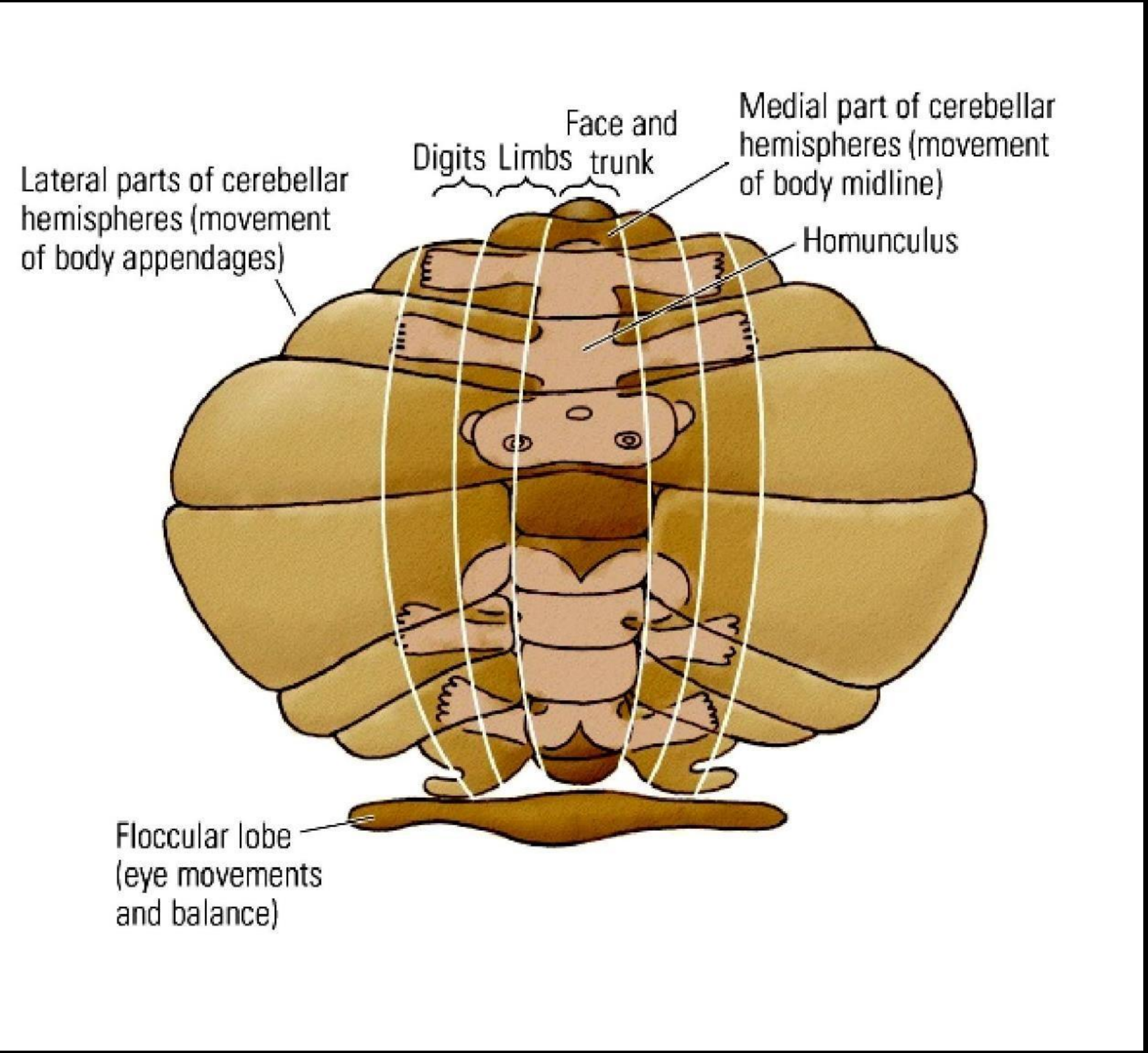
Cerebellar Contributions to Eye M



Cerebellar IMPORTANCE

Where the MAPS are corrected, learning, and stored.

75% of the Cortical Surface area, 70-80% of our neurons!



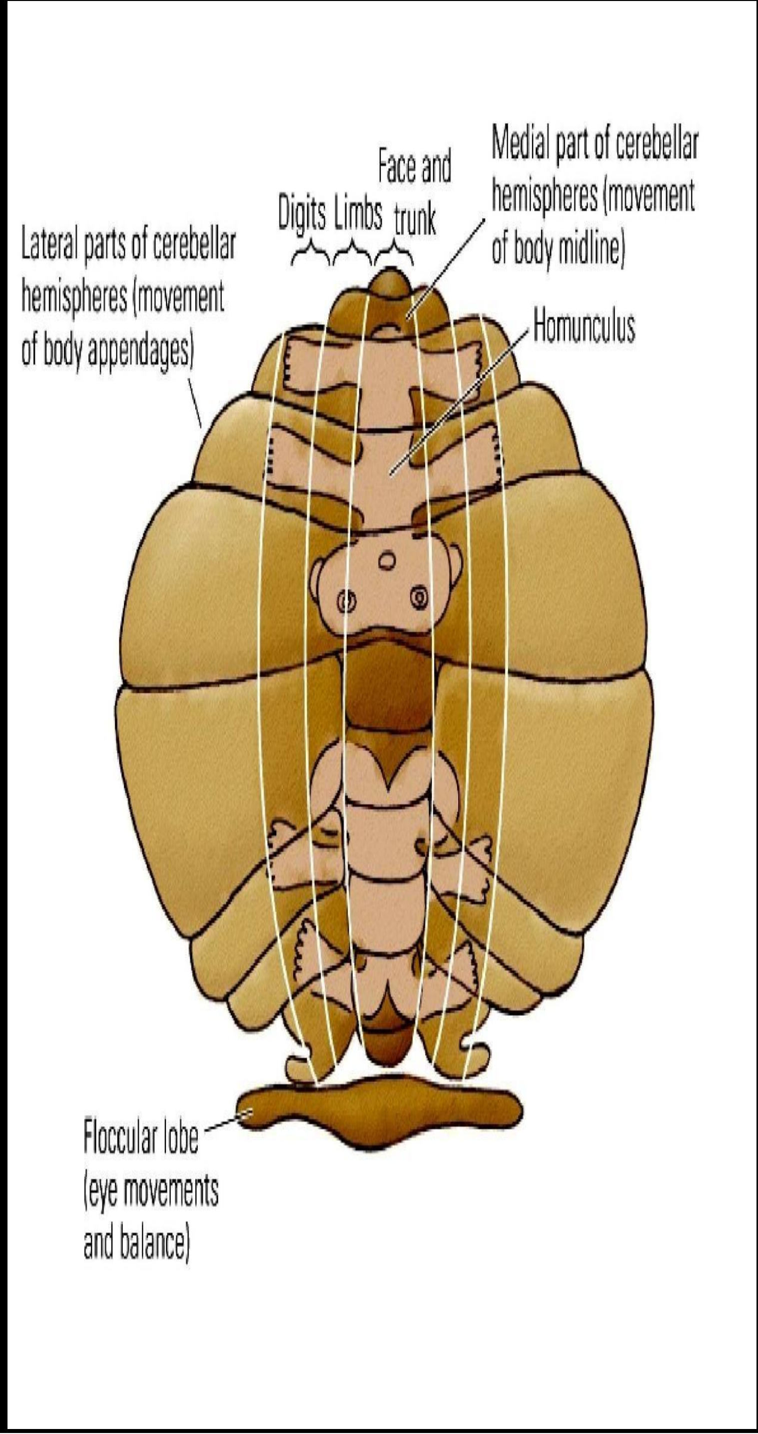
Cerebellar Contributions to Eye Movements

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 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



Brain Region Localization Form (Kharrazian)

Cerebellum - Spinocerebellum

67. Difficulty with balance, or balance that is worse on one side (0) (1) (2) (3) (4)

68. A need to hold the handrail or watch each step carefully when going down stairs (0) (1) (2) (3) (4)

69. Feeling unsteady and prone to falling in the dark (0) (1) (2) (3) (4)

70. Proness to sway to one side when walking or standing (0) (1) (2) (3) (4)

Cerebellum – Cerebrocerebellum

71. Recent clumsiness in hands (0) (1) (2) (3) (4)

72. Recent clumsiness in feet or frequent tripping (0) (1) (2) (3) (4)

73. A slight hand shake when reaching for something at the end of movement (0) (1) (2) (3) (4)

Cerebellum - Vestibulocerebellum

74. Episodes of dizziness or disorientation (0) (1) (2) (3) (4)

75. Back muscles that tire quickly when standing or walking (0) (1) (2) (3) (4)

76. Chronic neck or back muscle tightness (0) (1) (2) (3) (4)

77. Nausea, car sickness, or sea sickness (0) (1) (2) (3) (4)

78. Feeling of disorientation or shifting of the environment (0) (1) (2) (3) (4)

79. Crowded places cause anxiety (0) (1) (2) (3) (4)

Cerebellar Contributions to Eye Movements

Fastigial Oculomotor Region (FOR & OMV: Hard Palate)

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

Flocculus and Paraflocculus (TONSIL)

- 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 (Semi-C-Canals Triad)
- Directional adaptation and learning

Nodulus and (UVULA)

- Responsible for generating and maintaining the linear/translational VOR
- (Otolith Triad)
- Controls the velocity storage mechanism, a form of vestibular memory
- Slow aVOR and downward pursuits

Cerebellar Contributions to Eye Movements– Which Direction to Upregulate?

Directional Specificity

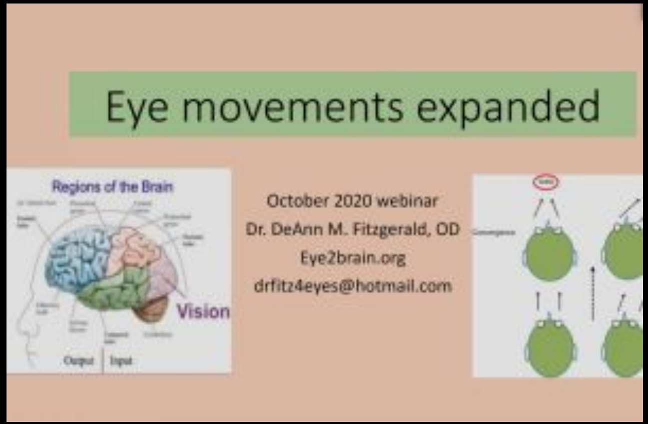
Fastigial Oculomotor Region

* 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

Eye2Brain Academy



The RETINA…the only part of the BRAIN the the MOVES!

The EYES should be treated as a COUPLED JOINT That needs to be EXPLORED and MAPPED by selective STIMULATION by MOVEMENT.

The Vestibulo-Ocular Reflex (VOR) is developed in utero with the vestibular fibers full myelinated at 24 weeks gestation and eye open at 28 weeks!

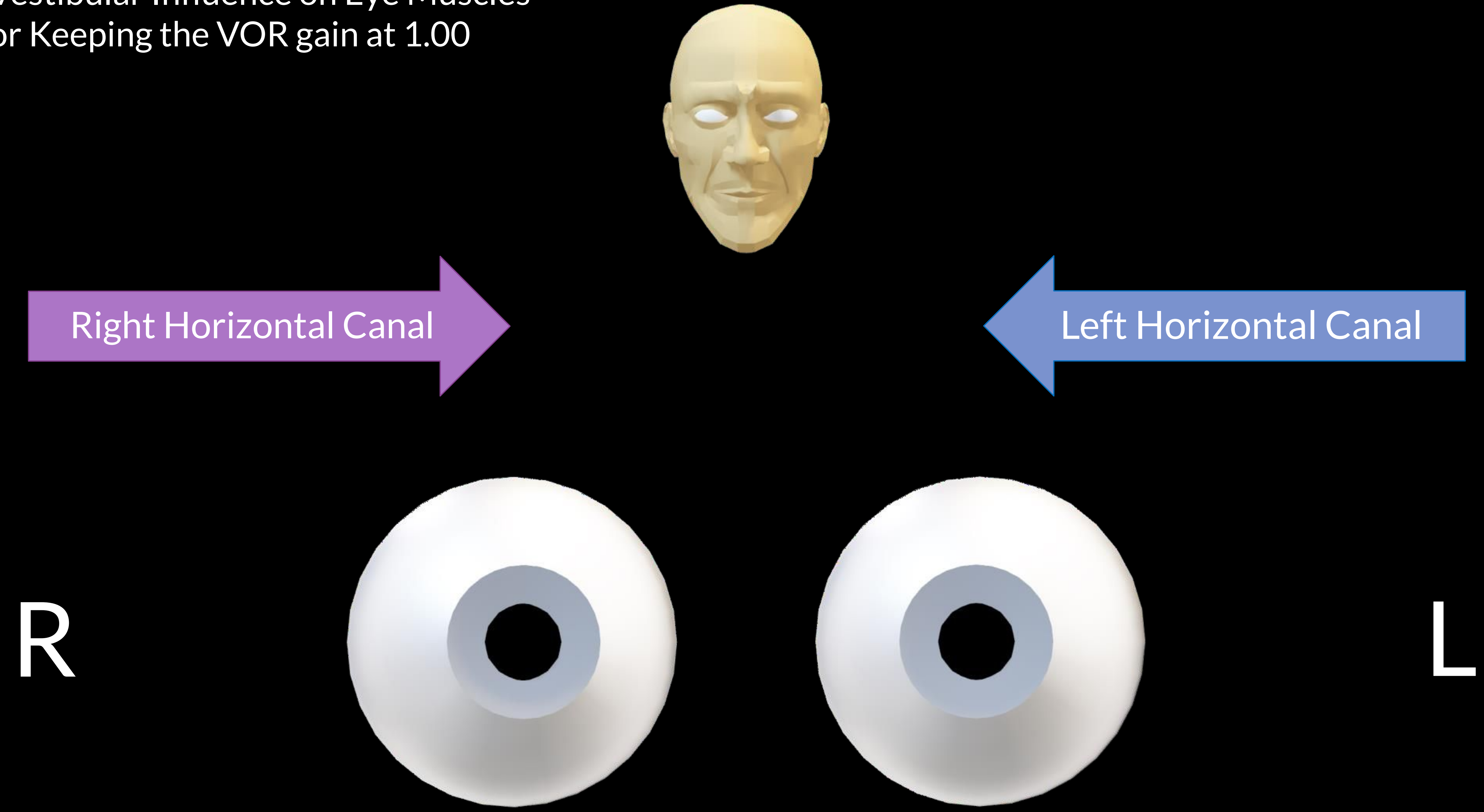
Neural Components – The Challenge of Integration

- The vestibular system has a resting tone (known in neurology circles as the frequency of firing of the presynaptic and postsynaptic neuronal pools).

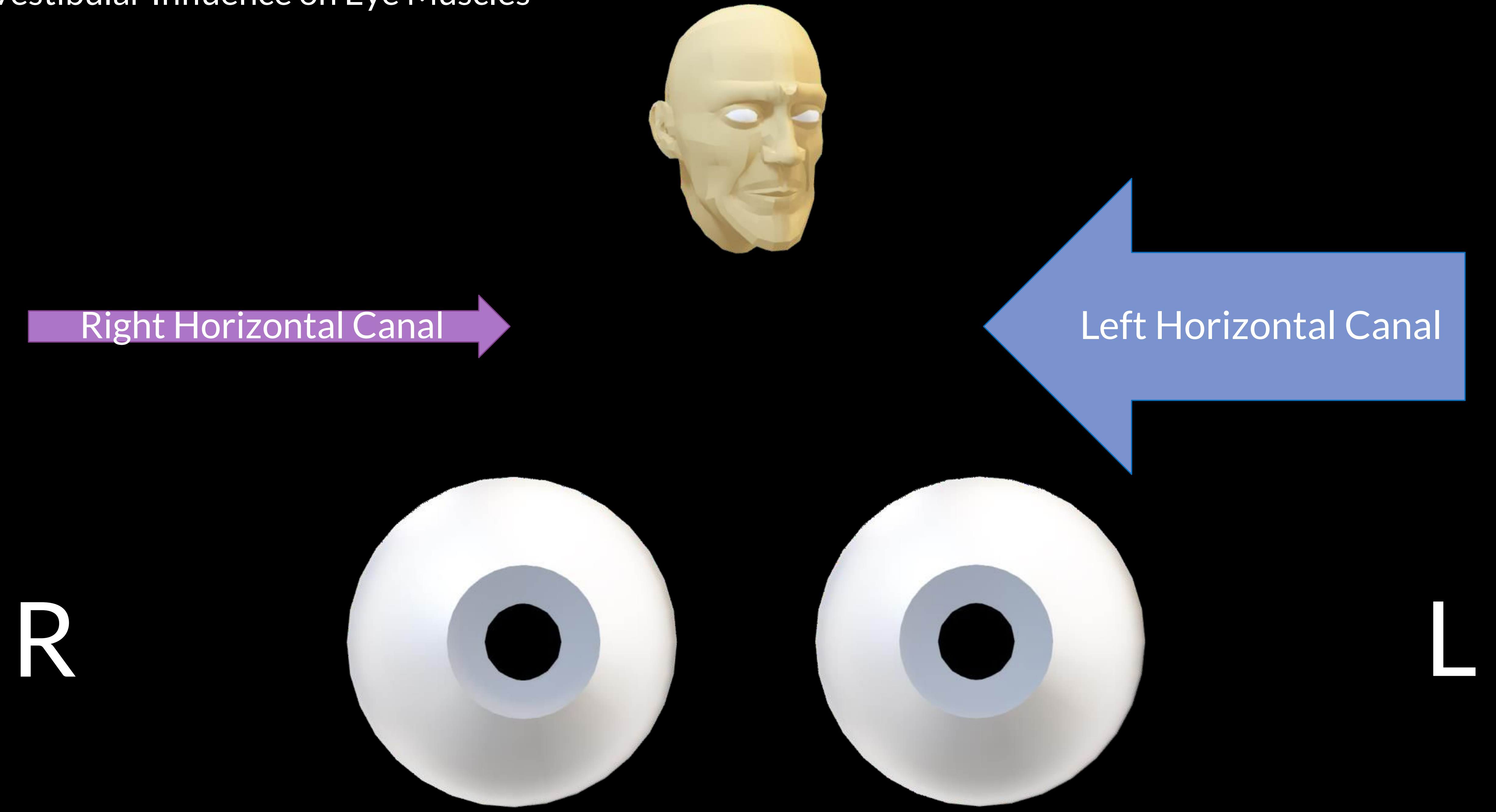
- “There are approximately 18,000 vestibular nerve fibres from each human labyrinth projecting into the vestibular nuclei (part of the brain). At rest, they fire at around 1,000,000 times per second (collectively) – even when the head is still! An injury then, silences many of these fibres, creating a huge imbalance between the two vestibular nuclei (i.e., processing areas for the right and left inner ear in the brain).”

“Vestibular Compensation: A review of the oculomotor, neural, and clinical consequences of unilateral vestibular loss.”
Curthoys and Halmagyi. 1995.

