Fundamentals of Video Head Impulse Test:

Lesson 1 – Principles and Mechanics

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    - Assessment and management of vestibular disorders (India)
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Risks/Benefits

- The applicability and accuracy of the course content may vary by the clinical, geographical, and cultural context; you should evaluate the course accordingly.
- As healthcare is rapidly evolving, new findings may change the validity of the information presented in this course. Providers should always consult the latest research and guidelines from professional associations.
- The interventions discussed in this course may be limited in generalizability, requiring practitioners to consider specific individual and population factors.
- The course may not cover all possible risk factors, diagnostic methods, or treatment options, and complex cases may require additional considerations.
- Healthcare providers should apply cultural competence and sensitivity to ensure effective and respectful care based on their patients' diverse needs.
- Providers should always evaluate the limitations of diagnostic and screening tools, considering their potential for false results as well as any ethical implications.
- It is the responsibility of course participants to critically evaluate the evidence from multiple sources to guide professional practice.

Learning Outcomes

- After this course, participants will be able to identify key diagnostic indicators of vestibular dysfunction through vHIT, including VOR gain values and saccadic responses.
- After this course, participants will be able distinguish between remote camera-based and head-mounted vHIT systems, explaining their acquisition principles andclinical applications.
- After this course, participants will be able to explain how to analyze vHIT results in the context of real clinical scenarios to guide vestibular assessment and rehabilitation strategies.

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Outline of the talk

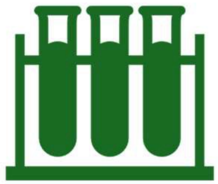
- Introduction
- Principles and Methods of Ocular Recording

- Measurement of Head and Eye Movements

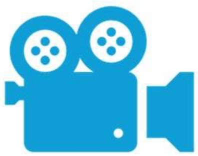
- Basic Interpretative Parameters of the vHIT

Introduction to the video Head Impulse Test

- Anatomy and Physiology of the Vestibular system



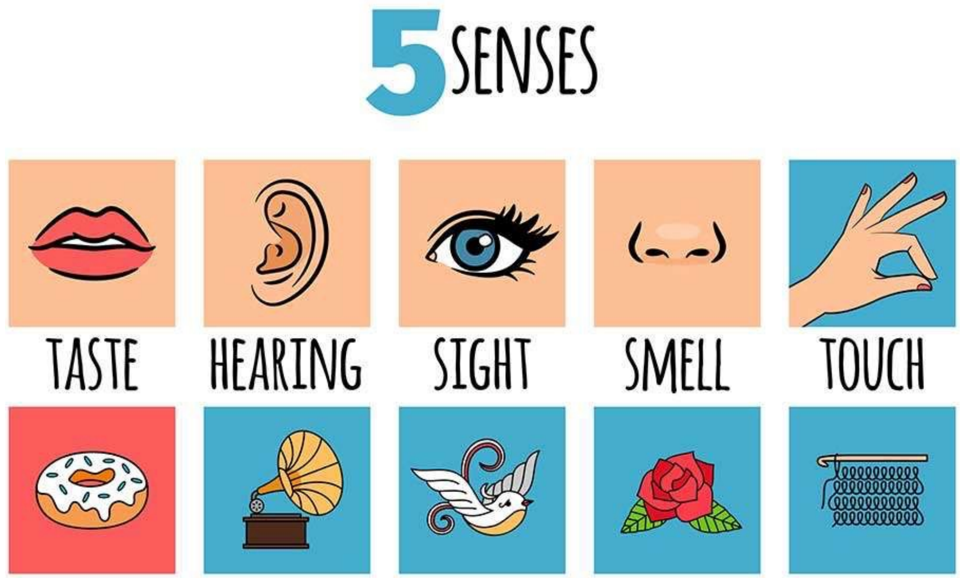
- Clinical Halmagyi's Test (cHIT)