Vestibular Influence on Eye Muscles or Keeping the VOR gain at 1.00

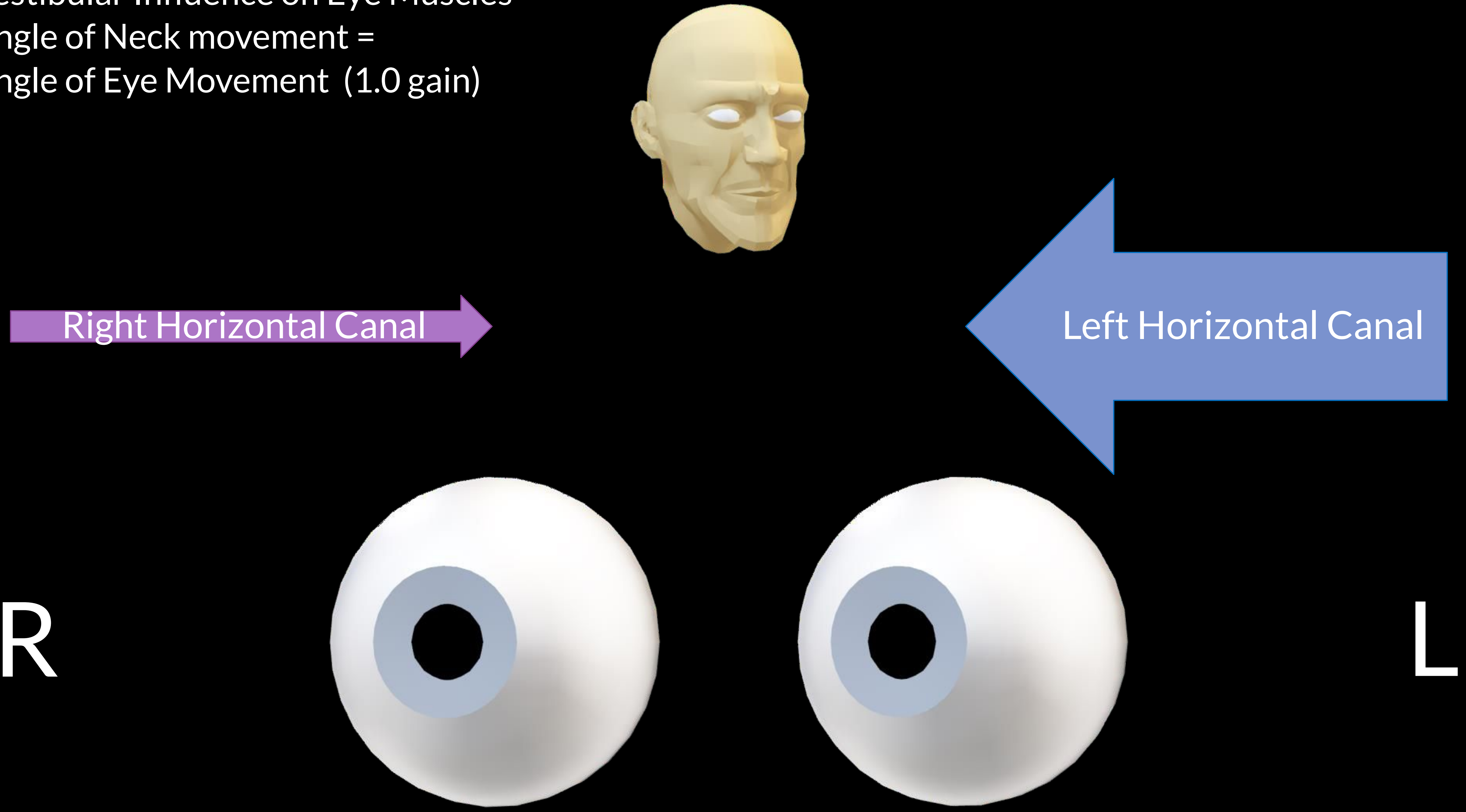


Vestibular Influence on Eye Muscles

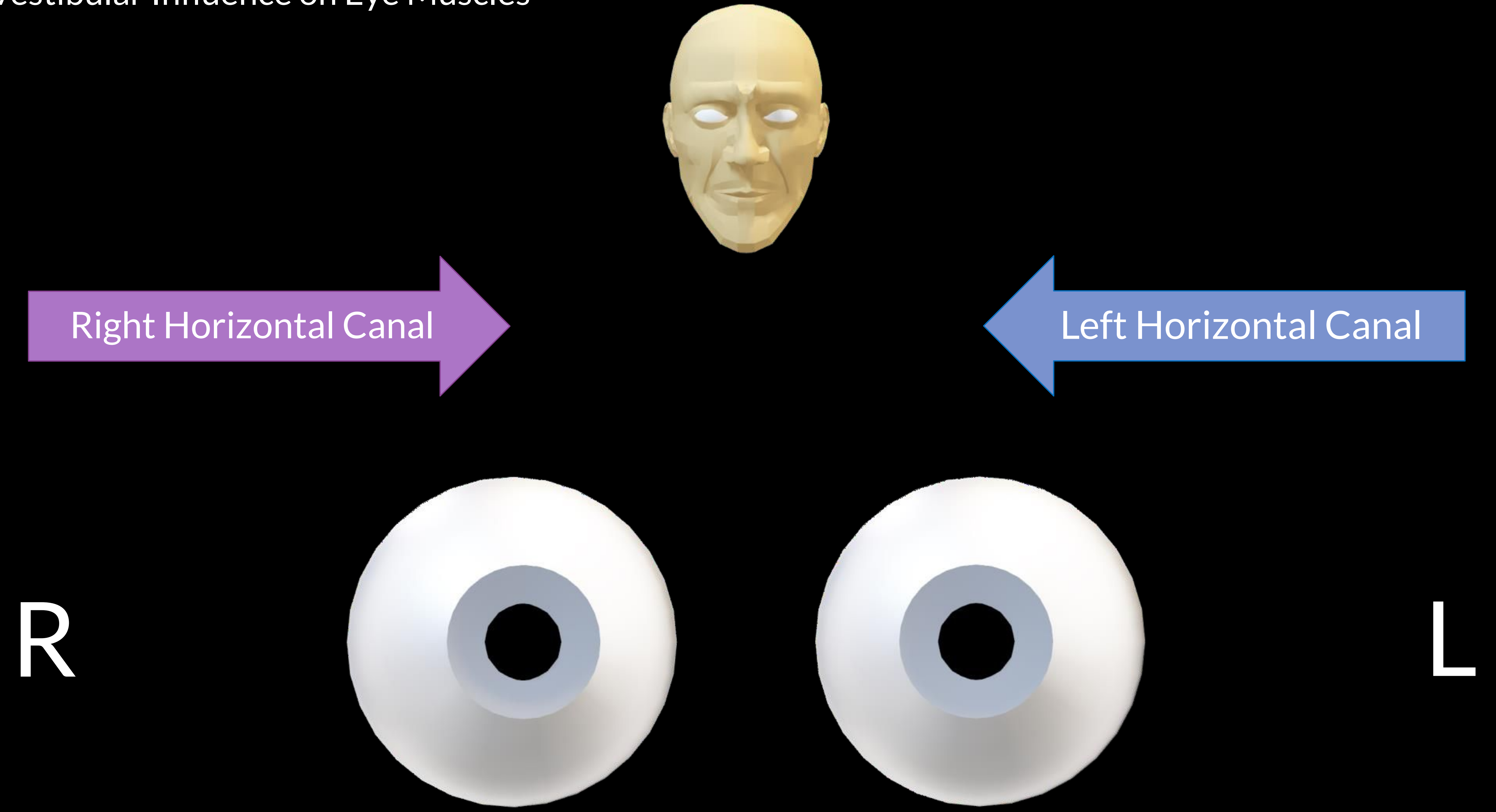


Vestibular Influence on Eye Muscles

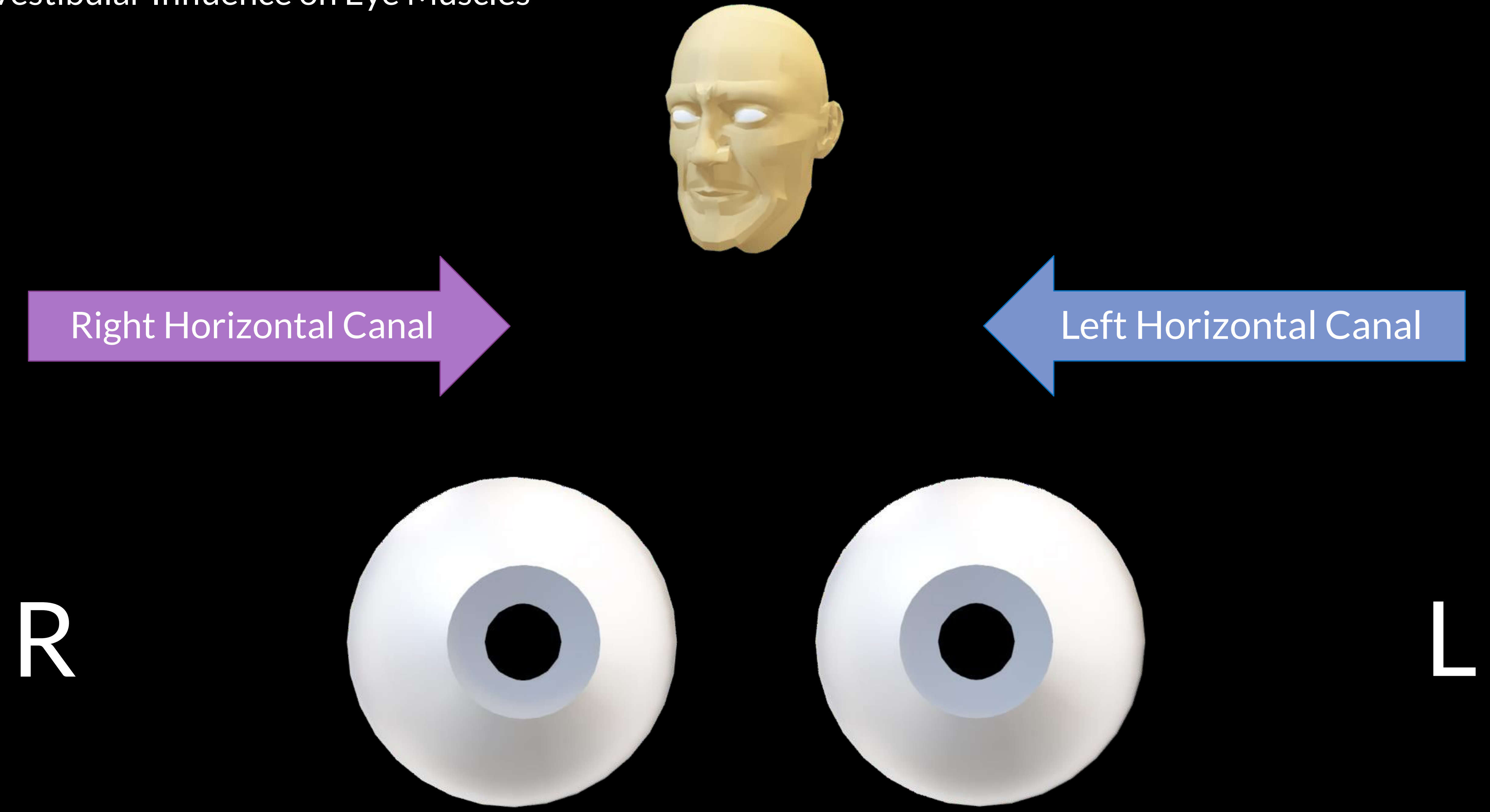
Angle of Neck movement =
Angle of Eye Movement (1.0 gain)



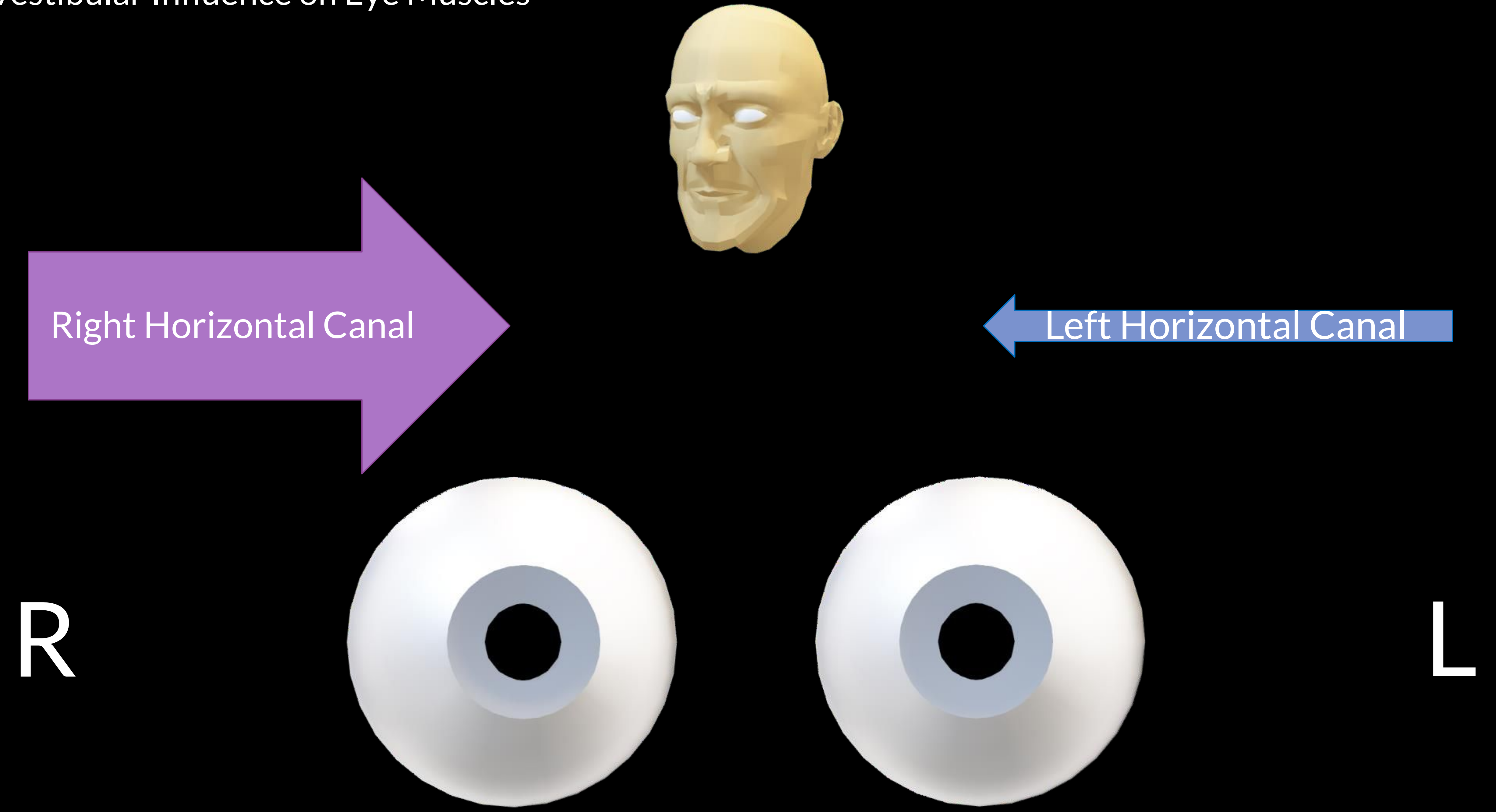
Vestibular Influence on Eye Muscles



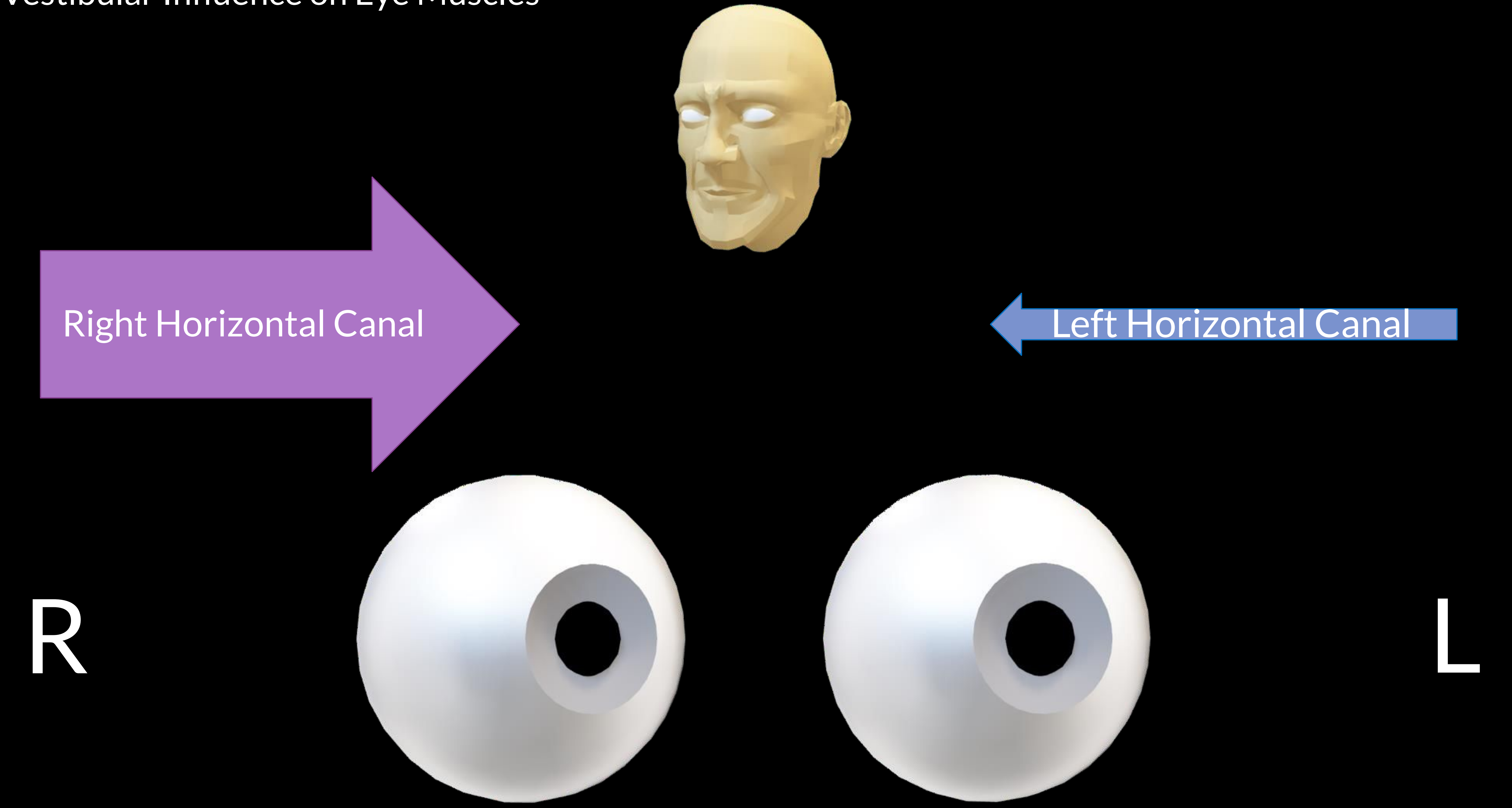
Vestibular Influence on Eye Muscles



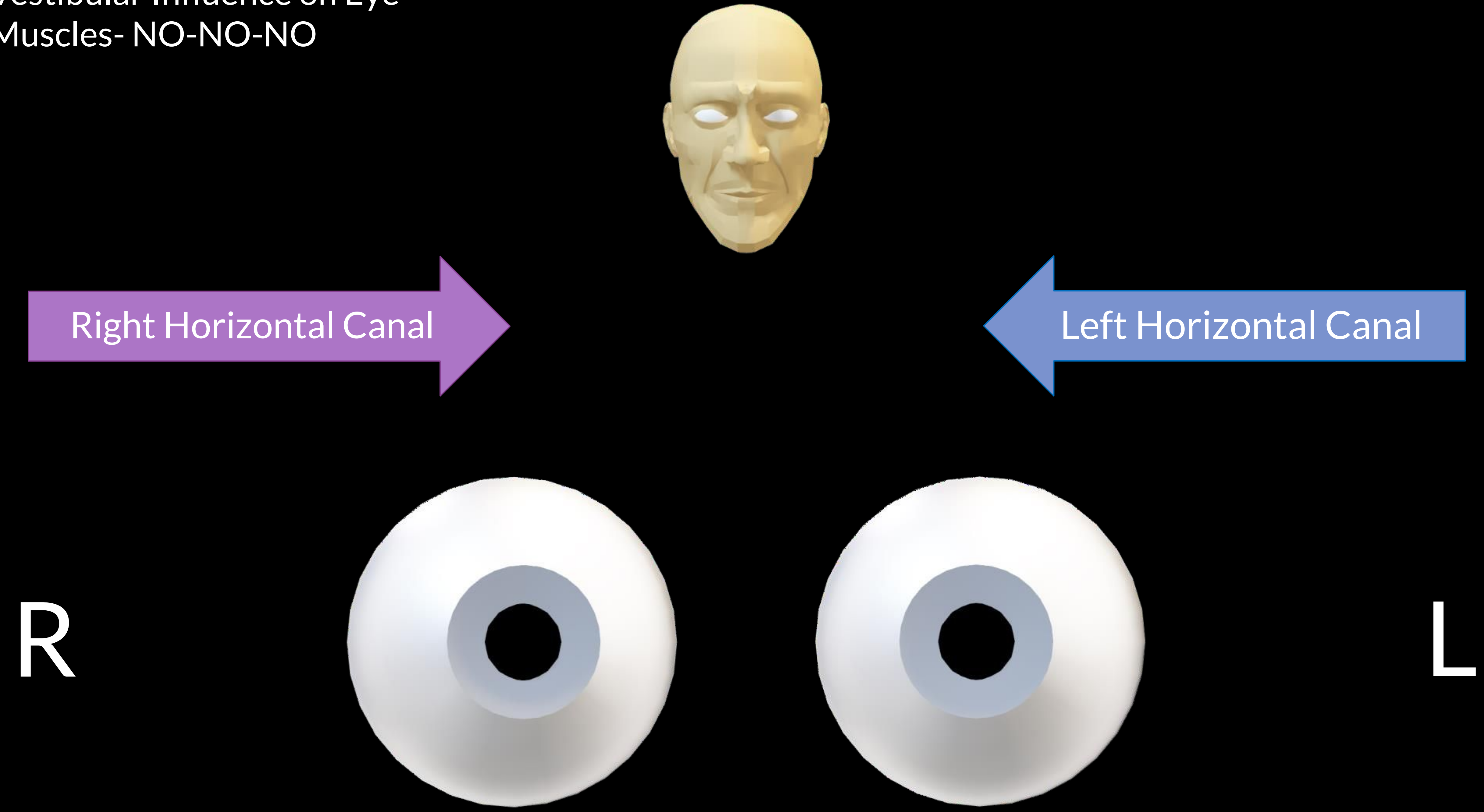
Vestibular Influence on Eye Muscles



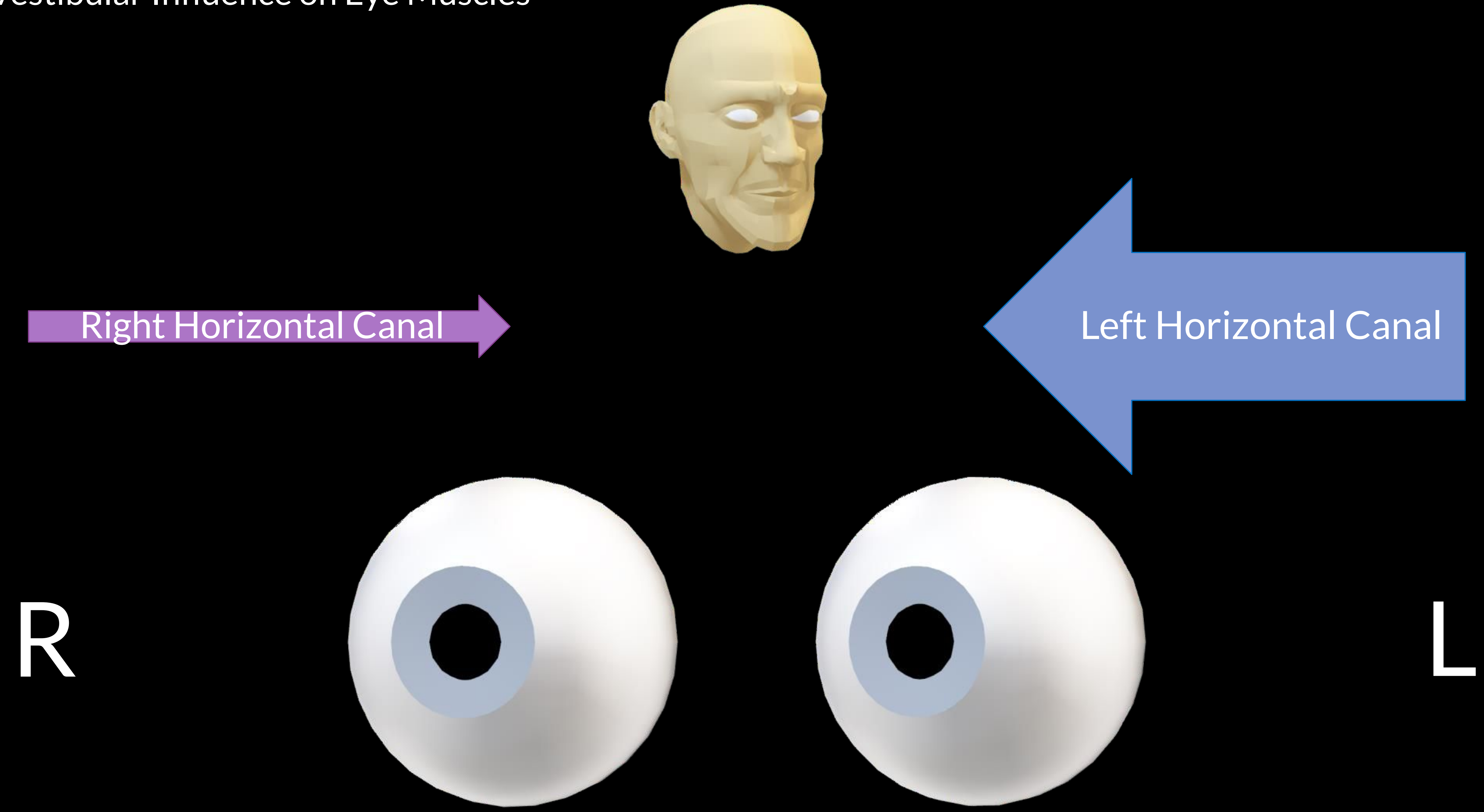
Vestibular Influence on Eye Muscles



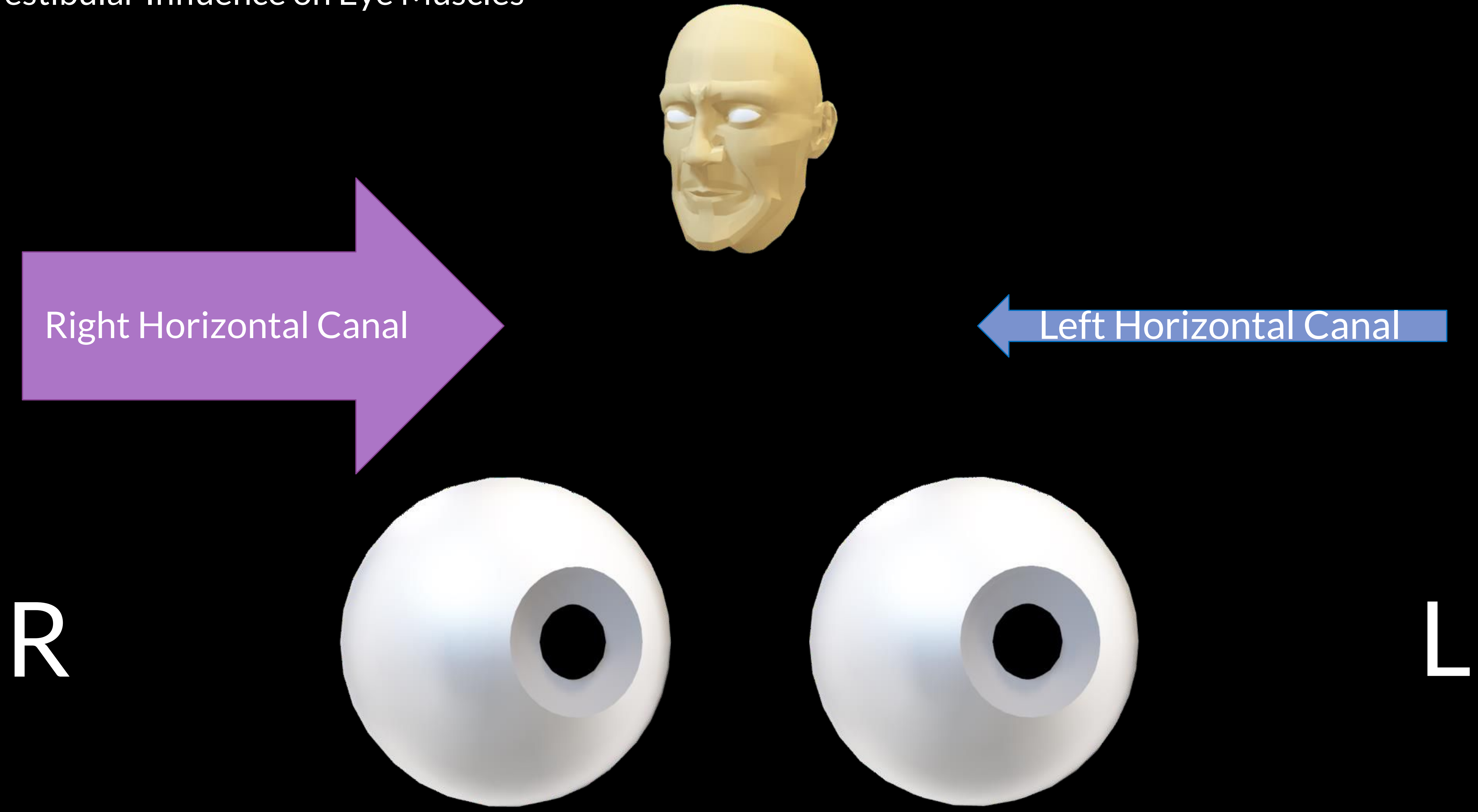
Vestibular Influence on Eye Muscles- NO-NO-NO



Vestibular Influence on Eye Muscles



Vestibular Influence on Eye Muscles



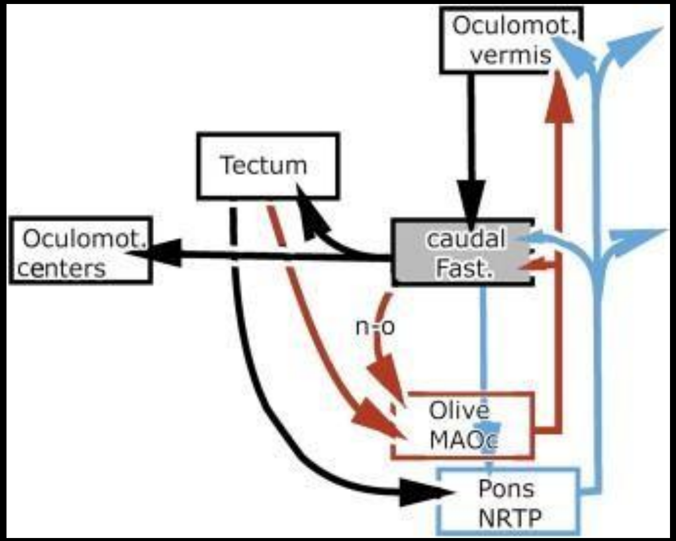
Cerebellar Contributions to Eye Movements/FOR, OMV (Hard Palate)

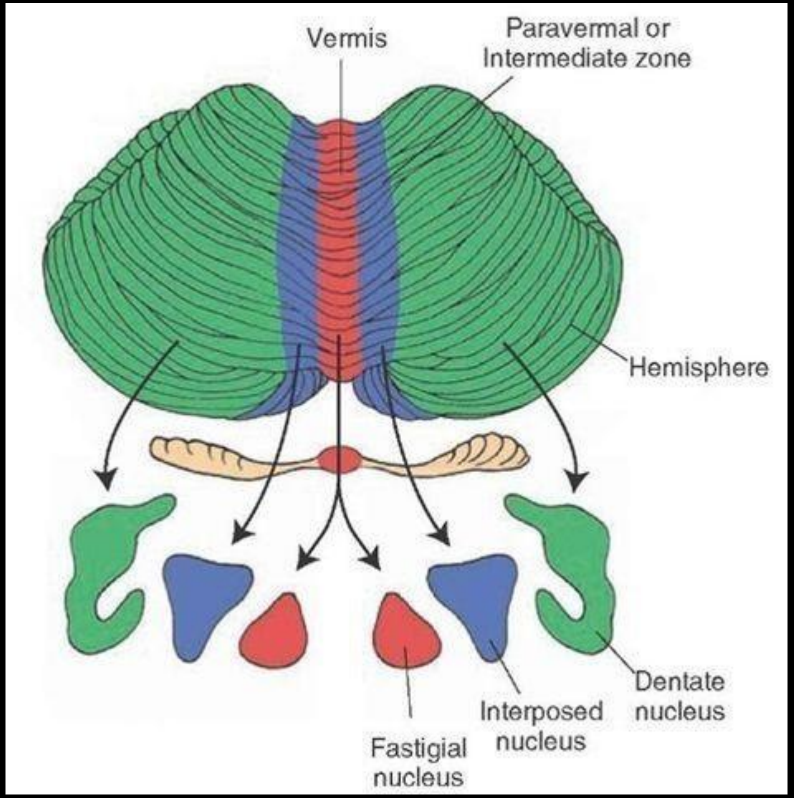
Fastigial Oculomotor Region

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.