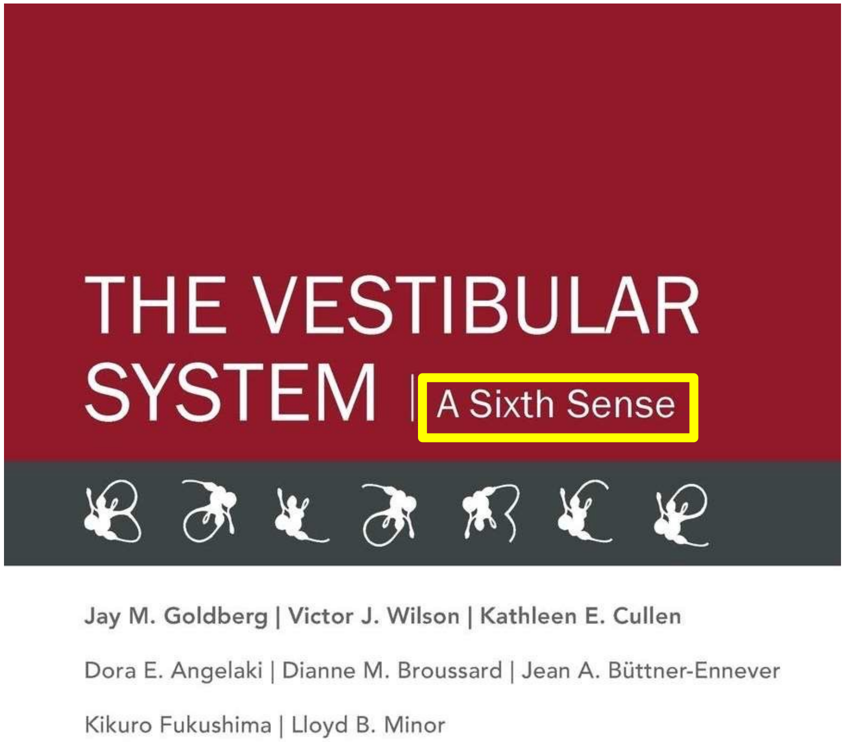
- Video Halmagyi's Test (vHIT)