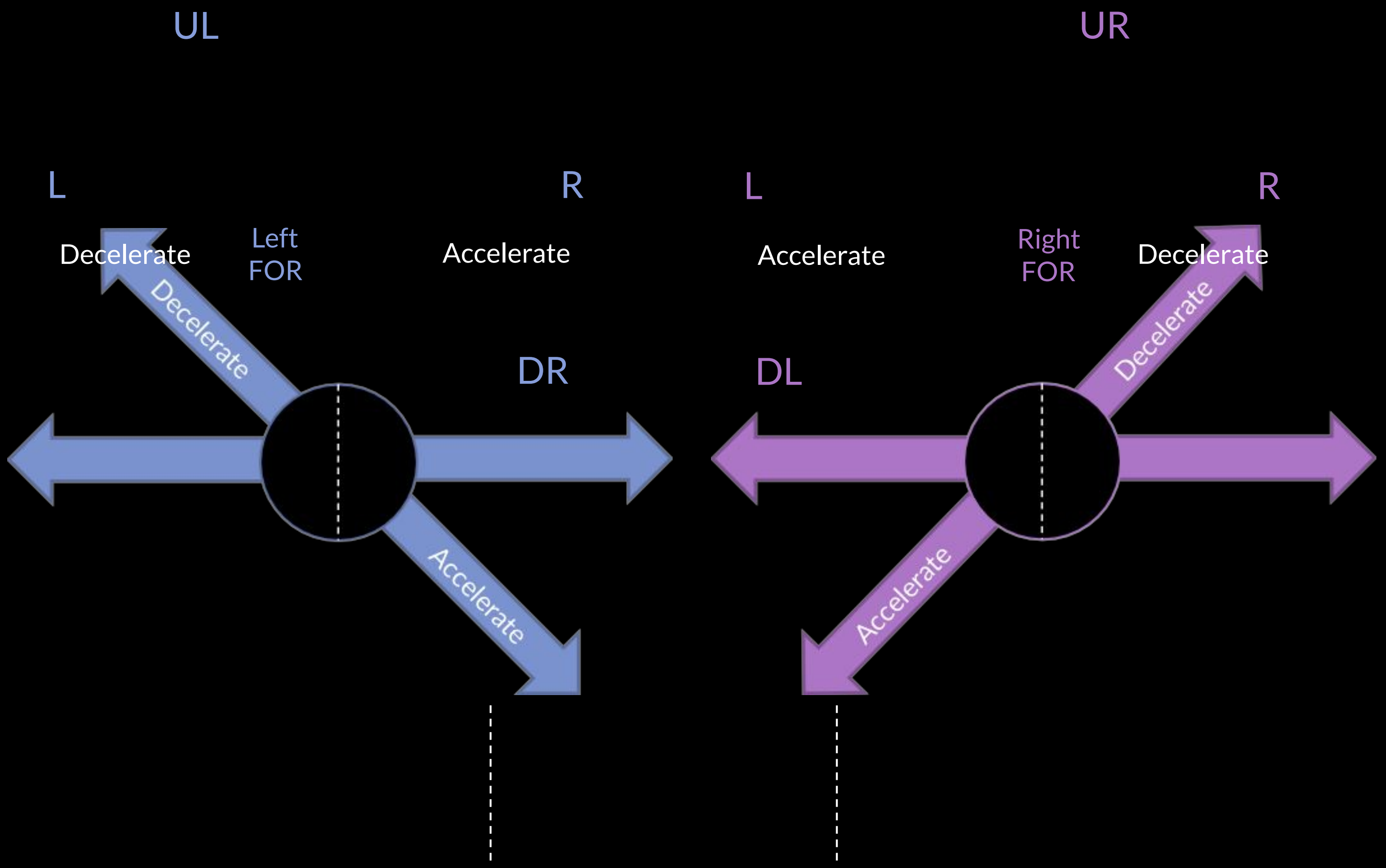


To simplify:

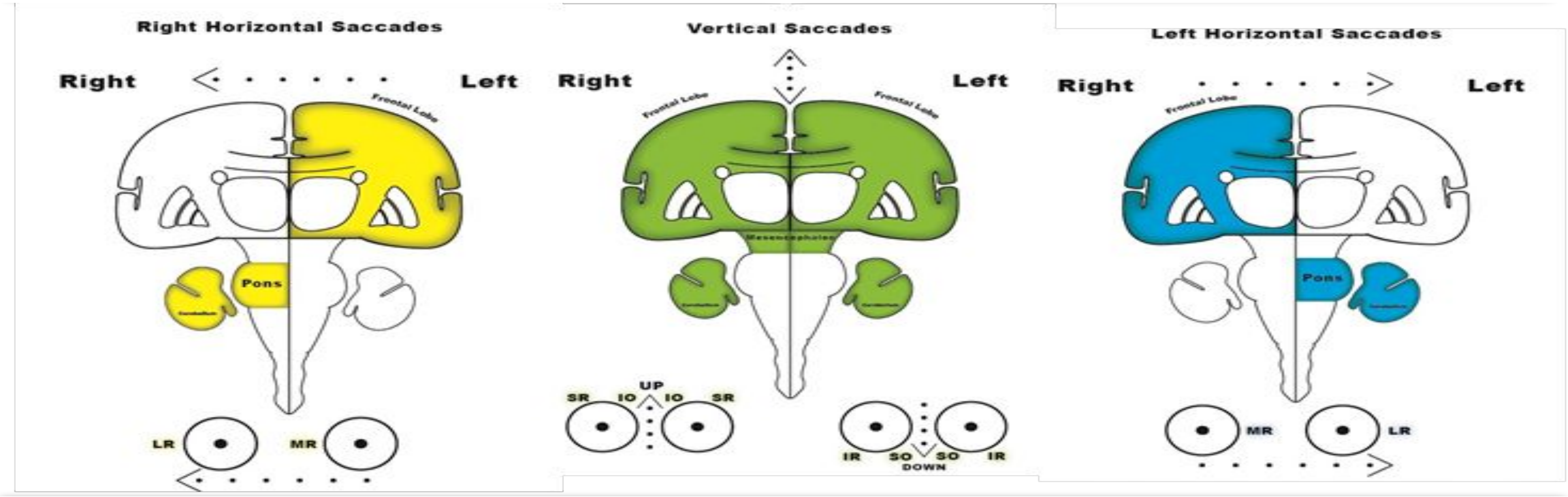
The fastigial oculomotor region speeds up eye movements going to the opposite side and slows down eye movements coming toward it.

Cerebellar Contributions to Eye Movements
Activates down and in for convergence

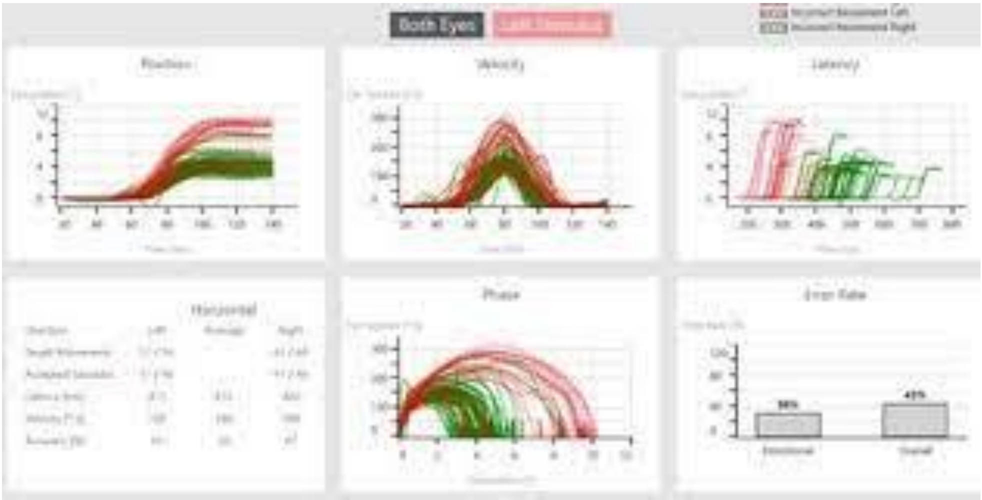
Laterality for the FOR

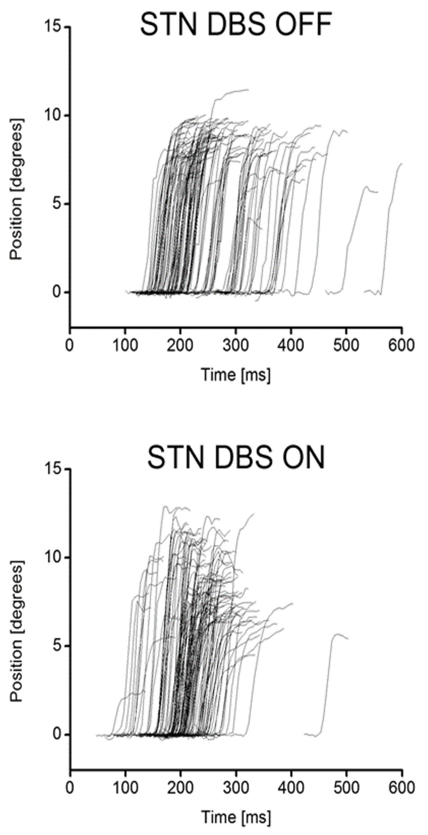


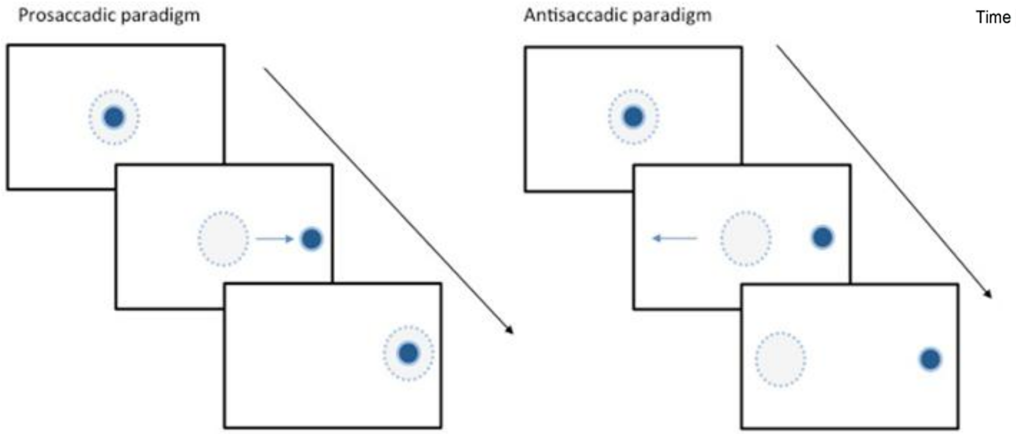
FOR and OMV upregulation with Saccades
Pons Abduct(VI) Mesencephalon (III)



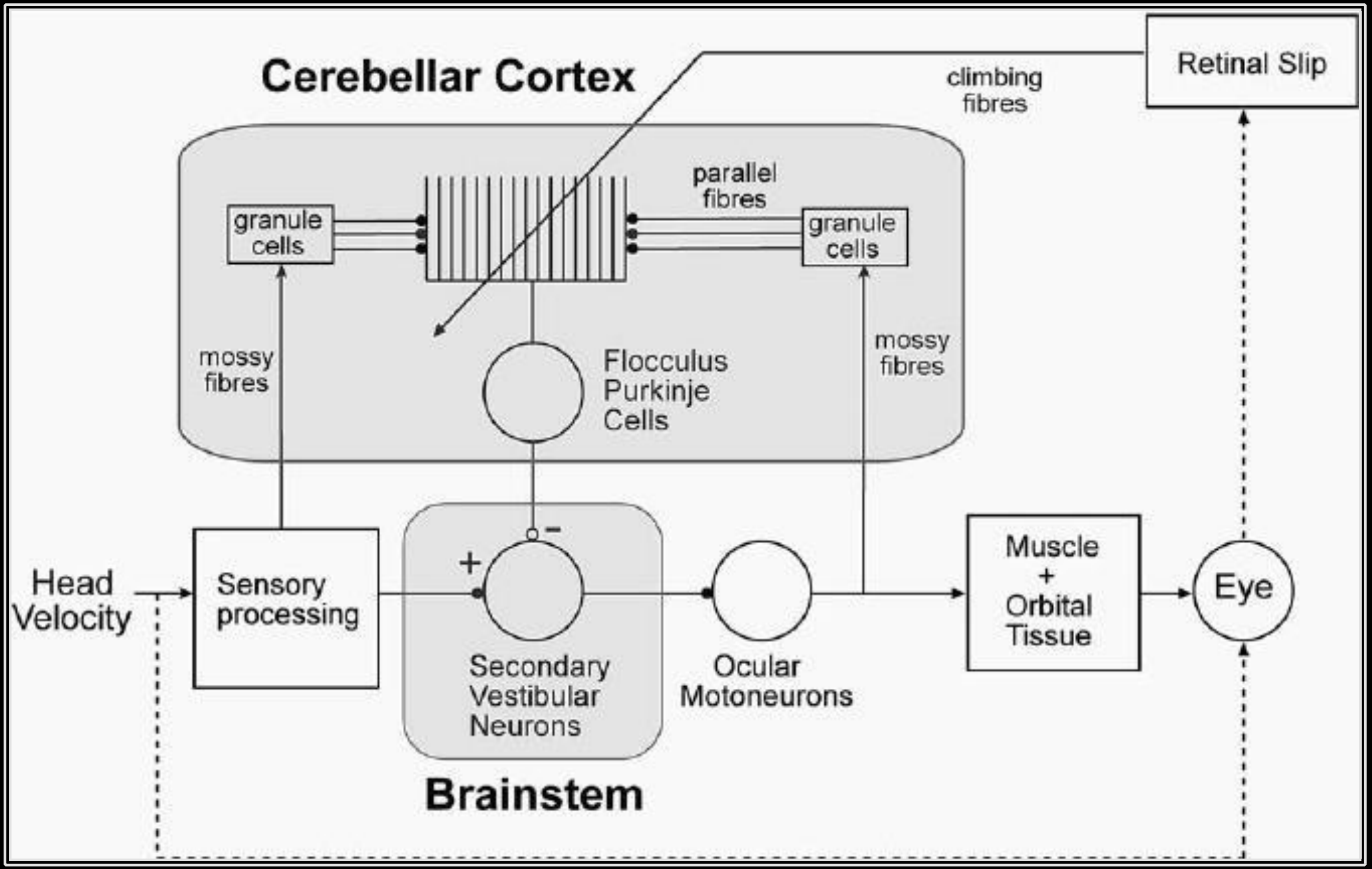
Explore the Saccacometer functions on RIGHTEYE







Cerebellar Contributions to Eye Movements



Flocculus and Paraflocculus (TONSIL)

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 VORs.

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

Purpose:

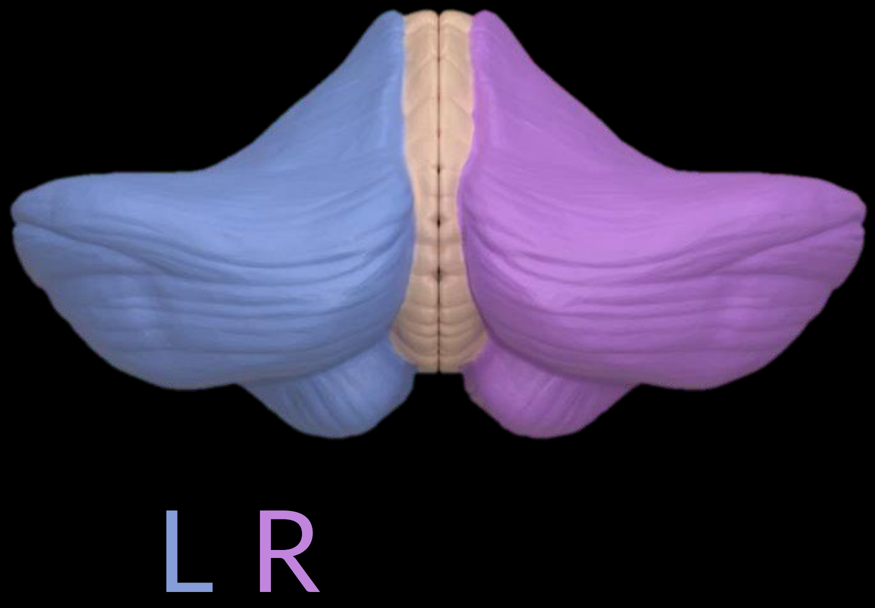
- Foundational element of all other eye movements
- Allow us too see objects clearly
- Sample the visual scene to create perception
- Dysfunction: Cerebellum, Basal Ganglia, Lateral Prefrontal Cortex

Eye Movements, Reading, Visual Attention and Automaticity Are They All Related?

REFERENCES: Richman JE ; The Influence of Visual Attention and Automaticity on the Diagnosis and Treatment of Clinical Oculomotor , Accommodative, and Vergence Dysfunctions. Vol 30 (3): Fall 1999 ; J Optom Vis Develop.

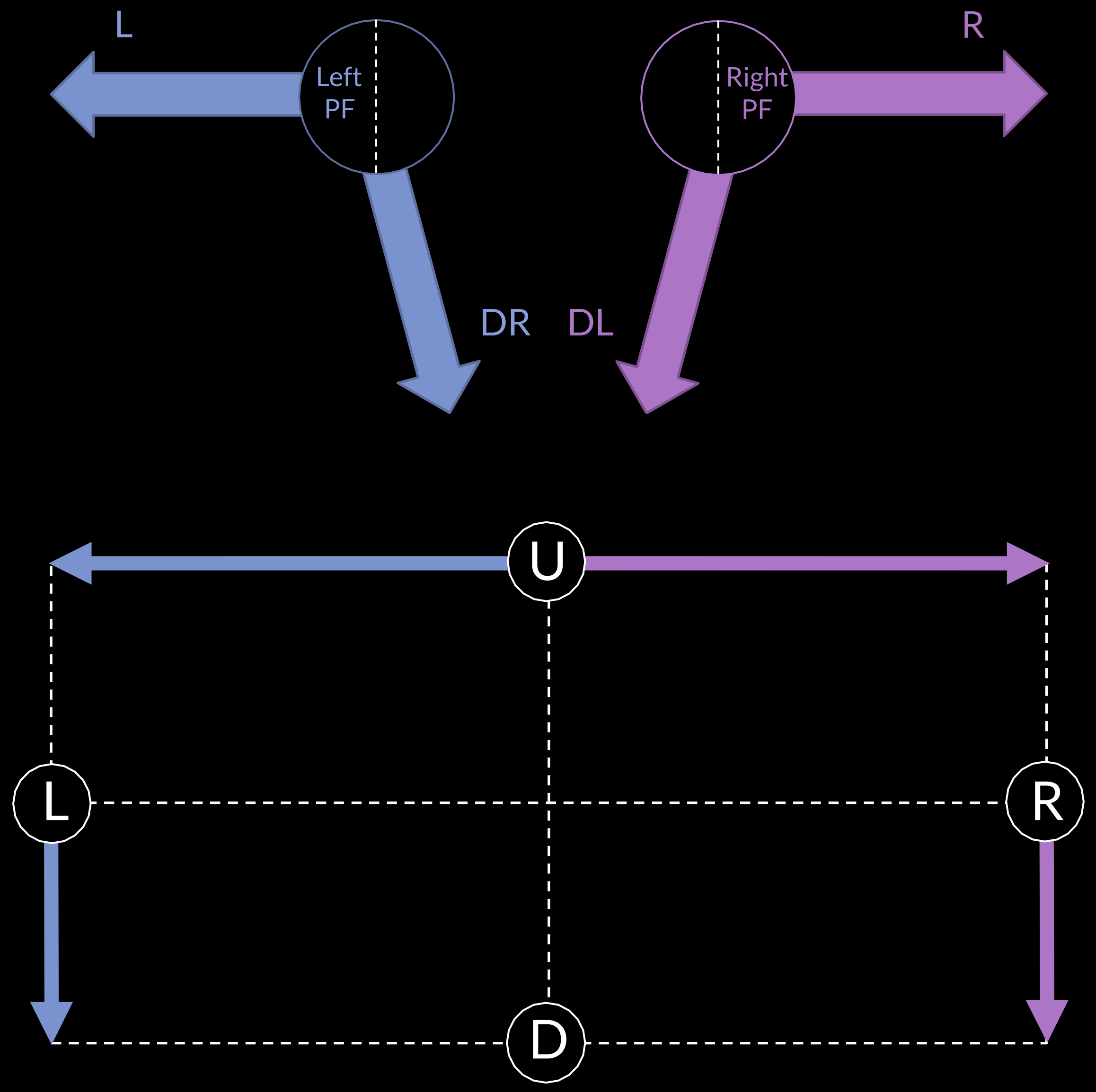
Richman JE; Garzia RP: Eye Movements and Reading, in Vision and Reading, (Mosby's Optometric Problem Solving Series) , Ed. Garzia RP. Mosby. St. Louis. 1995: pp 133-148

Richman JE; Relationship Between Visual Attention And Learning, In Optometric Management of Learning –Related Vision Problems, Scheiman,M Rouse M (Eds) CV Mosby St. Louis MO. 2005; pp121-164

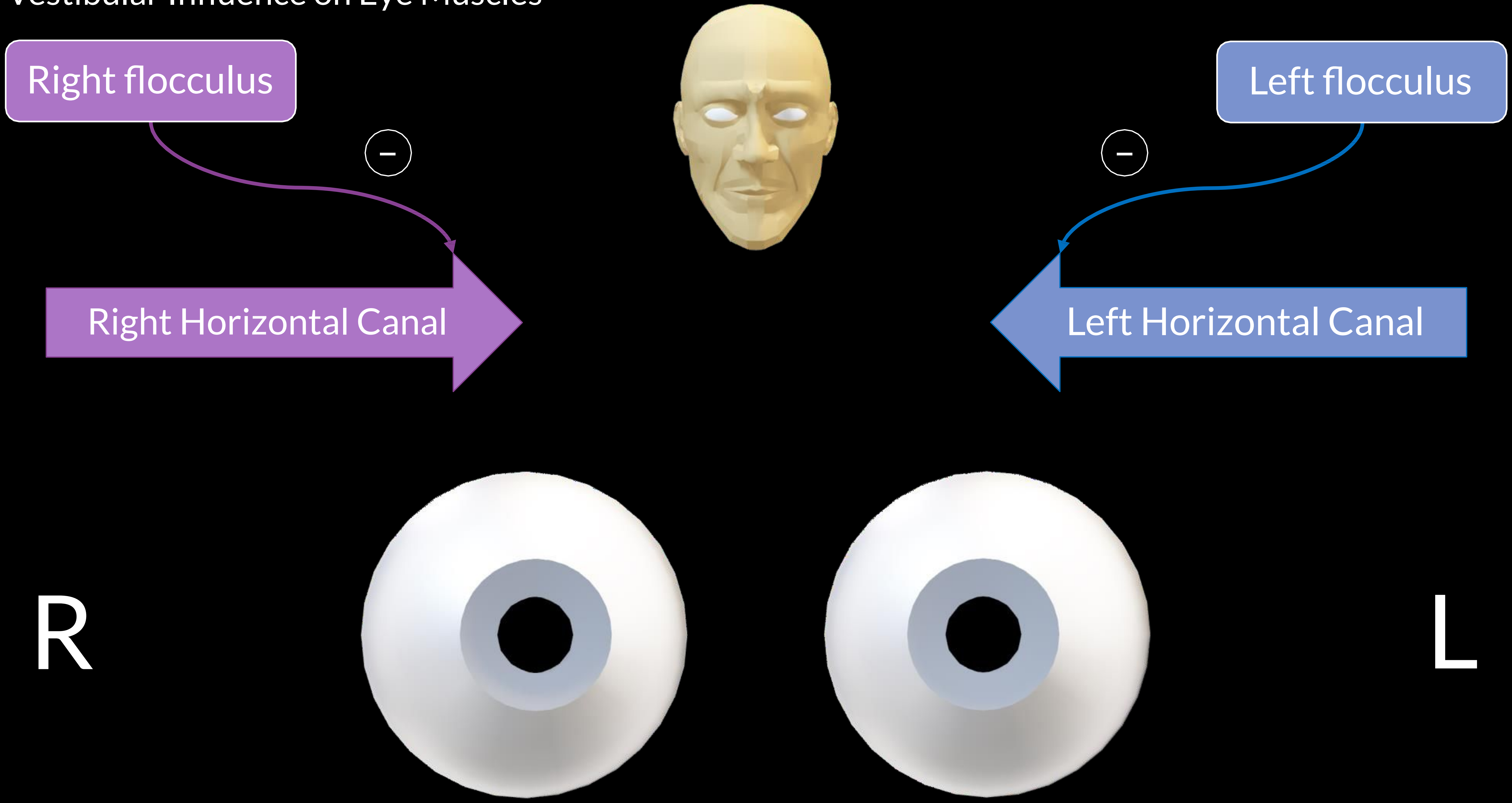


The Flocculus and Paraflocculus will be our most common cerebellar areas of interest for smooth pursuits, fixations, and aVORs.

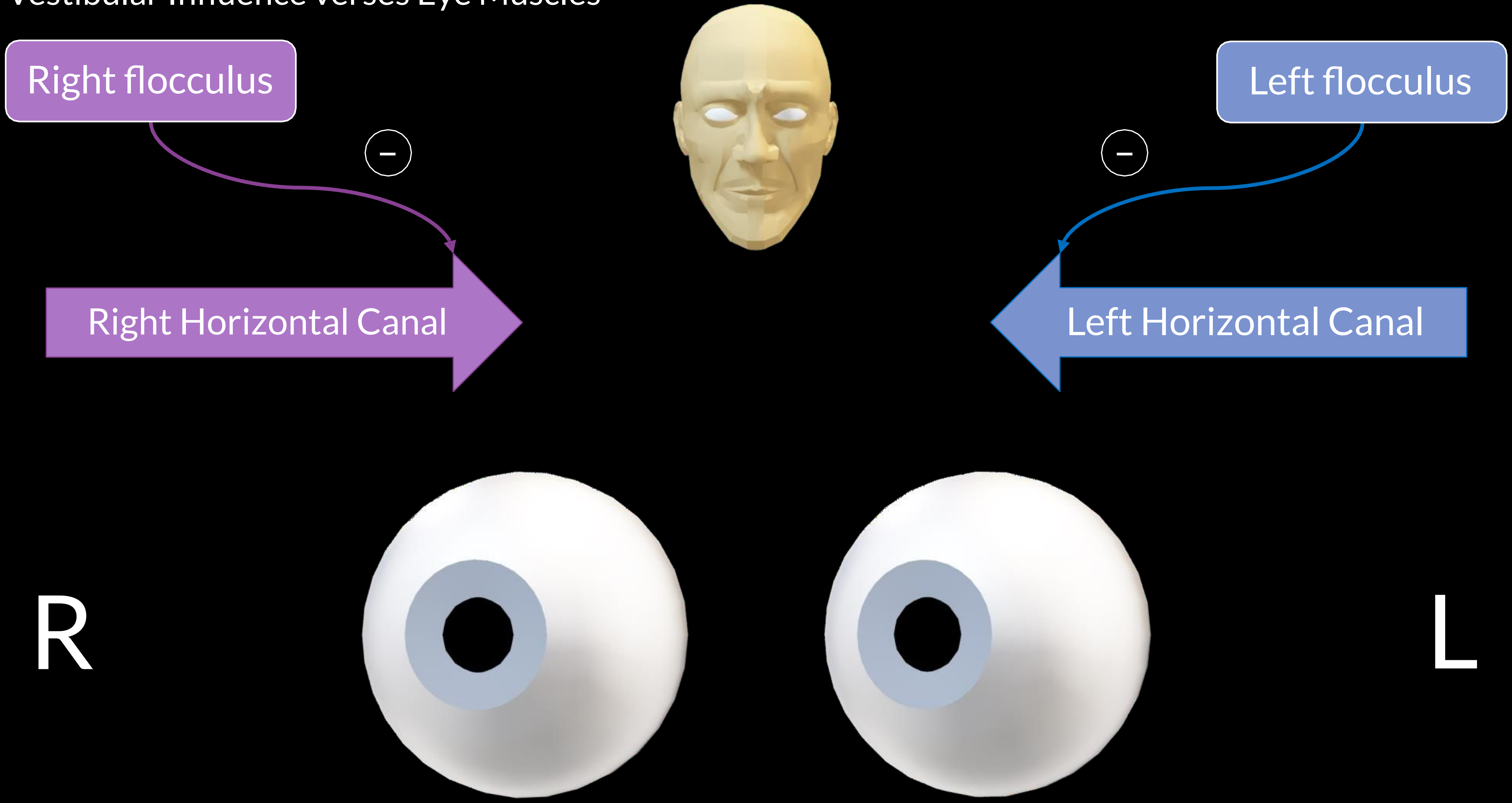
Laterality for the FL/PF



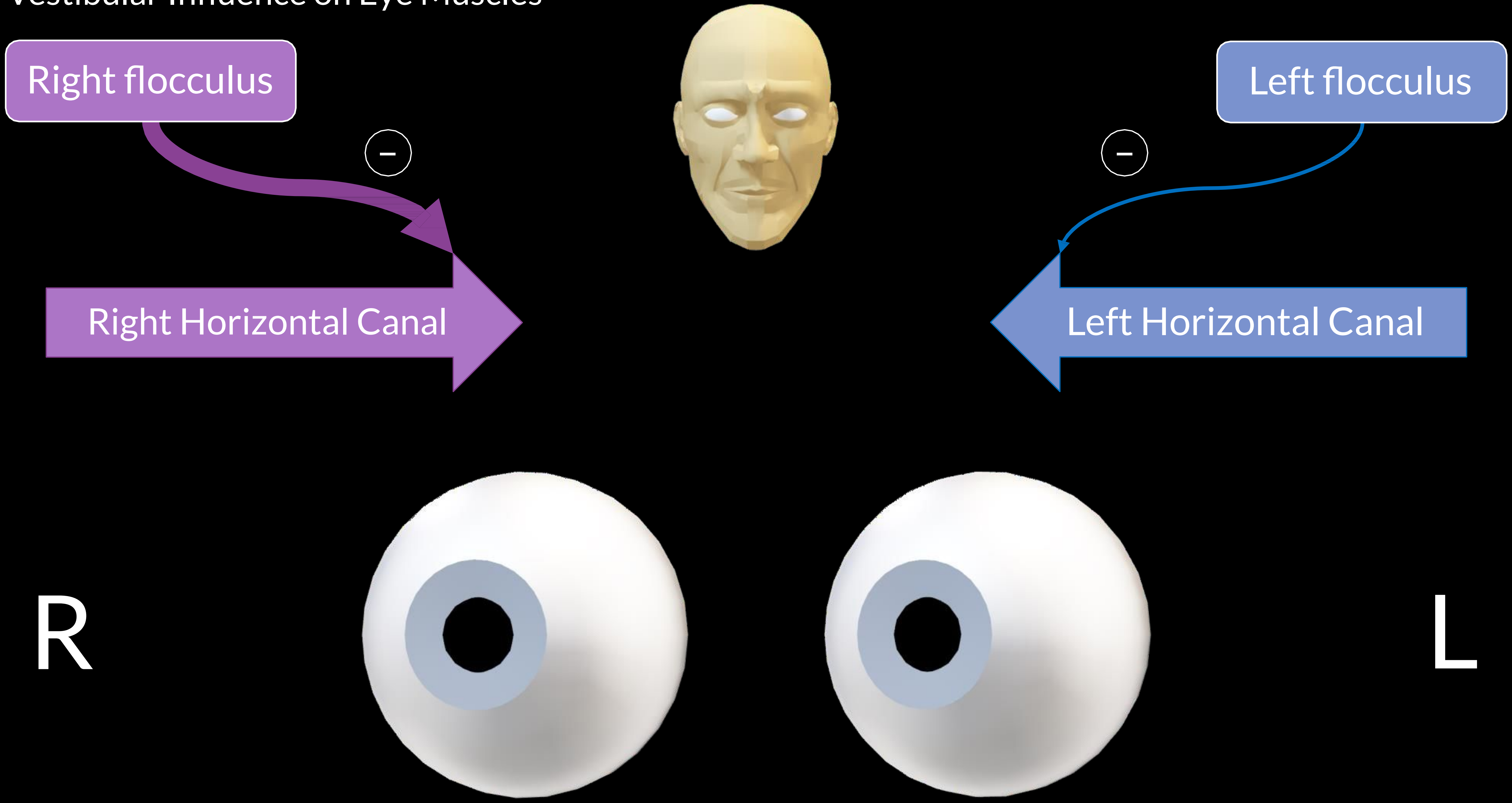
Vestibular Influence on Eye Muscles



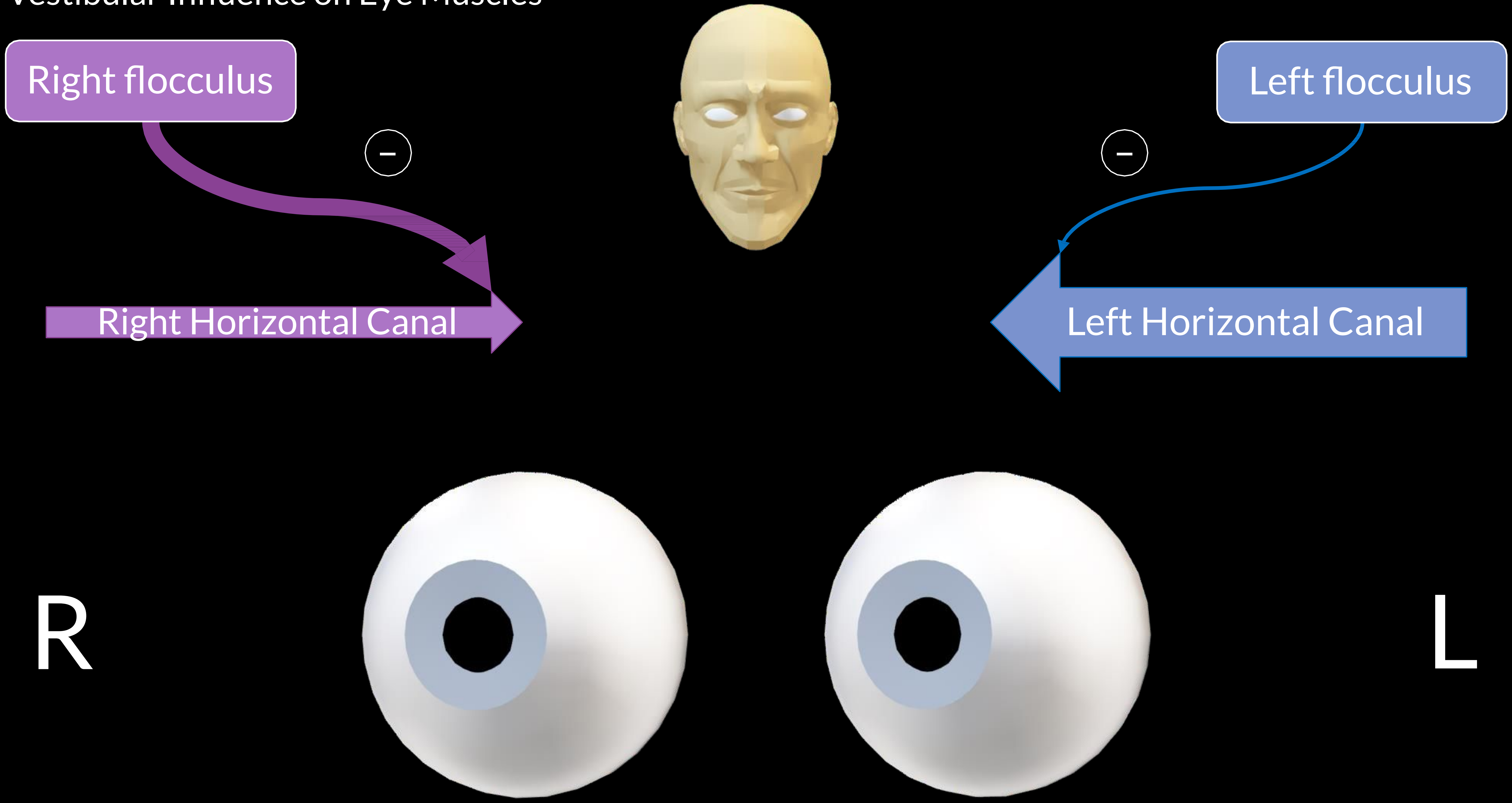
Vestibular Influence verses Eye Muscles



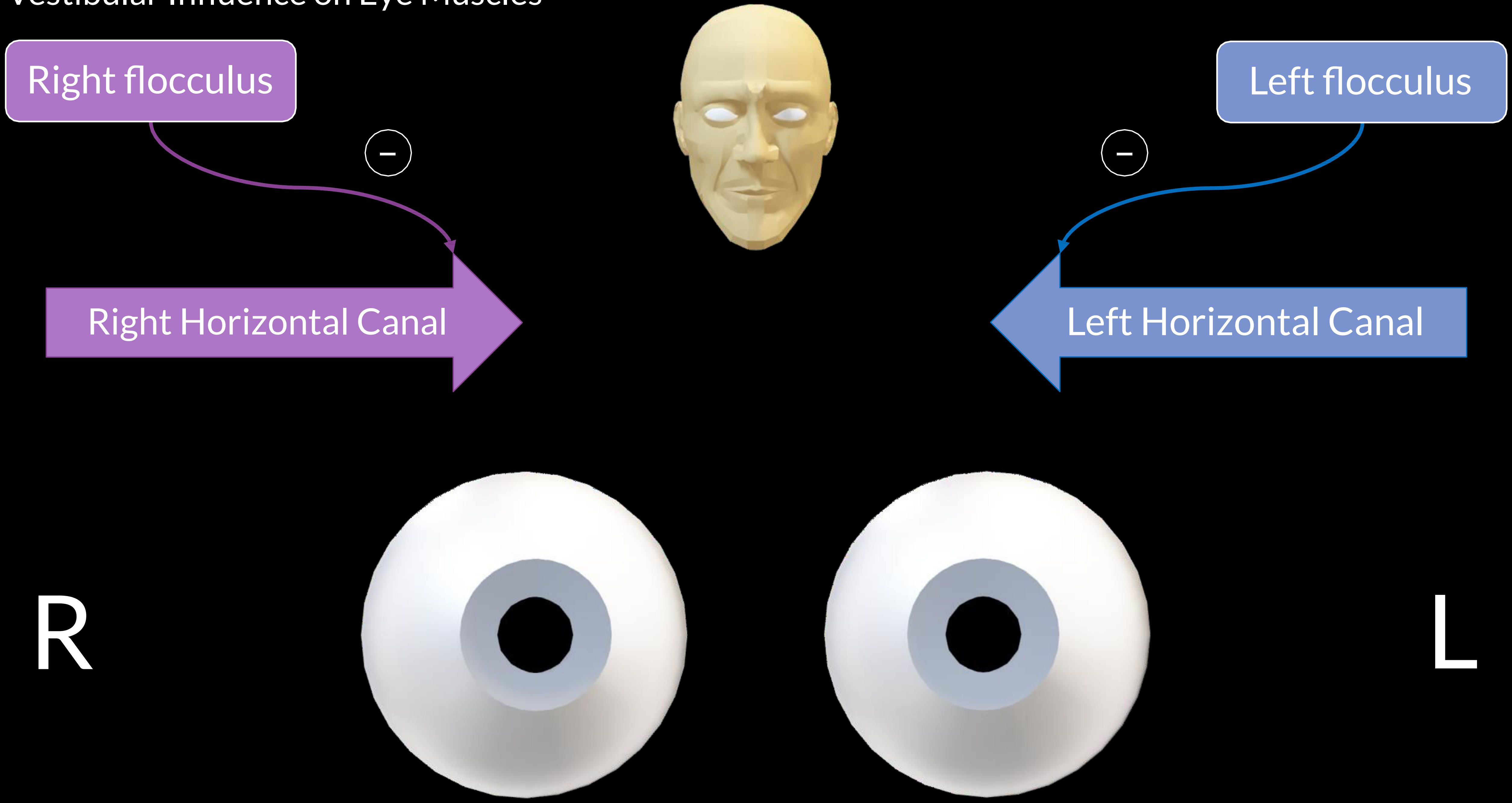
Vestibular Influence on Eye Muscles



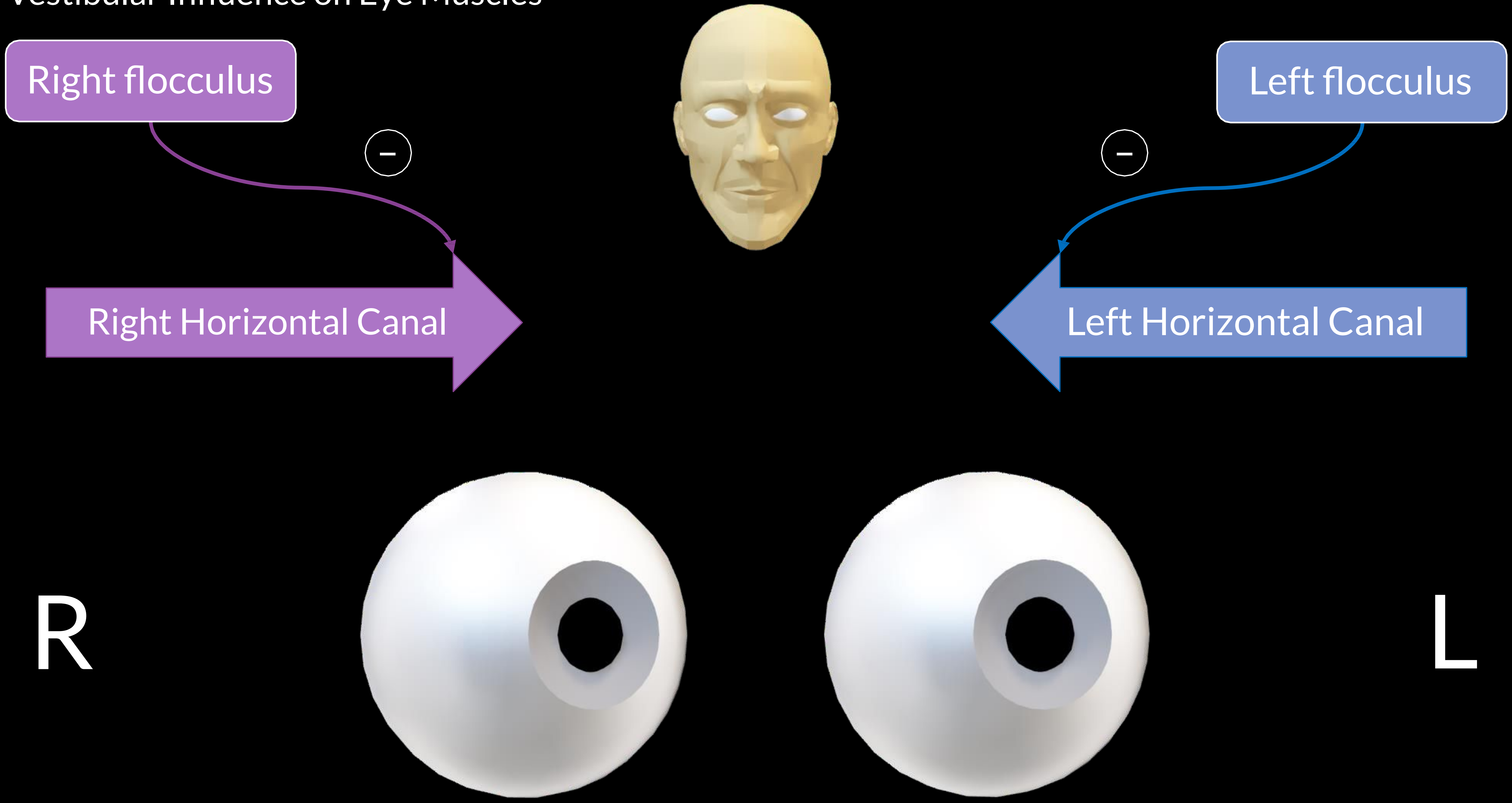
Vestibular Influence on Eye Muscles



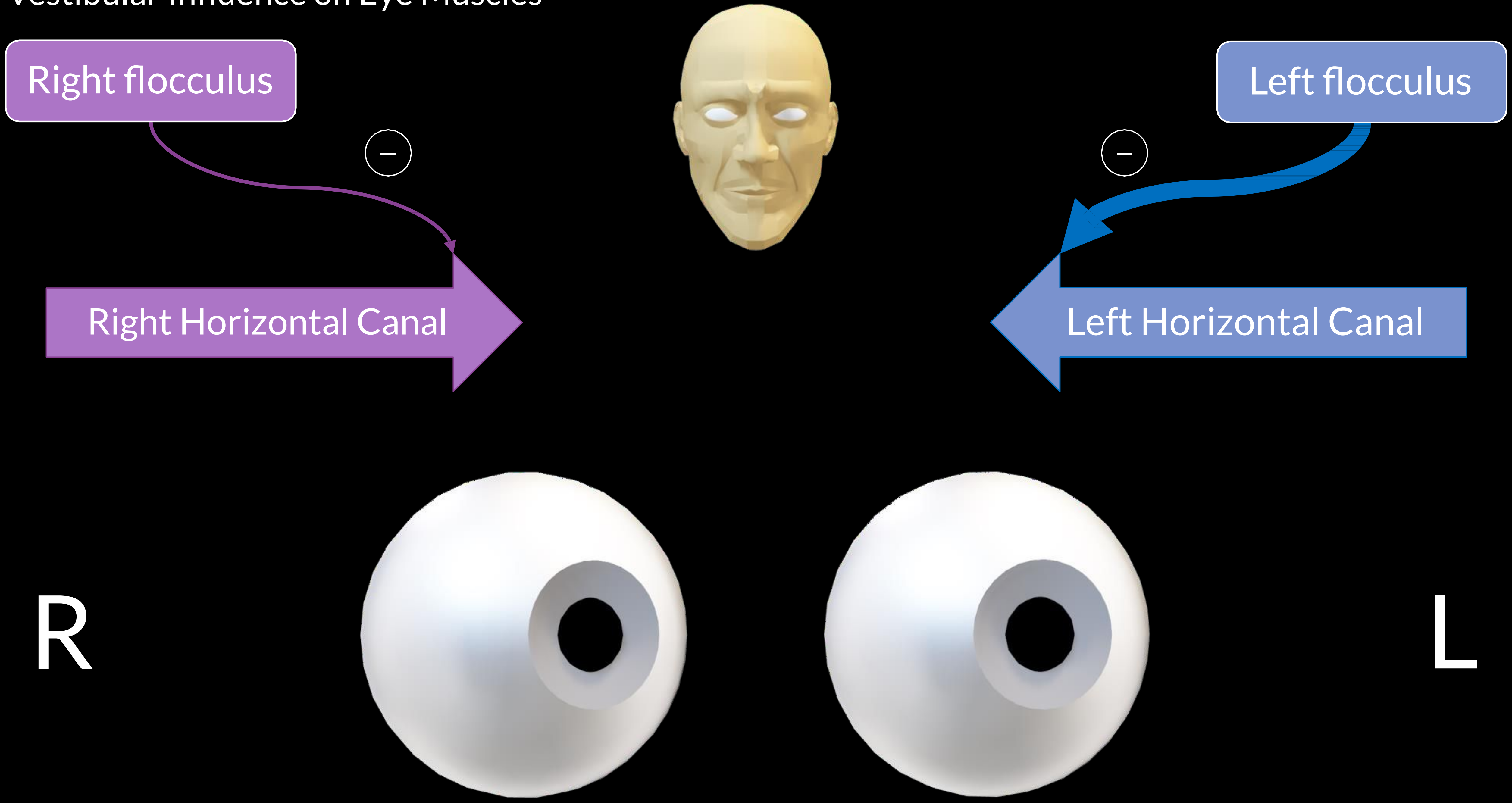
Vestibular Influence on Eye Muscles



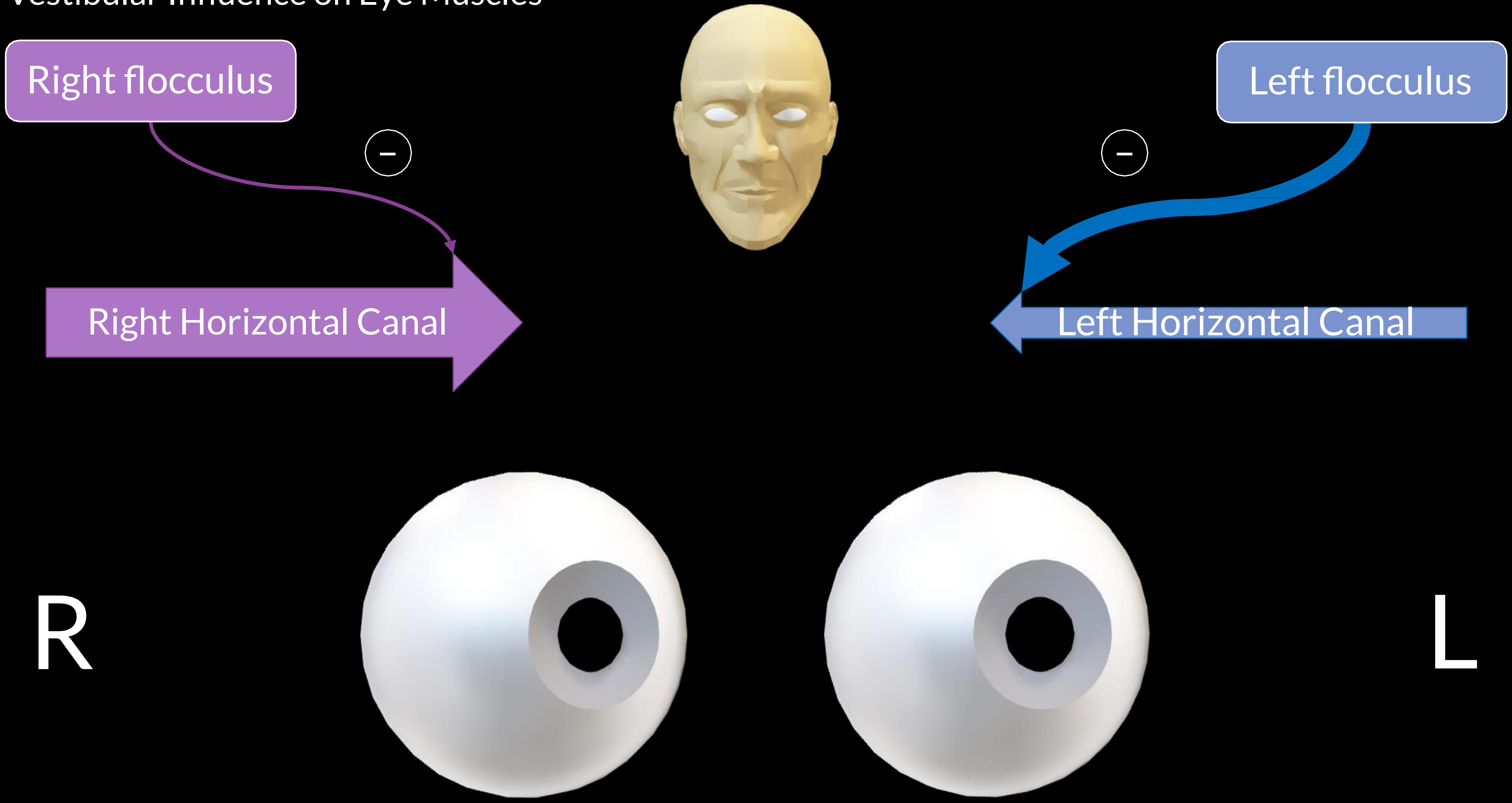
Vestibular Influence on Eye Muscles



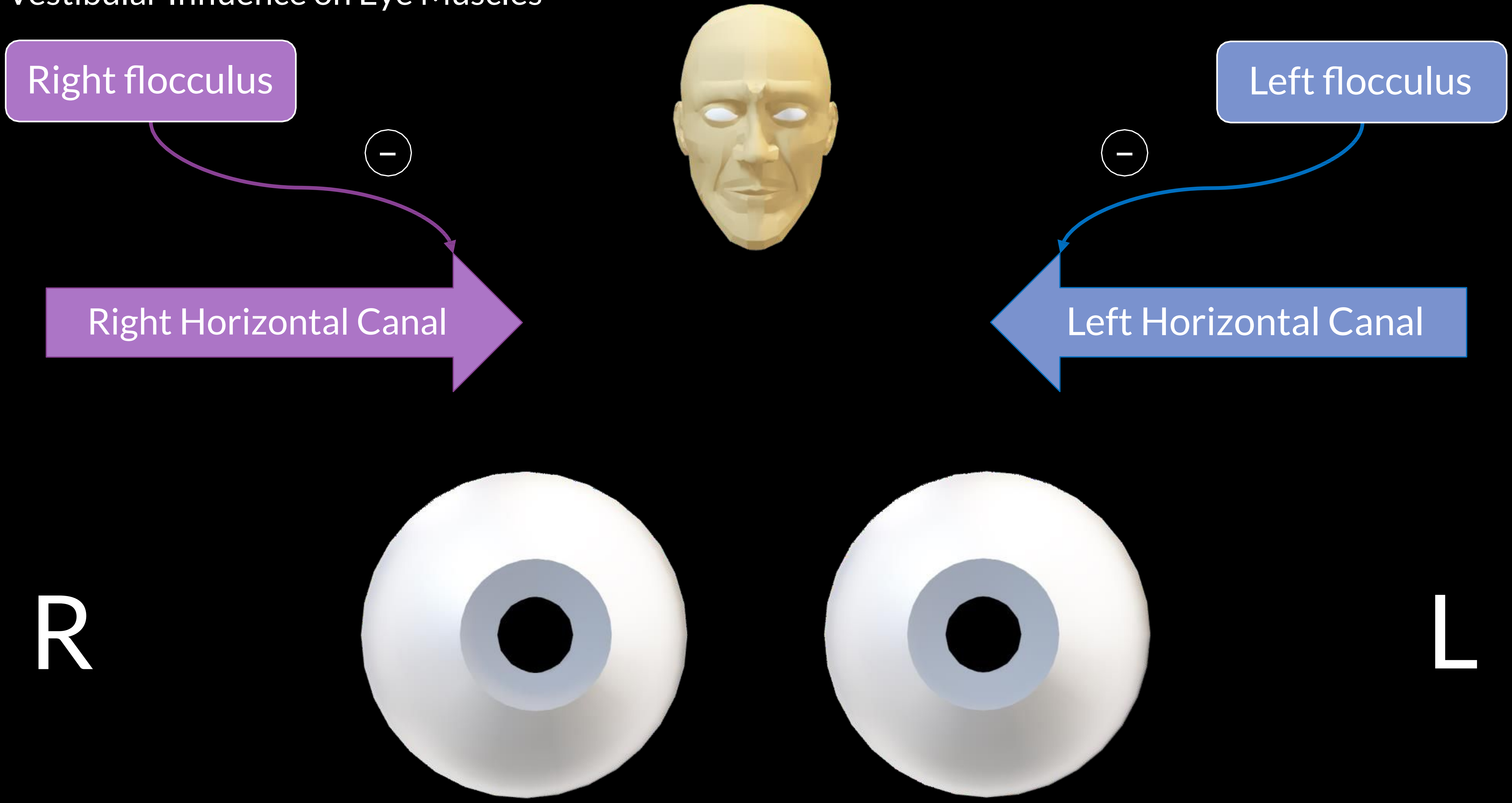
Vestibular Influence on Eye Muscles



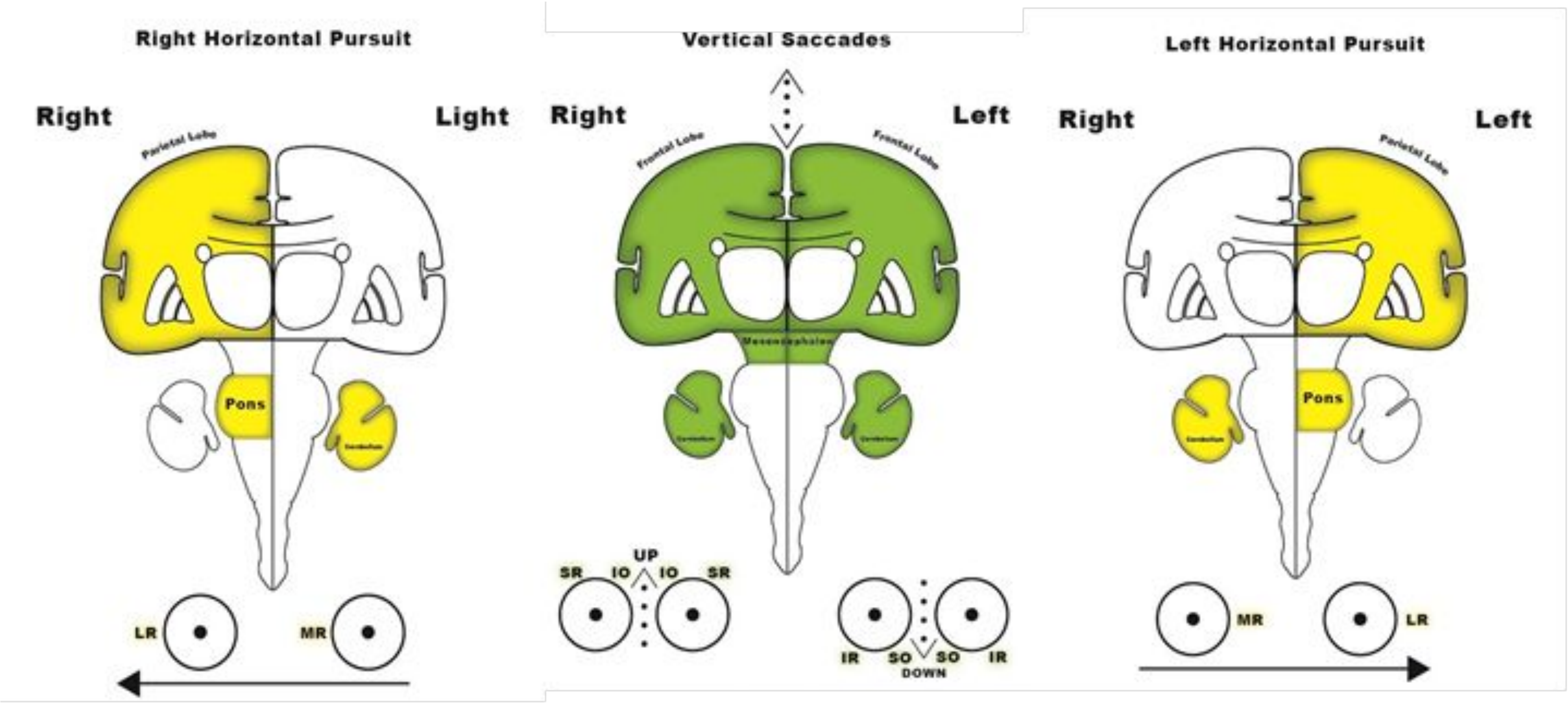
Vestibular Influence on Eye Muscles



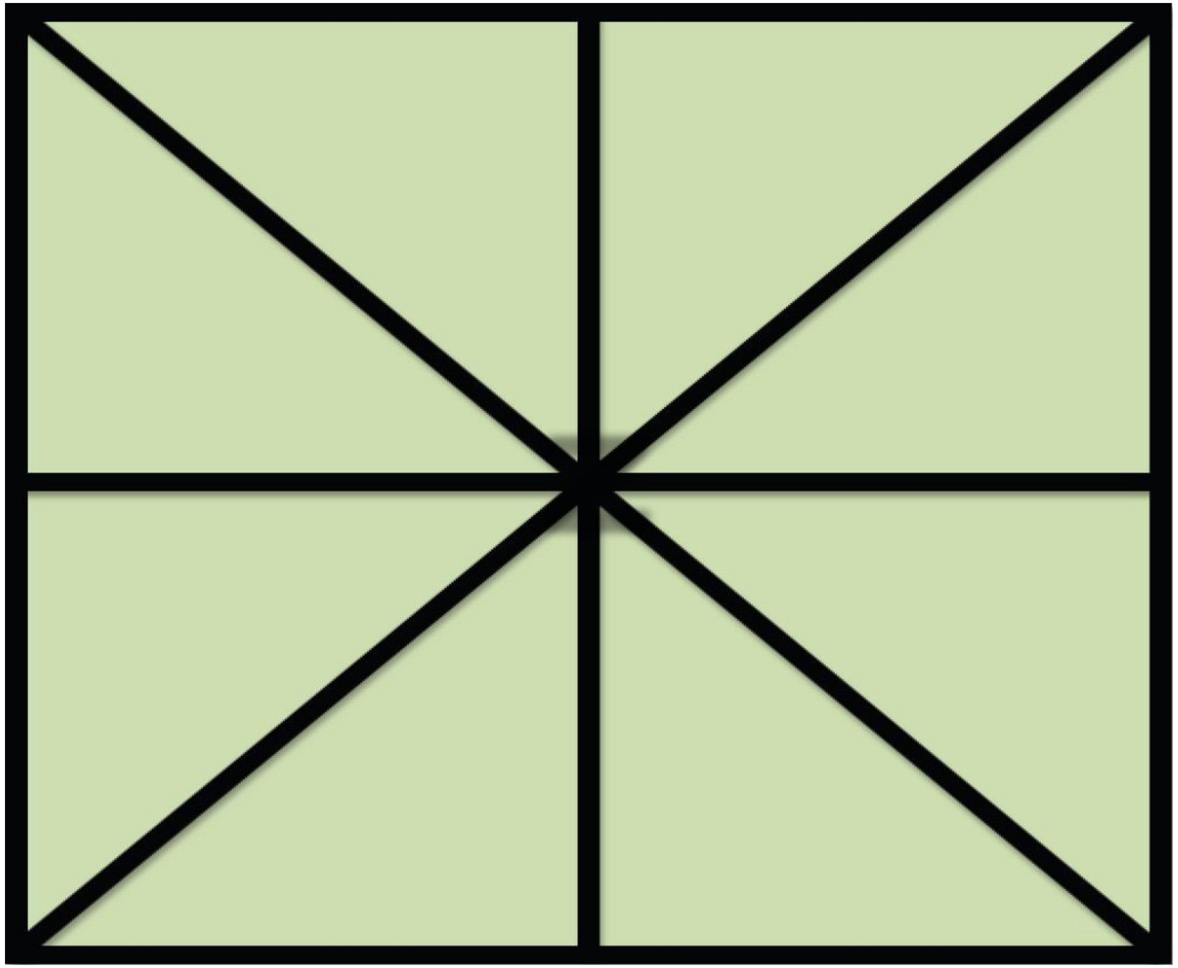
Vestibular Influence on Eye Muscles

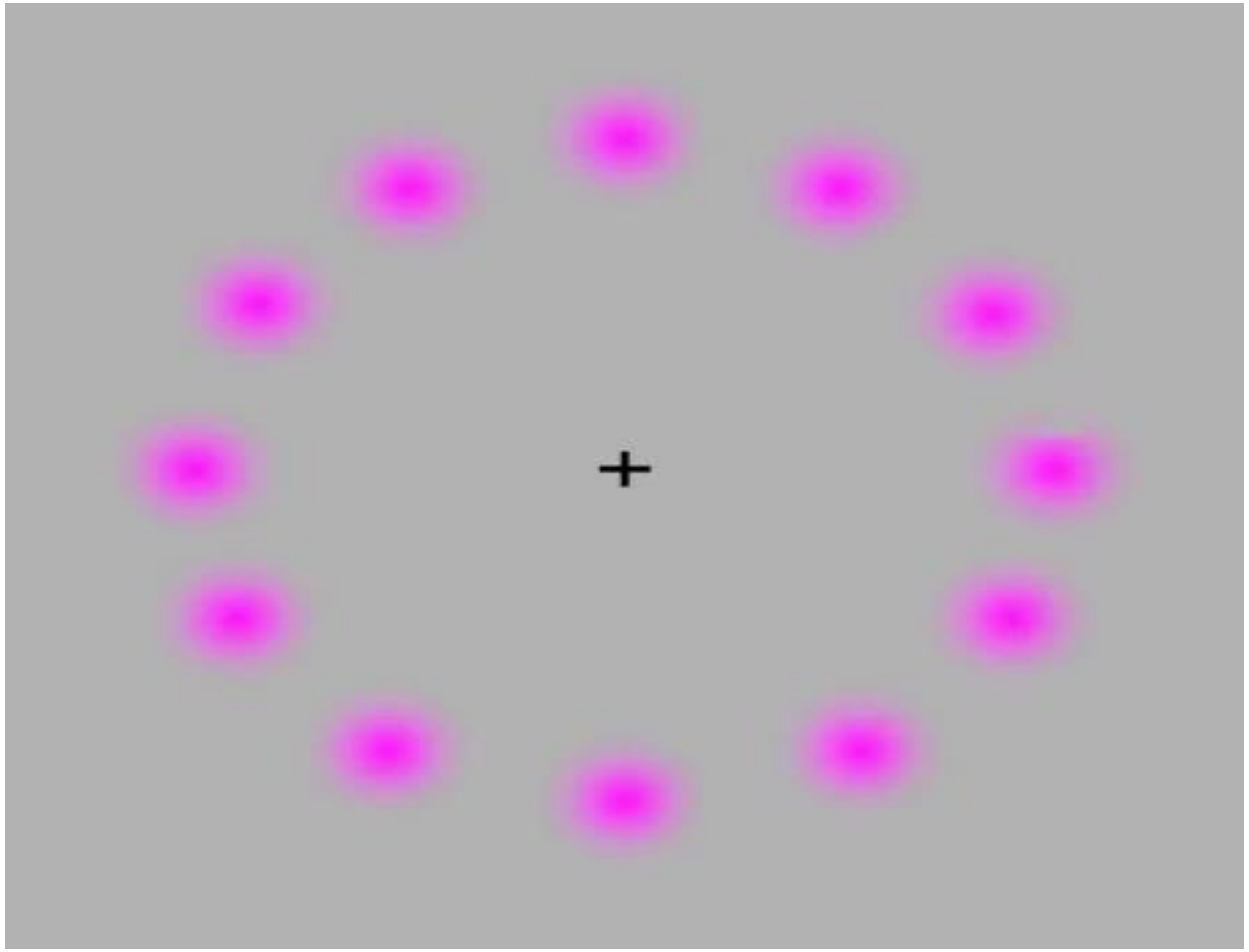


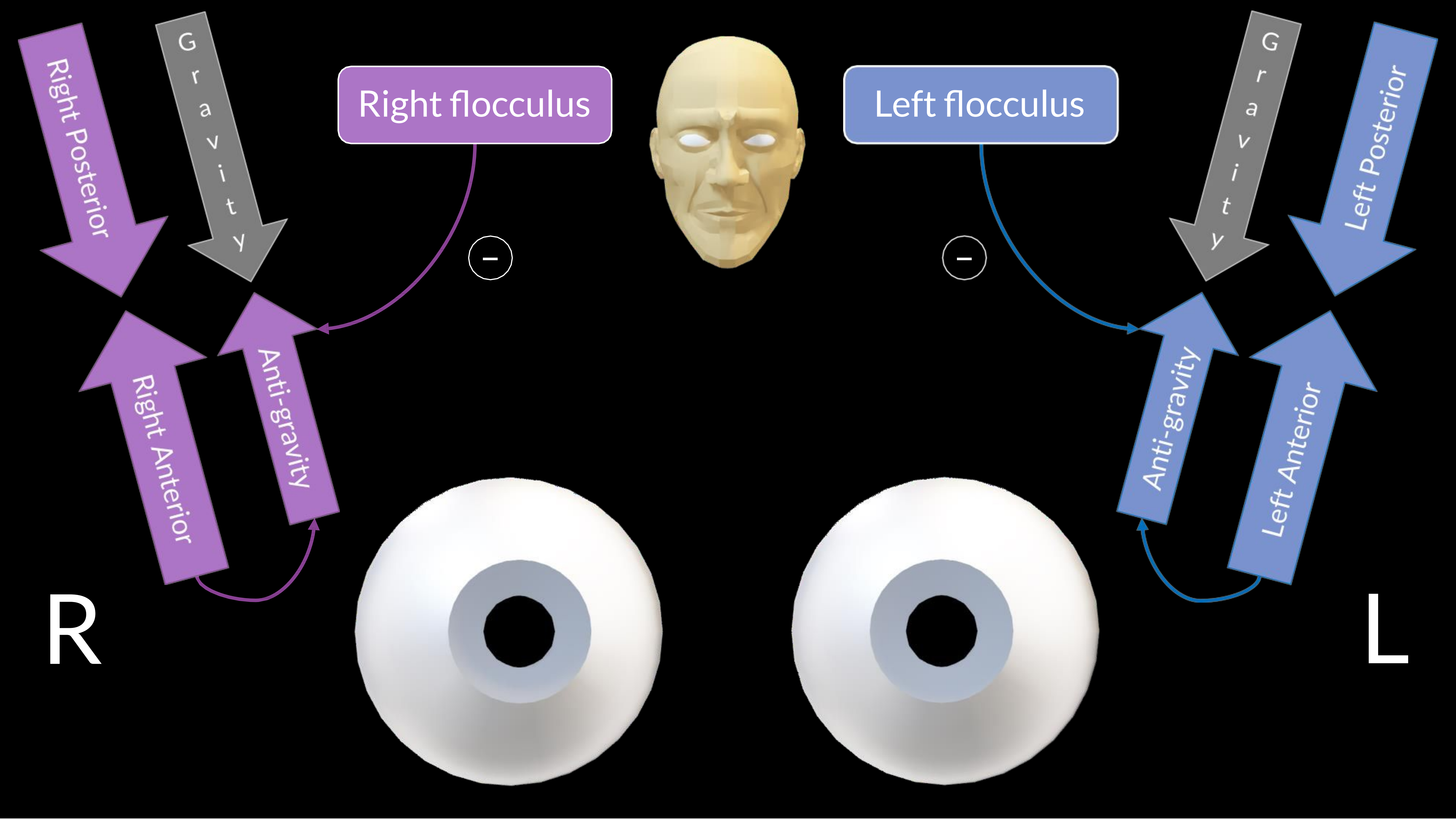
Upregulation patterns with SPEM away from laterally activated cerebellum. A cancelation of the Cervico-Ocular Reflex present in infancy as the Symmetrical Tonic Neck Reflex.

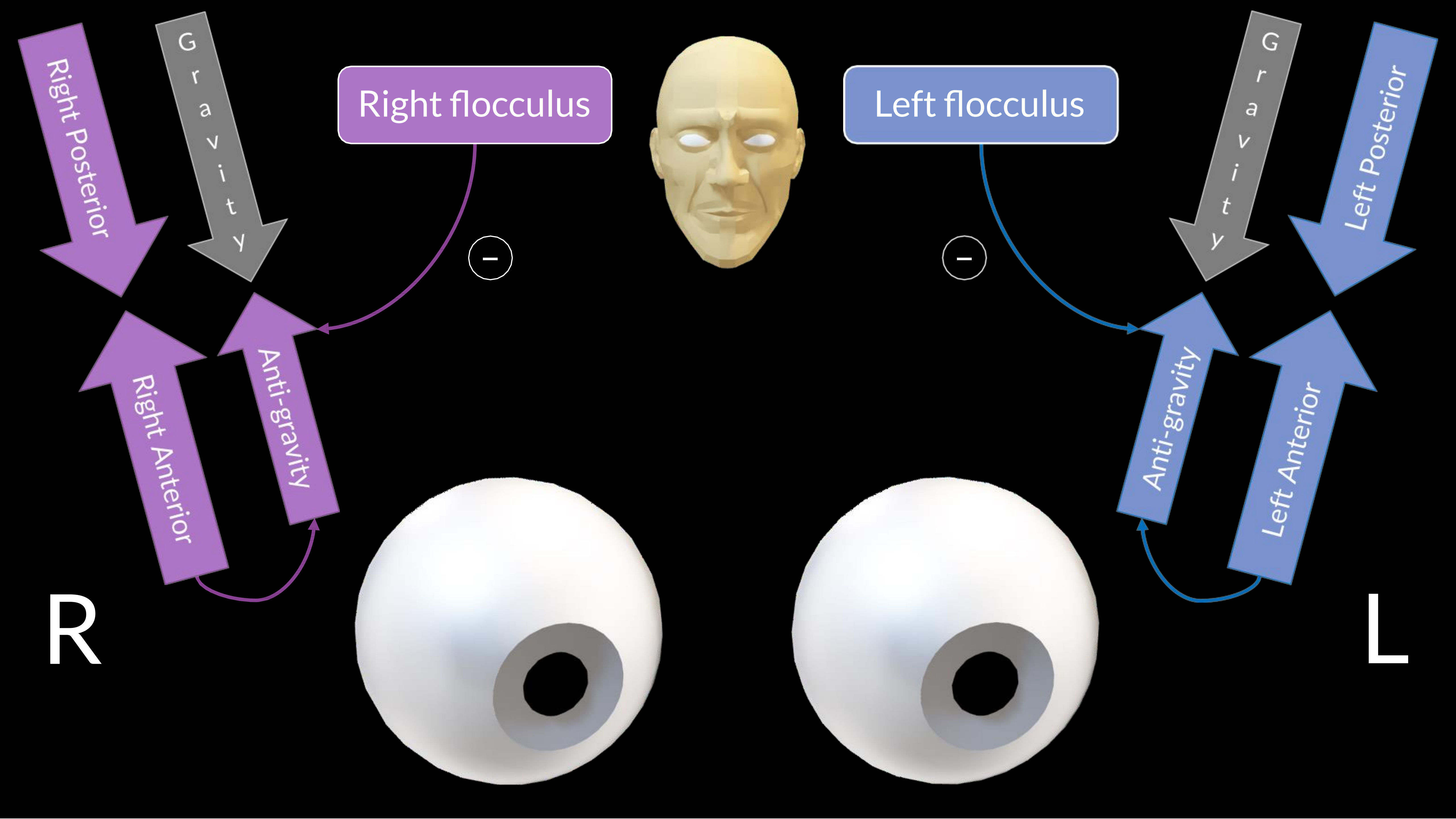


Maintaining Fixations of up to 30 seconds off central gaze a powerful neurologic tool!

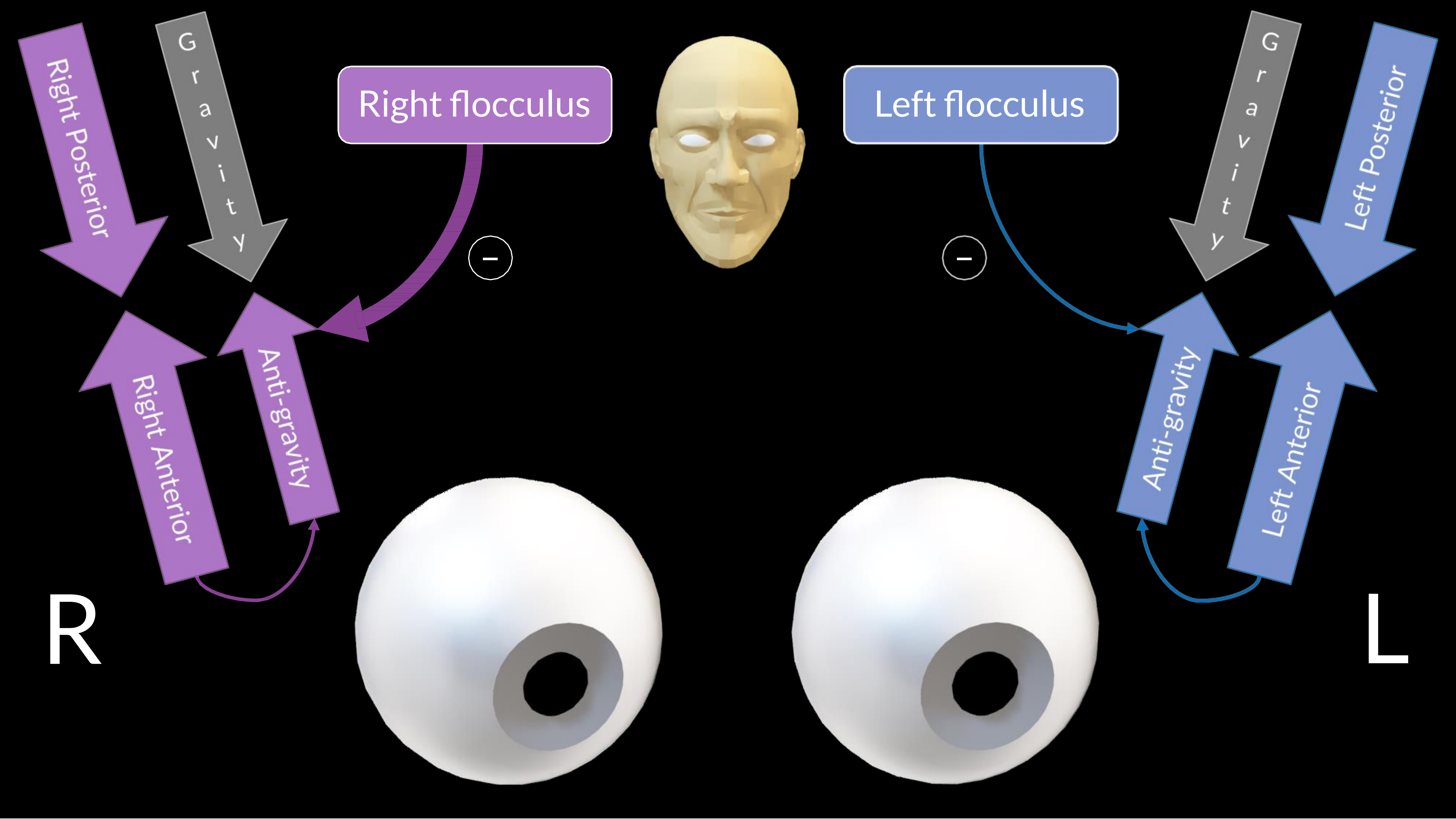


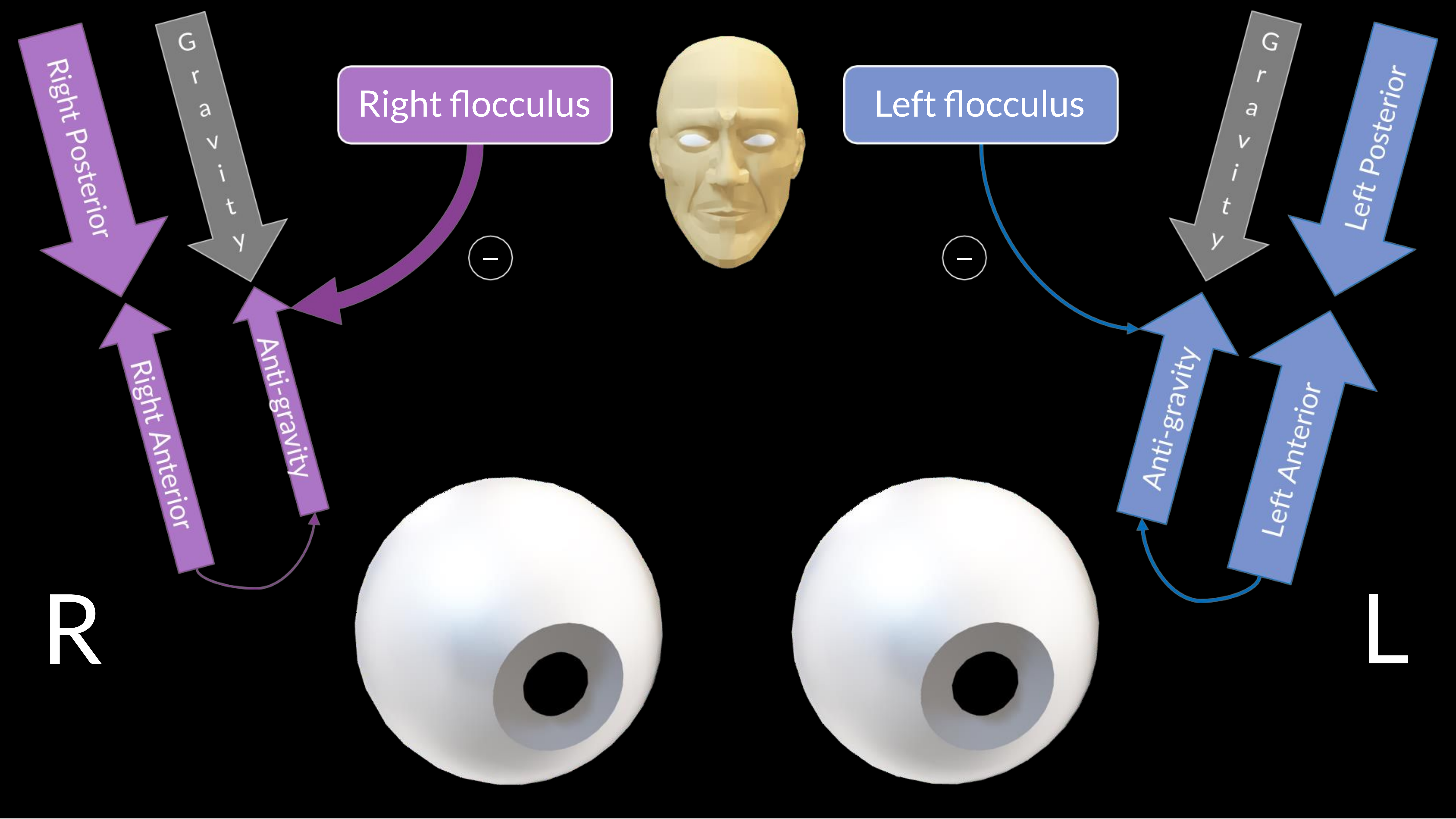


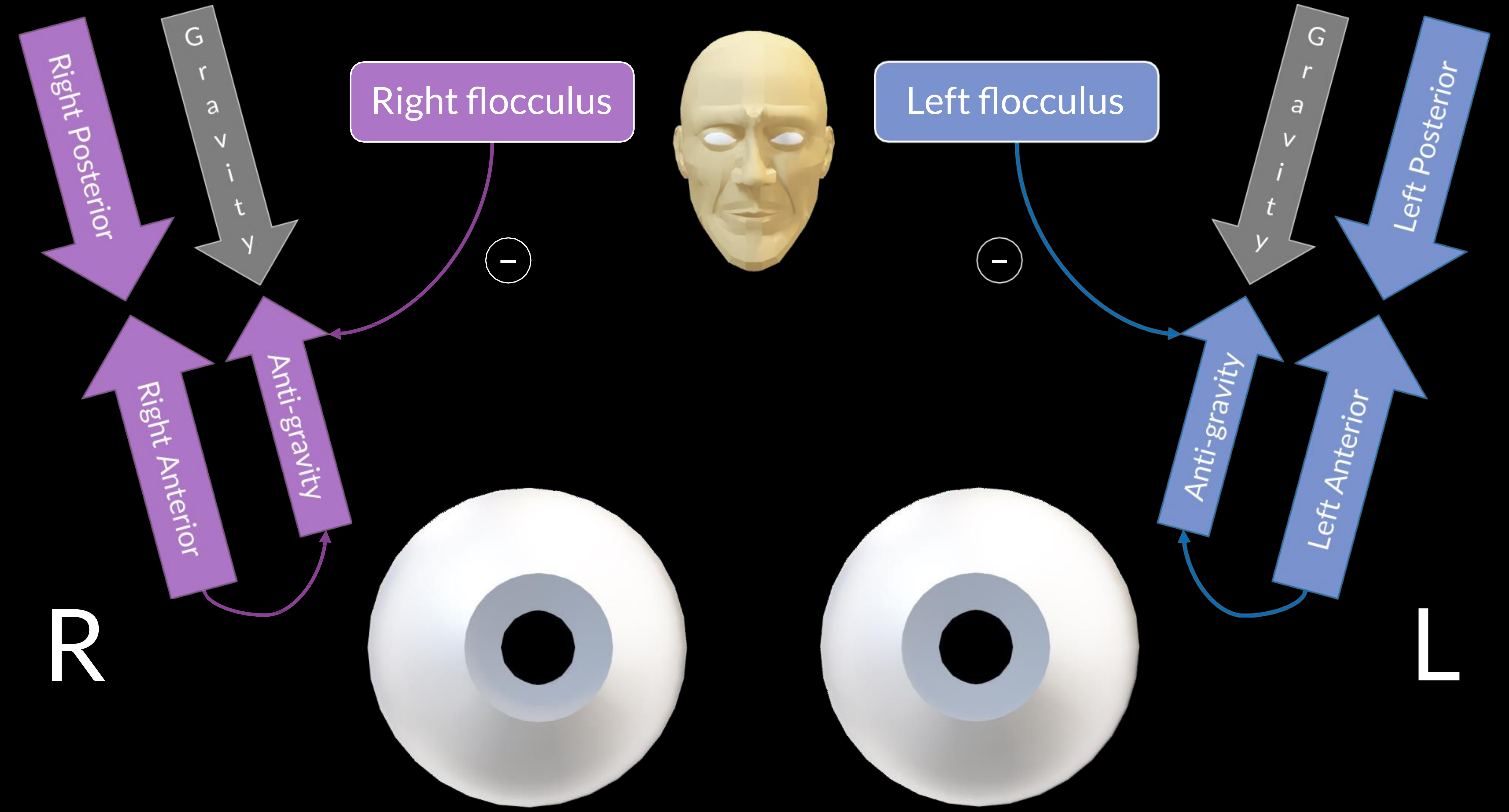

Right flocculus
Left flocculus
Right Posterior
Gravity
Right Anterior
Anti-gravity
Gravity
Left Posterior
Anti-gravity
Left Anterior
–
–
R
L



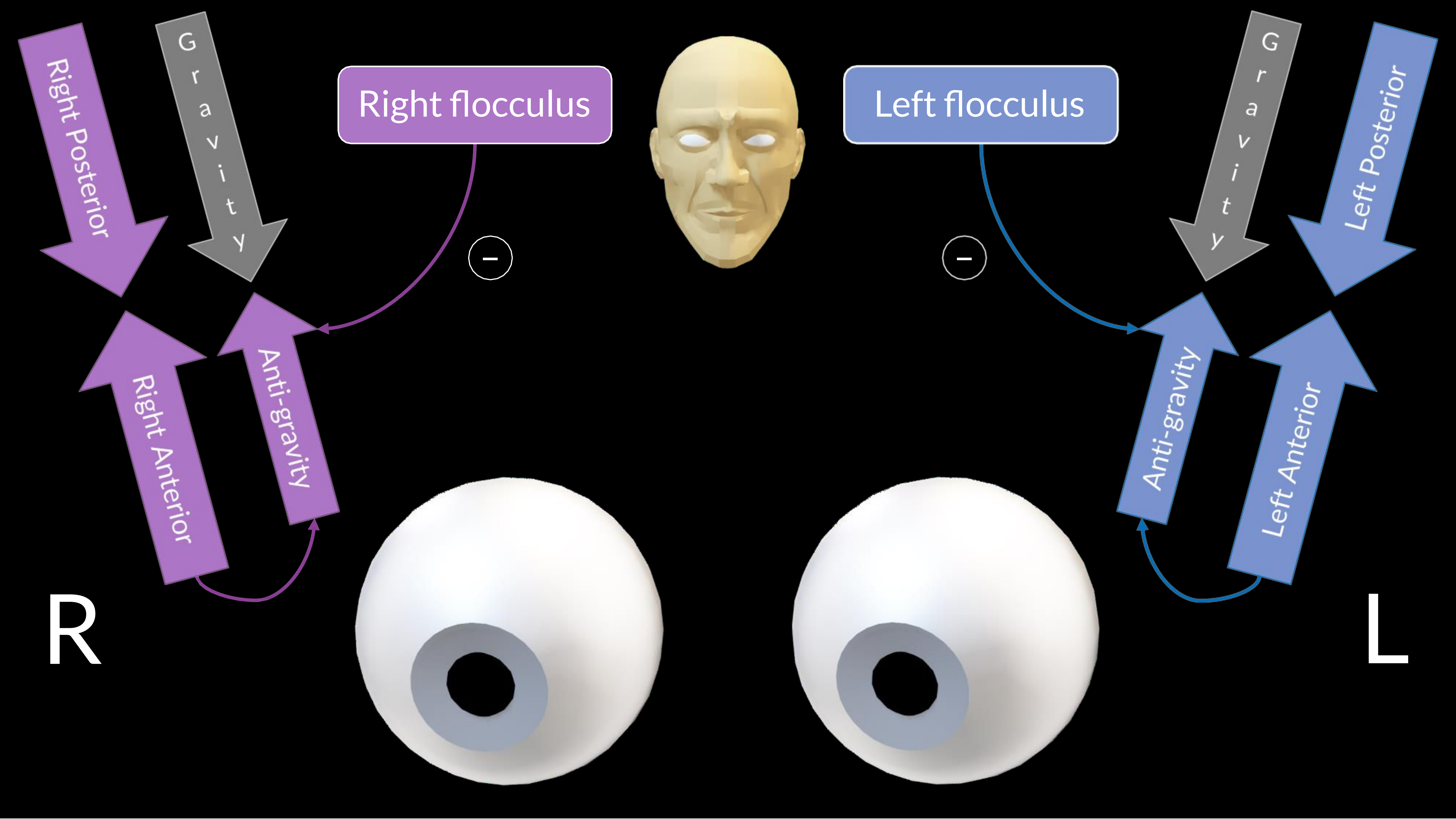
Right Posterior
Gravity
Right flocculus
Left flocculus
Gravity
Left Posterior
–
–
Right Anterior
Anti-gravity
Anti-gravity
Left Anterior
R
L

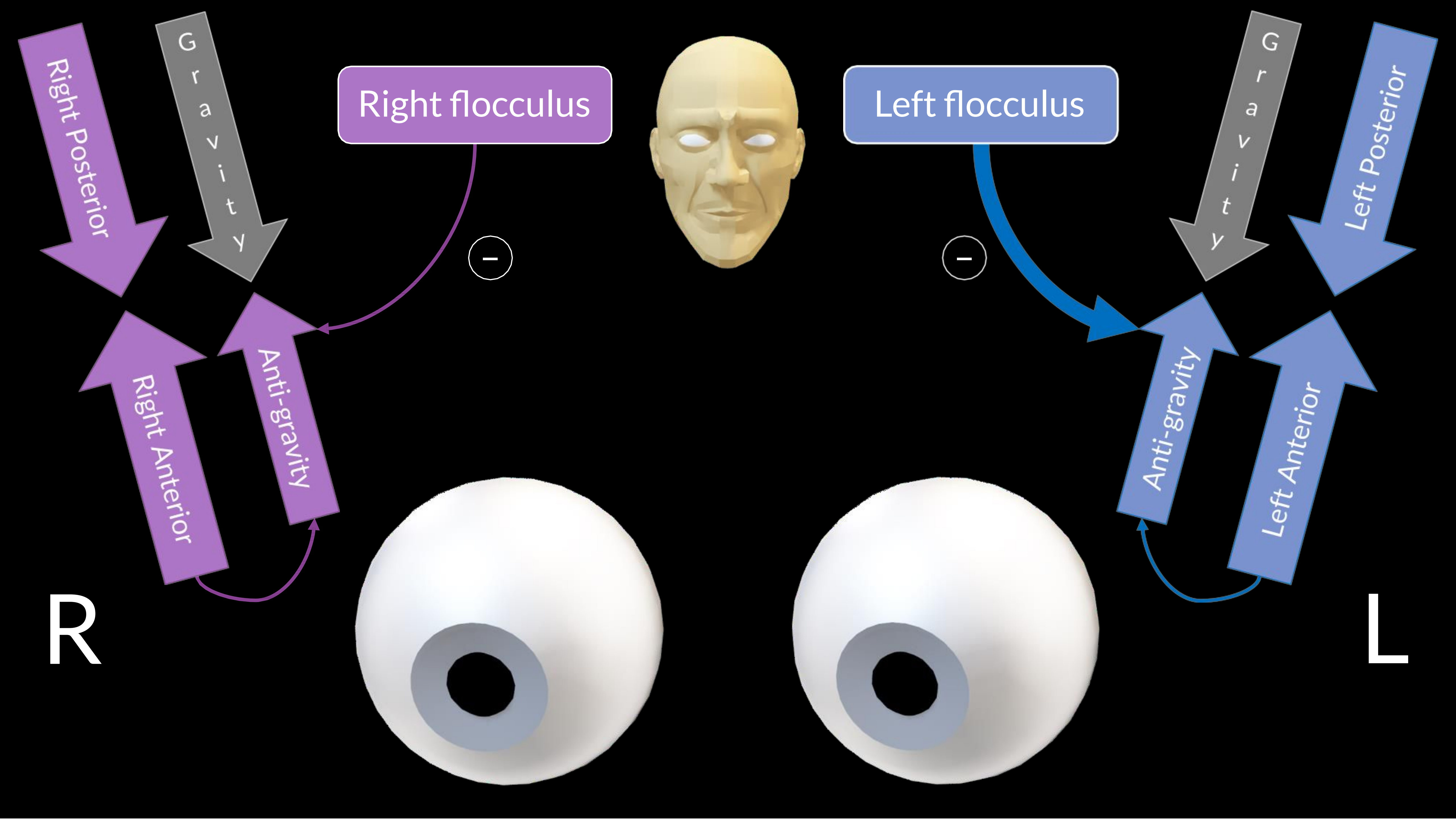

Right Posterior
Gravity
Right flocculus
Left flocculus
Gravity
Left Posterior
–
–
Right Anterior
Anti-gravity
Anti-gravity
Left Anterior
R
L


Right Posterior
Gravity
Right flocculus
Left flocculus
Gravity
Left Posterior
Right Anterior
Anti-gravity
Anti-gravity
Left Anterior
R
L

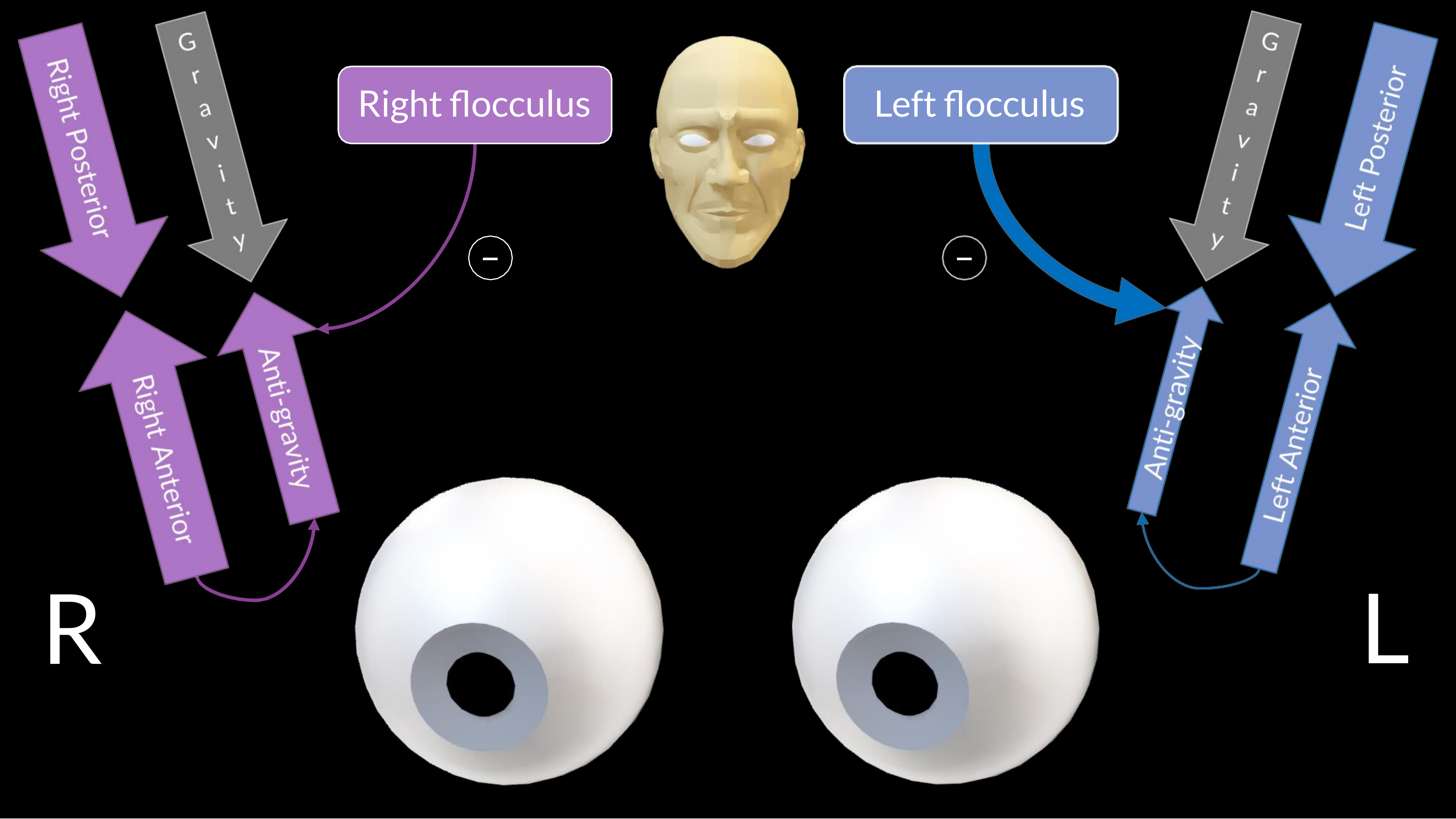


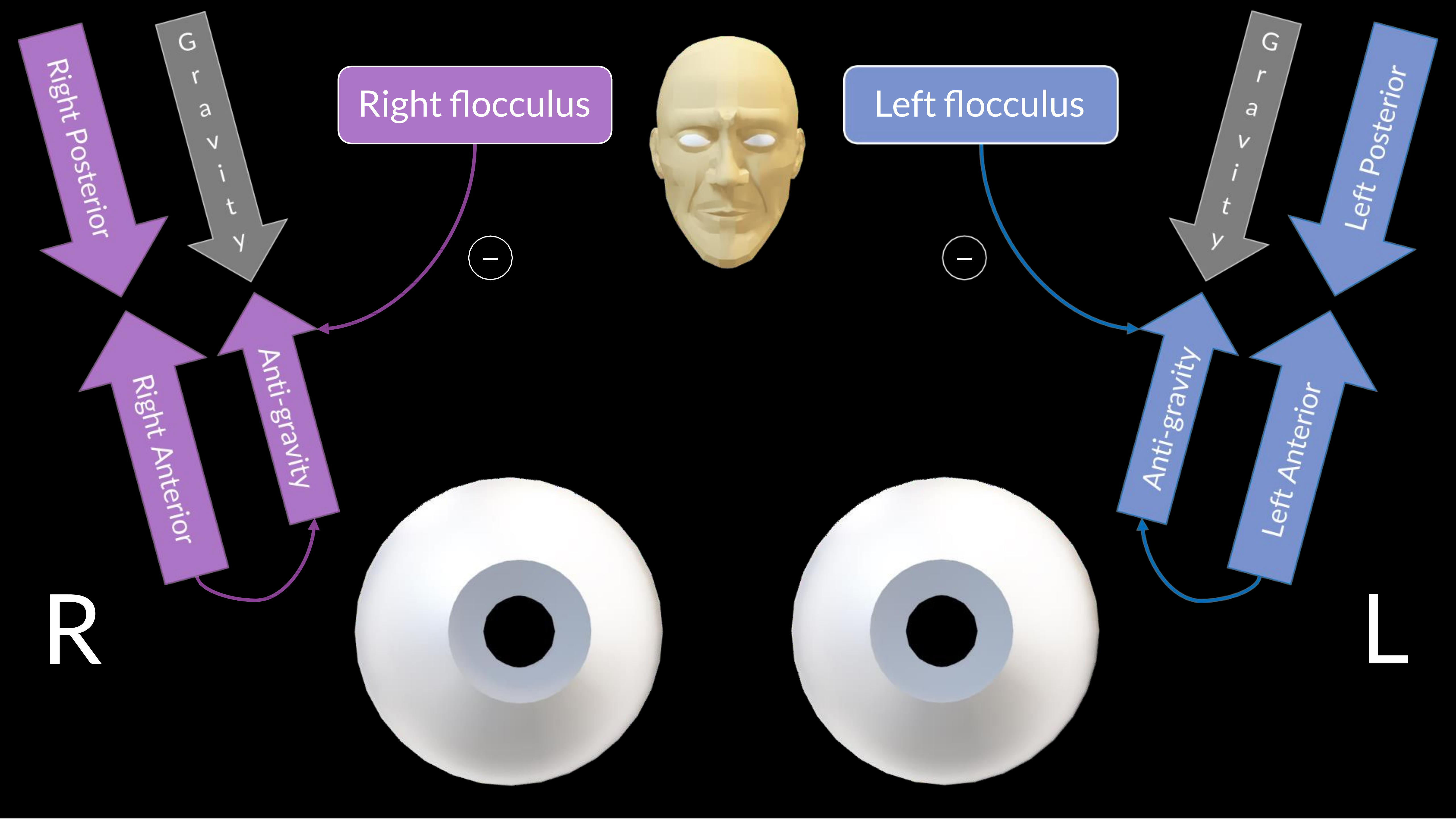
Right Posterior
Gravity
Right flocculus
Left flocculus
Gravity
Left Posterior
Right Anterior
Anti-gravity
Anti-gravity
Left Anterior
R
L


Right flocculus
Left flocculus
Right Posterior
Gravity
Right Anterior
Anti-gravity
Gravity
Left Posterior
Anti-gravity
Left Anterior
–
–
R
L

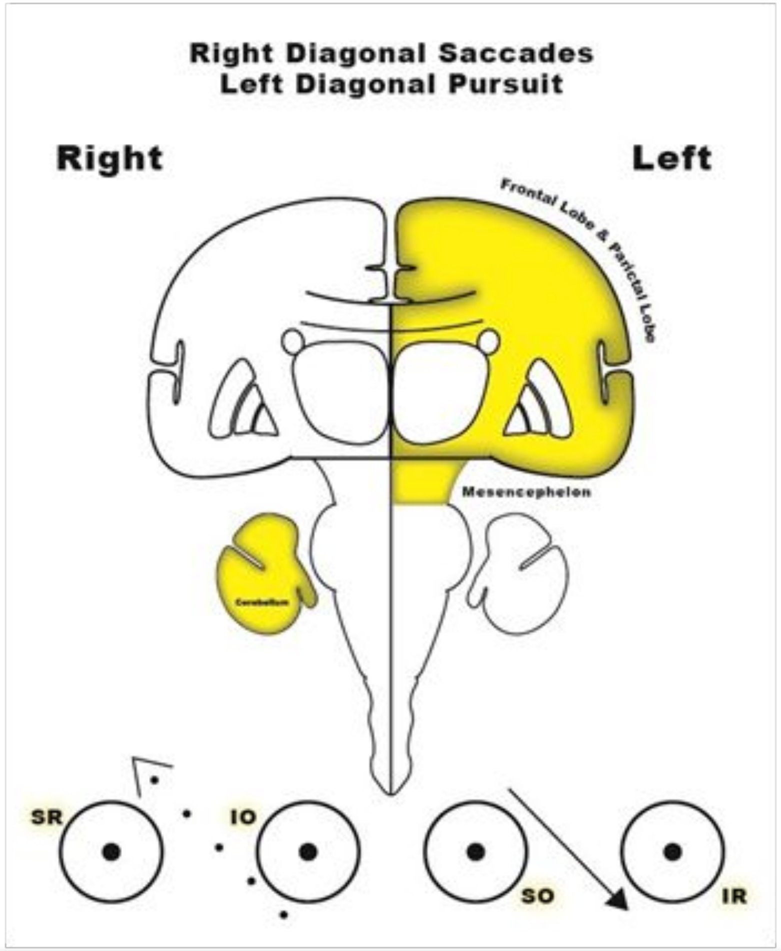


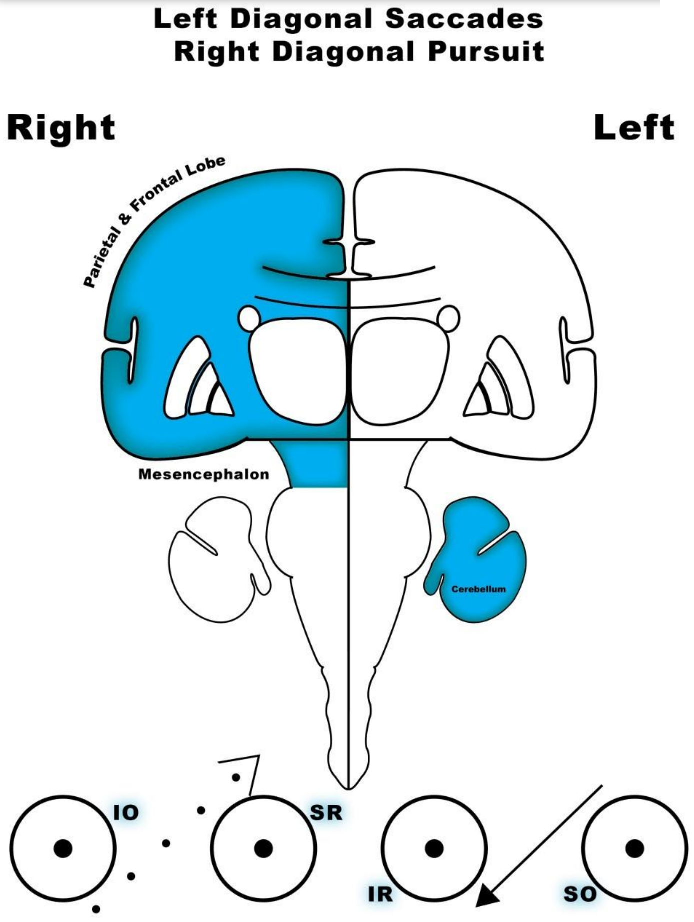
Right flocculus
Left flocculus
Right Posterior
Gravity
Right Anterior
Anti-gravity
Anti-gravity
Left Anterior
Gravity
Left Posterior
R
L


Right Posterior
Gravity
Right flocculus
Left flocculus
Gravity
Left Posterior
Right Anterior
Anti-gravity
Anti-gravity
Left Anterior
R
L

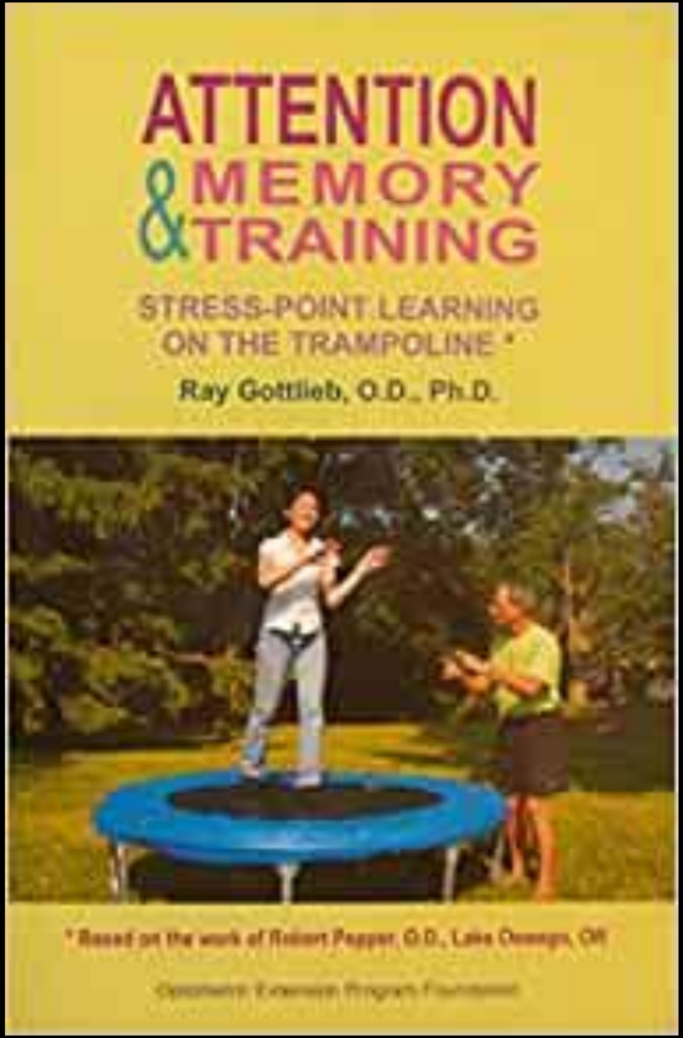

Right Posterior
Gravity
Right flocculus
Left flocculus
Gravity
Left Posterior
–
–
Right Anterior
Anti-gravity
Anti-gravity
Left Anterior
R
L

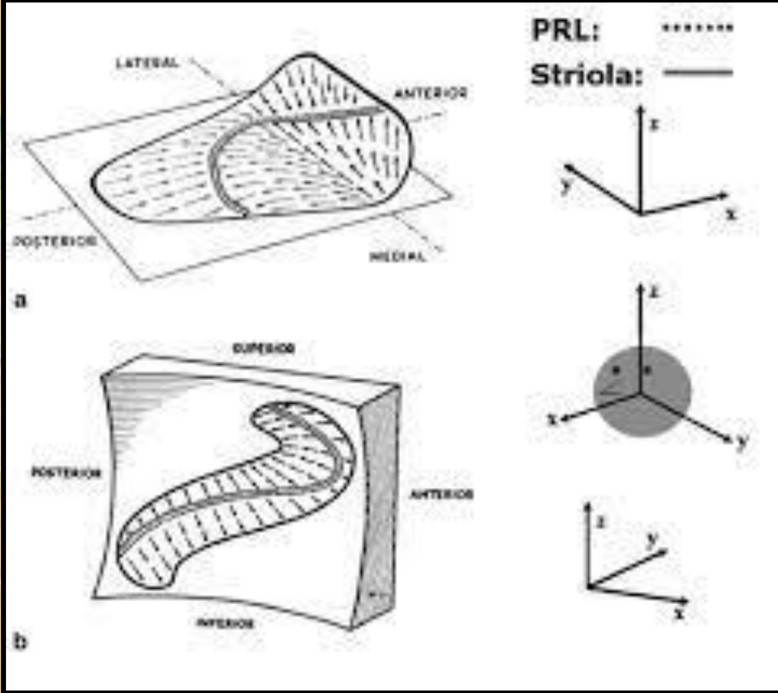
Combination Saccades and Pursuits
Powerful Colliculus Mapping Activity

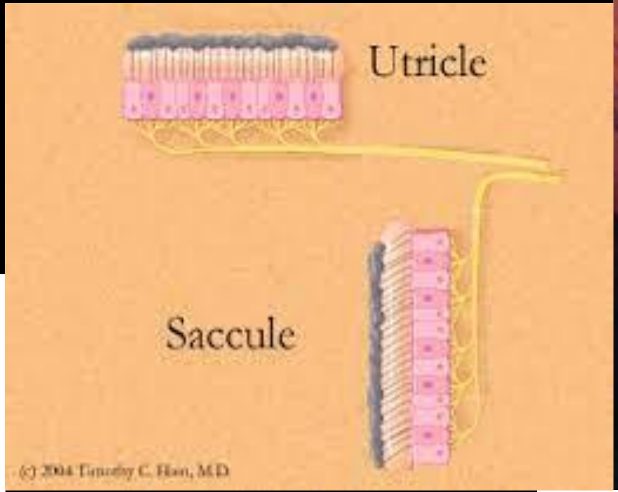


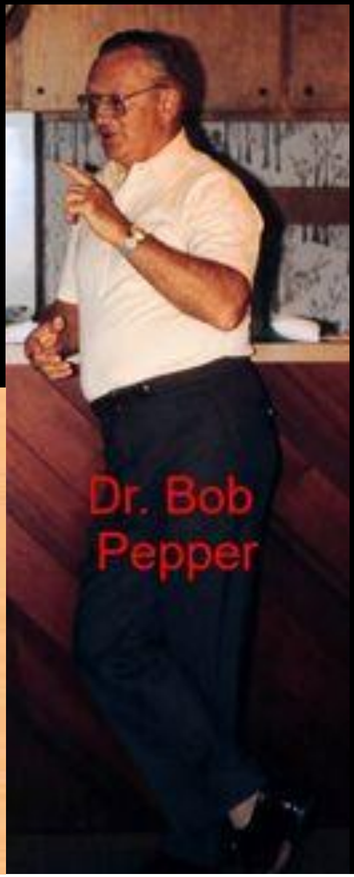


Uvula:Move, walk, jump, bob and weave!



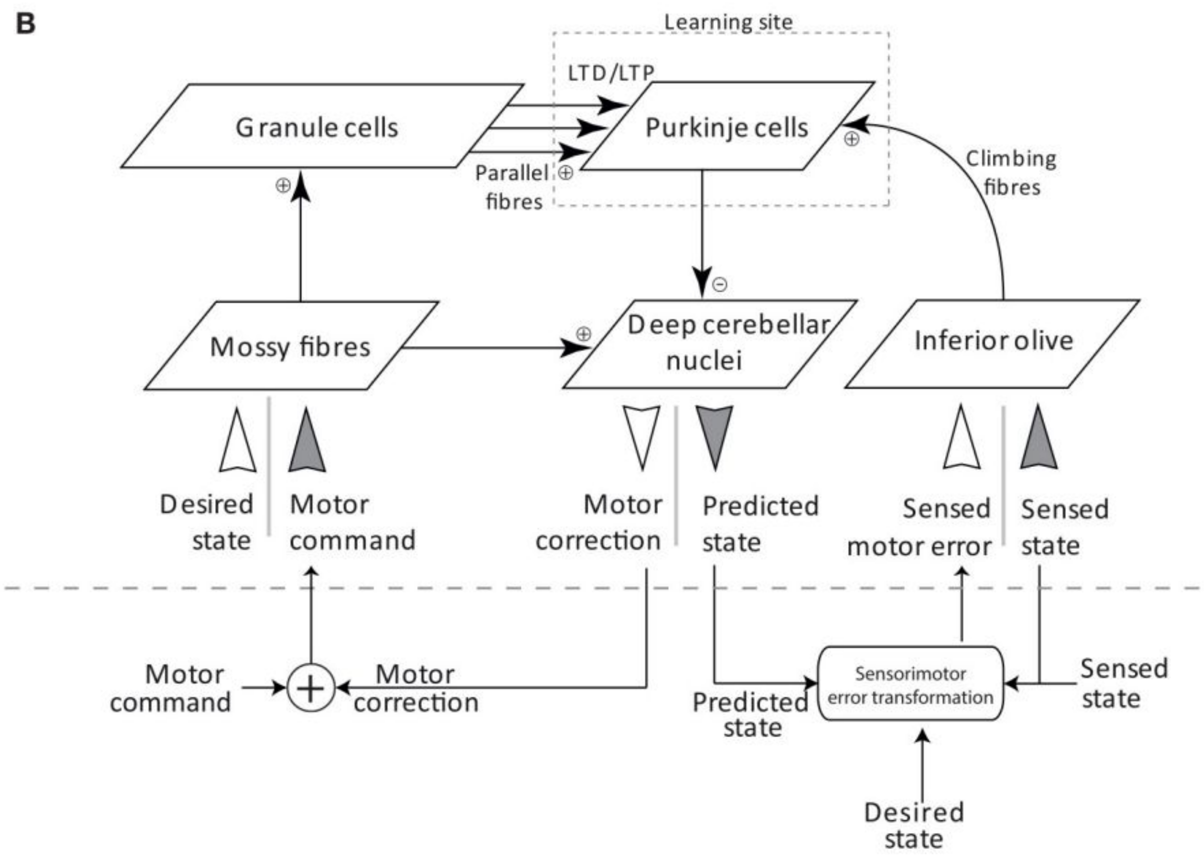


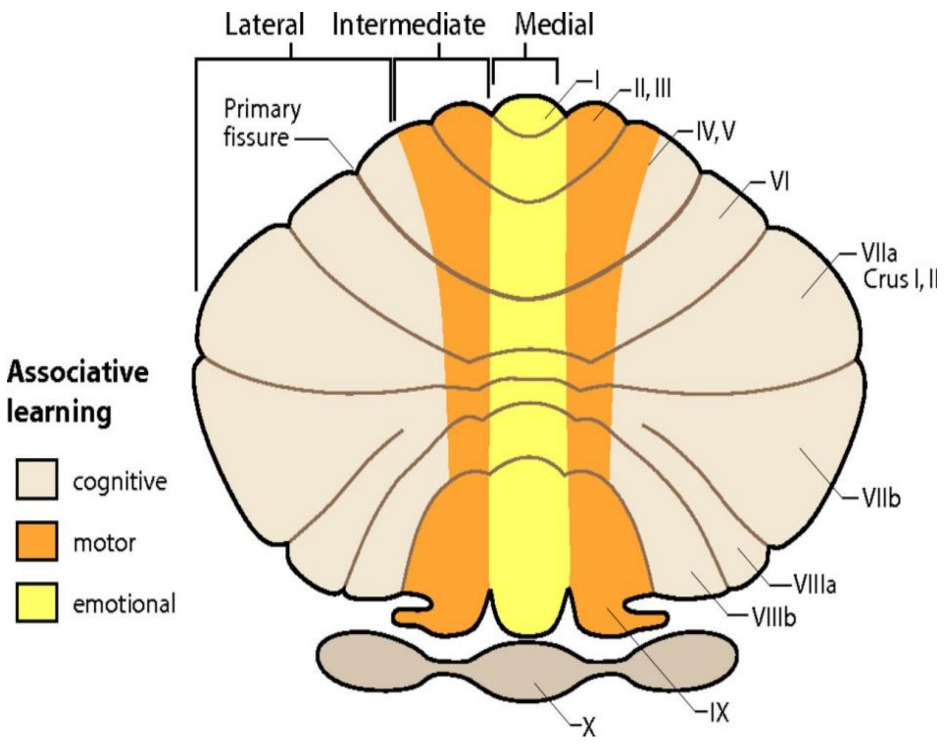




Fastigial Oculomotor Region	Flocculus and Paraflocculus	Nodulus and Uvula
Initial acceleration of smooth pursuits	Maintaining fixations and pursuits	Integrating canal and otolith information
Terminal deceleration of smooth pursuits	Adjusting and adapting the aVOR	Adjusting and adapting the tVOR
Less predictable smooth pursuits	More predictable smooth pursuits	Controls the velocity storage mechanism
Speed adaptation	Directional adaptation	
Go/No-Go decisions for pursuits		
Faster pursuits → more activation	Faster pursuits, aVOR → more activation	Faster tVOR and slower, more sustained aVOR → 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

Almost immediate correction/learning and predication takes place with OM vision therapy

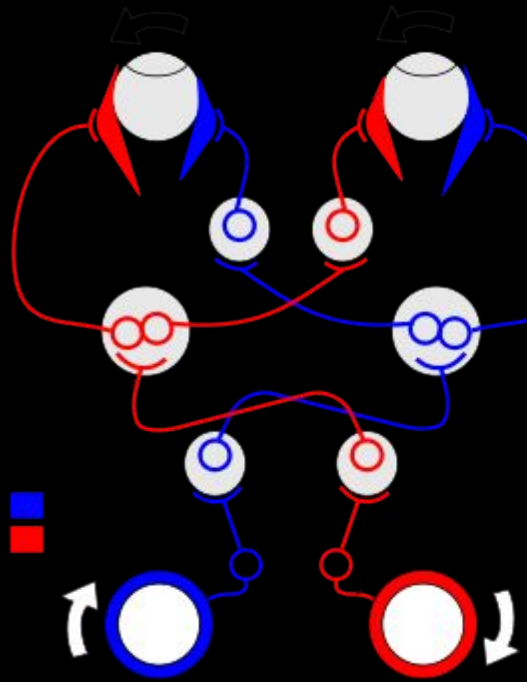


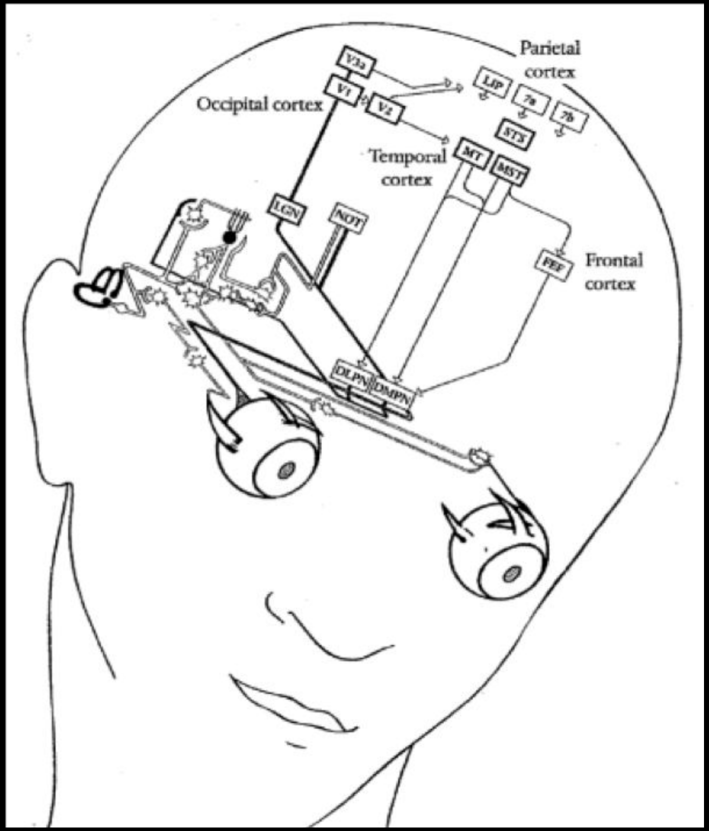


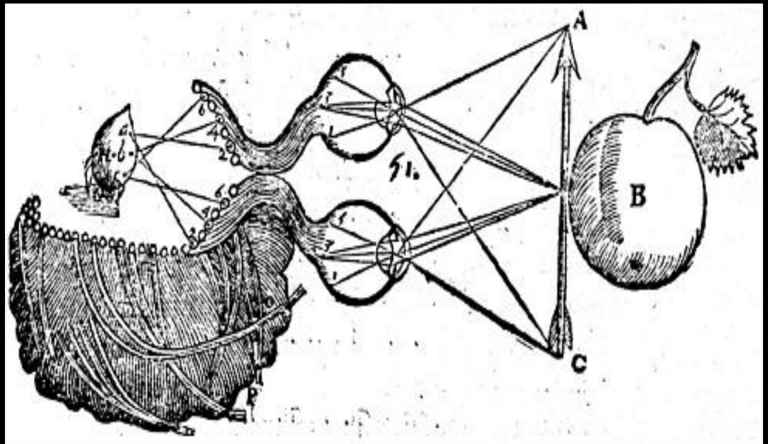
THE VESTIBULAR SYSTEM IS A VALUABLE PORTAL TO GET INTO THE NEUROCHEMICAL STATES THAT FAVOR PLASTICITY

This anti gravity system is also reflexively connected with the oculomotor system in all directions of gaze. (VOR)

So adding eye movements to balance activates and enhances disruptions and neuroplasticity.

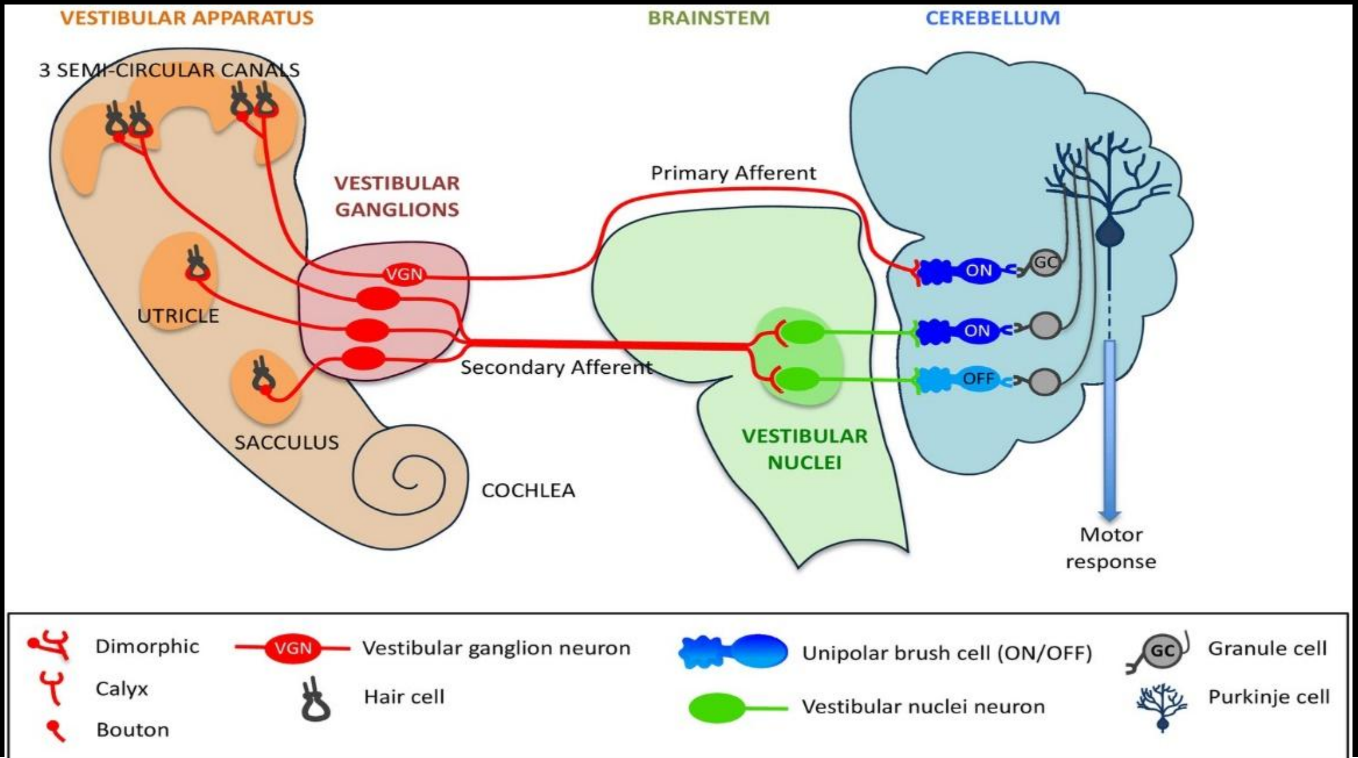


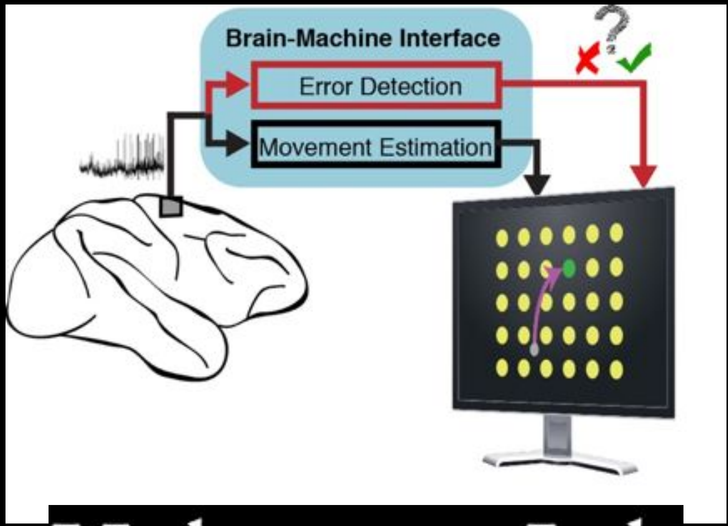




Using the Vestibular System to drive neuroplasticity

The vestibular system is hardwired through the cerebellum to the neurochemical pathways of plasticity
Exploring the sensory motor vestibular space to cause gravitational mismatching accelerates change
A disruptive vestibular motor relationship can drive neuroplastic change if it is novel
New orientations to gravity or being in a posture of slight instability supplies the needed novelty for change

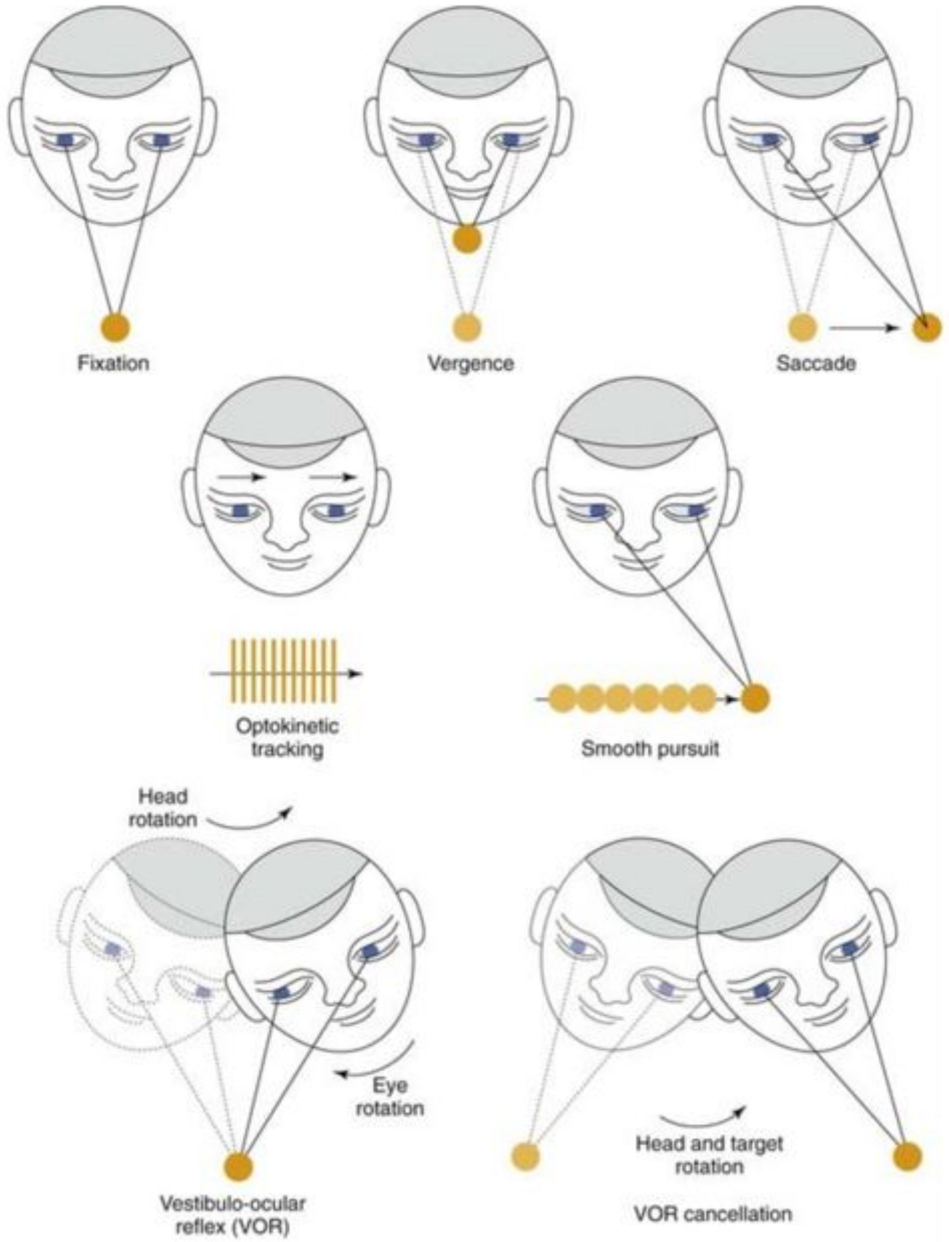




Huberman Lab
Department of Neurobiology
Stanford University

Eye movement tasks

Requires prediction

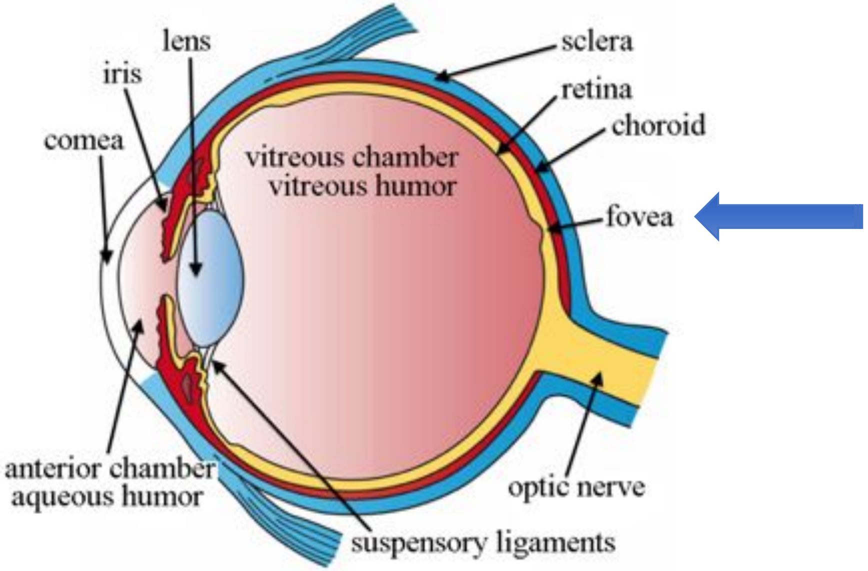


Optometry (head still)

Vestibular/ENT (head moving)

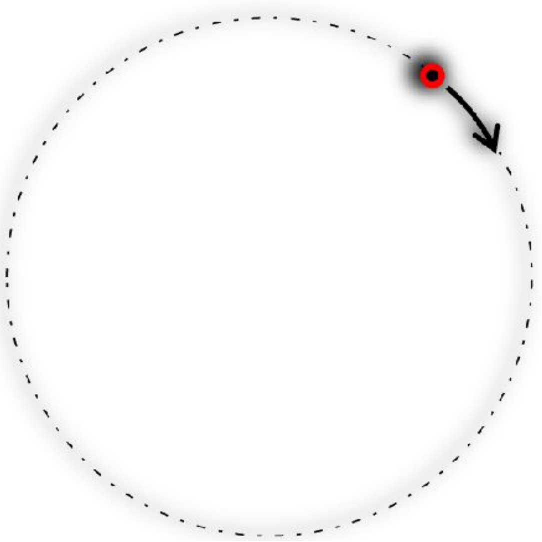
Measuring Attention (Prediction)

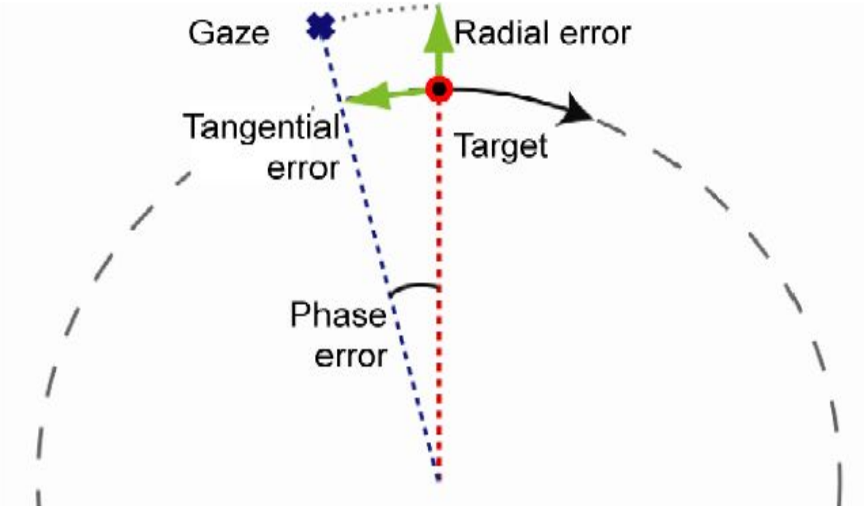
Through Variability in Eye Movements



Need to move eyes to keep image on fovea –
prediction needed

EYESYNC®





Timing (Tangential) Error:
Standard Error of Mean (Variance) between the subject's gaze and the target position along the target trajectory.

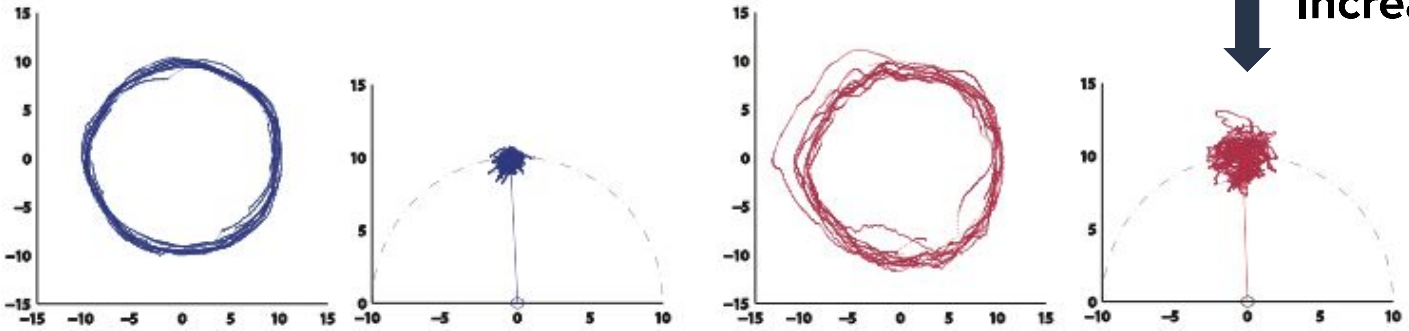
Spatial (Radial) Error:
Standard Error of Mean (Variance) between the gaze and the target position perpendicular to the target trajectory.

Lead/Lag (Phase) Error:
The average phase error between the subject's gaze position and the target position.

Oculomotor Assessments- fatigue and injury

Sleep Deprivation

Increased Radial variance

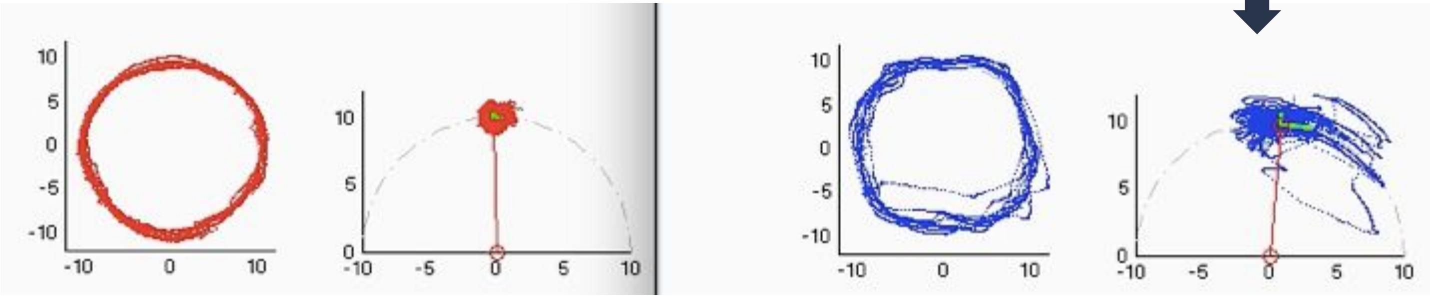


Baseline

26hr sleep deprivation

Concussion

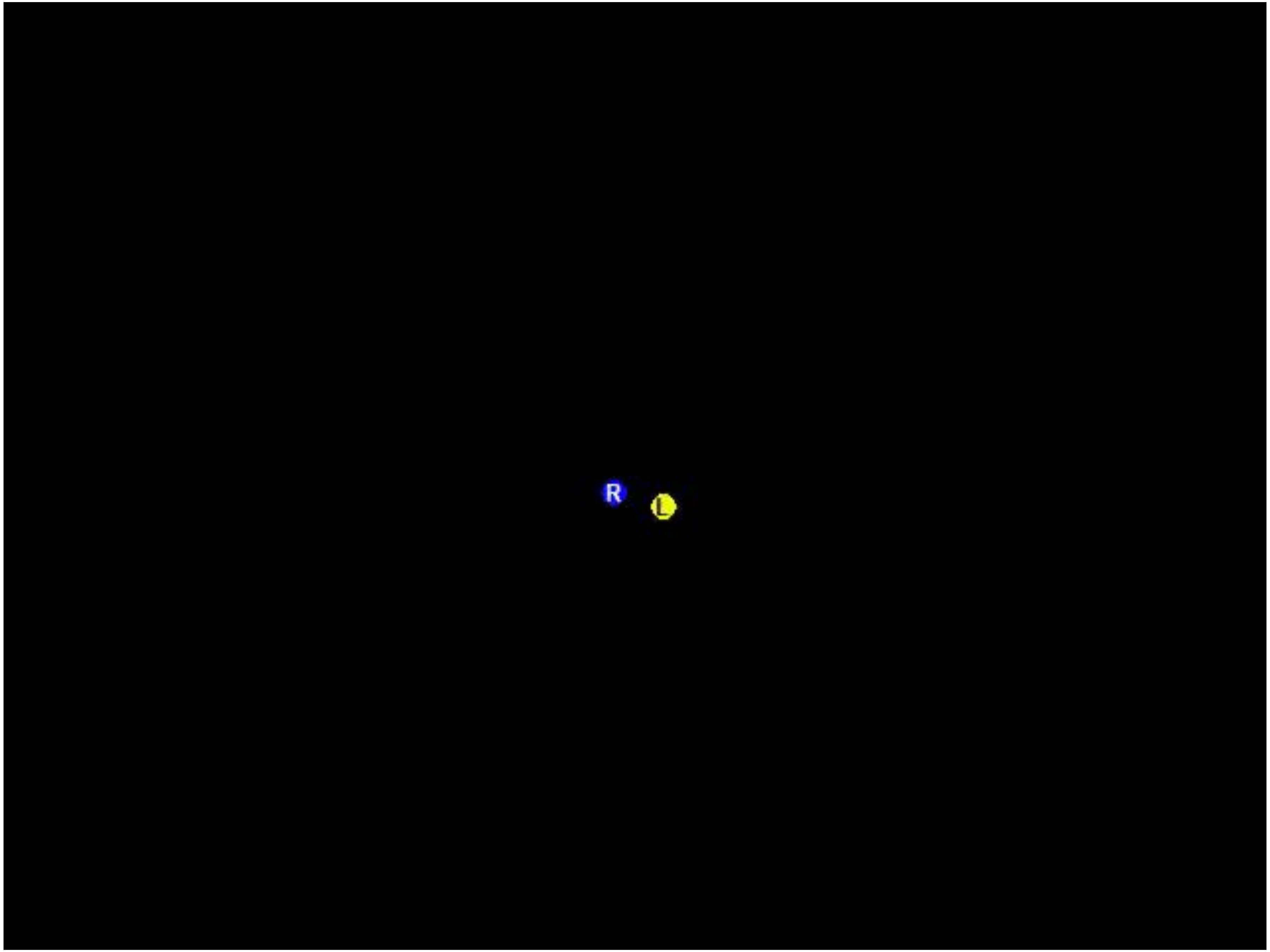
Increased Tangential variance



MILITARY MEDICINE, 179, 6:619, 2014

Predictive Visual Tracking: Specificity in Mild Traumatic Brain Injury and Sleep Deprivation

Jun Maruta, PhD; Kristin J. Heaton, PhD†‡; Alexis L. Maule, MPH†‡; Jamshid Ghajar, MD, PhD*§*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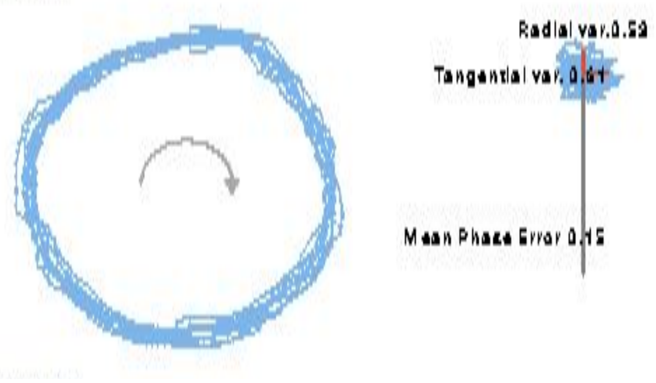
EYESYNC® SMOOTH PURSUIT – UNDERSTANDING TIMING

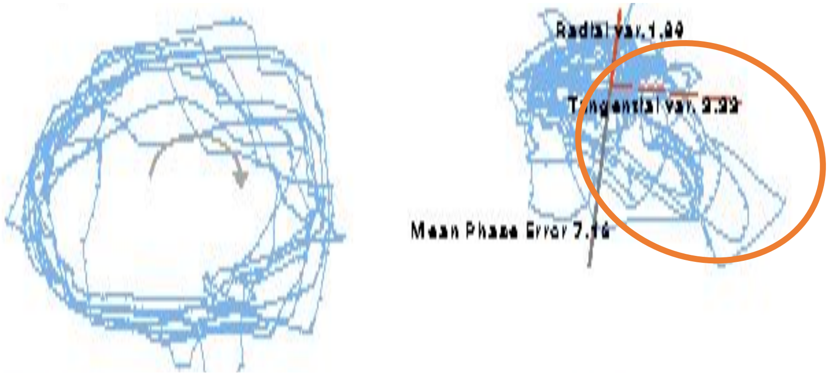
Low Timing Variability



There is very little gaze error around the target location, resulting in low timing error

Timing Error

High Timing Variability



There are a lot of gaze errors around the target, especially in front of the target, resulting in high timing error

EYESYNC® SACCADE METRICS

Precision

How tightly clustered together are all gaze locations?

Precision: The standard deviation of the error between the subject's fixation(s).

Accuracy

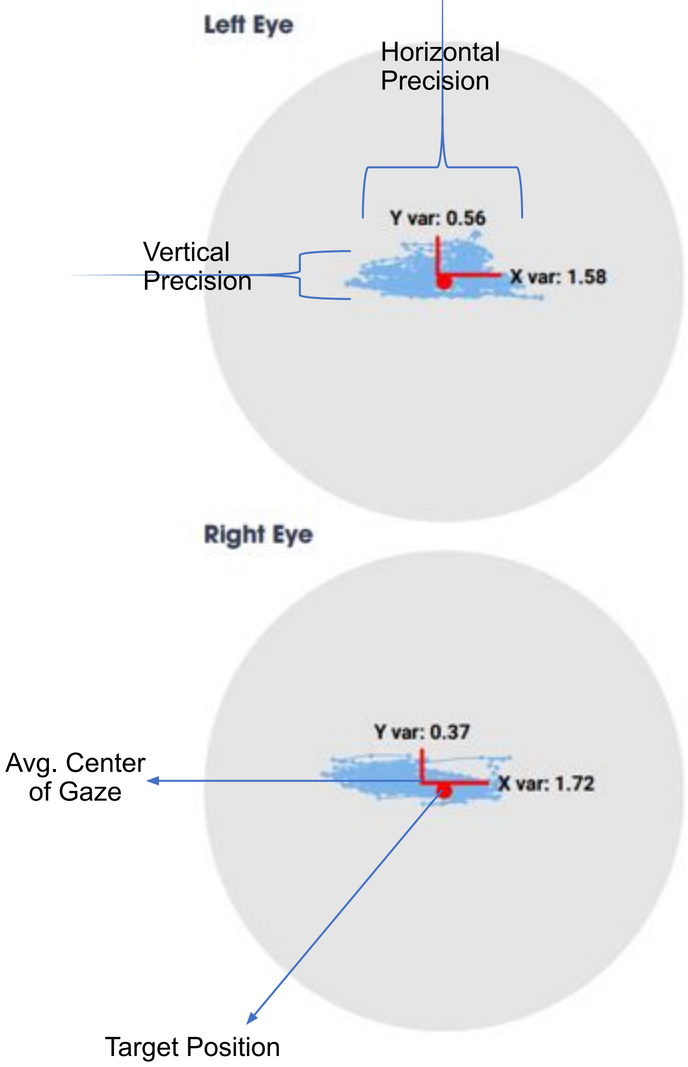
How close to target center is average gaze location?

Accuracy: The average error between the subject's fixation(s) and the target's position.

EYESYNC® VOR METRICS also VORx and Convergence (NPC)

Precision

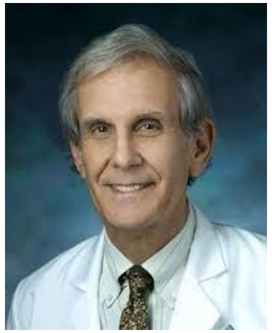
Accuracy



<u>Precision:</u> The standard deviation of the error between the subject's gaze position and target position.

<u>Accuracy:</u> The average error between the subject's average center of gaze and the target's position.

Eye Movement Disorders and the Cerebellum
Ari A. Shemesh and David S. Zee (J Clin Neurophysiol 2019;36: 405-414)



- New technology – for example, quantitative bedside video-oculography…**will assist in developing better diagnostic algorithms, and novel treatments,** including medications and **rehabilitation programs** that can **take advantage of the central role of the cerebellum in monitoring and adjusting movements to keep them accurate**.
- **The Technology is here! It is time to integrate into our clinics to improve diagnostic accuracy and outcomes.**

Questions?

Comments?