Anatomy and Physiology of the Vestibular system

Special senses



It works in background



Ear

External Ear

Middle Ear

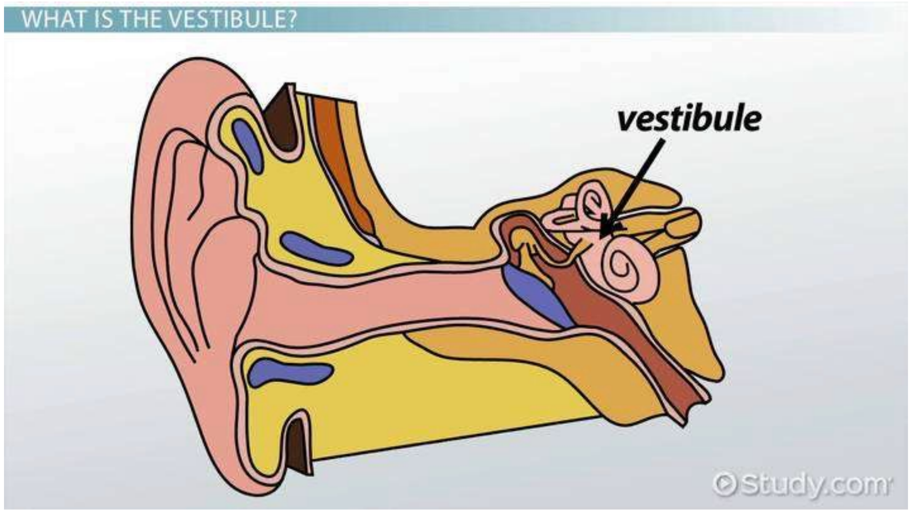
Internal Ear

Cochlea

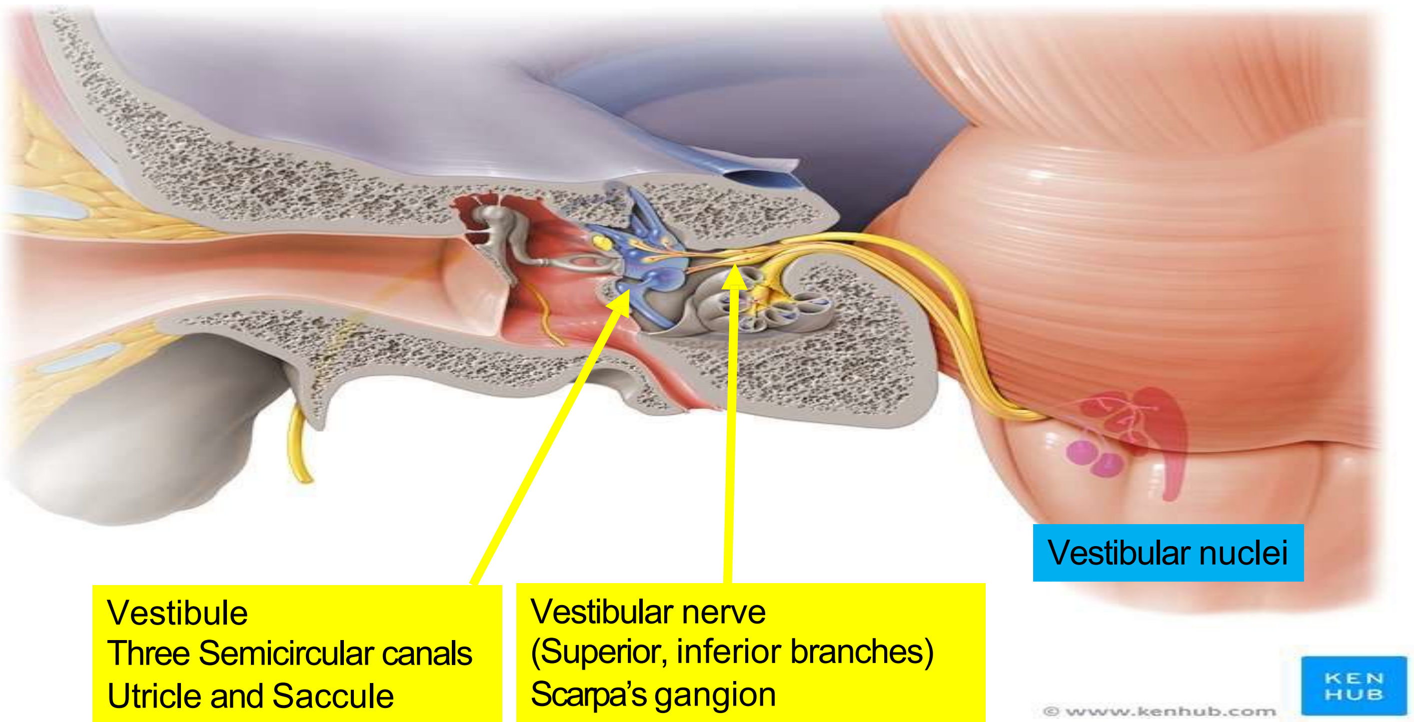
Vestibule

Hearing

Equillibrium



Organisation of vestibular system

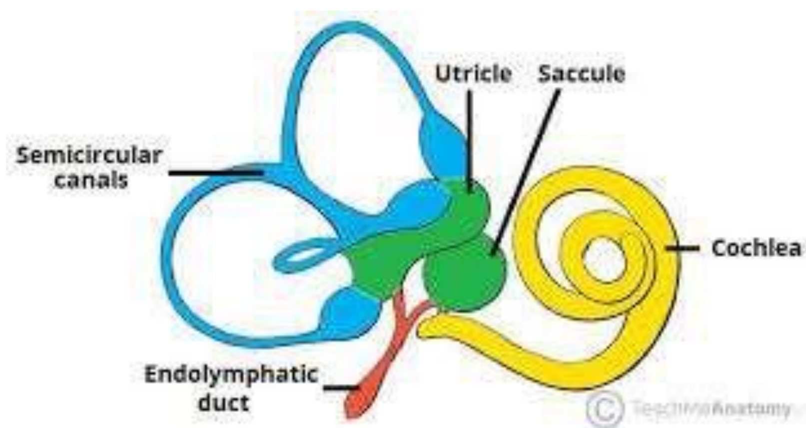


Peripheral vestibular system

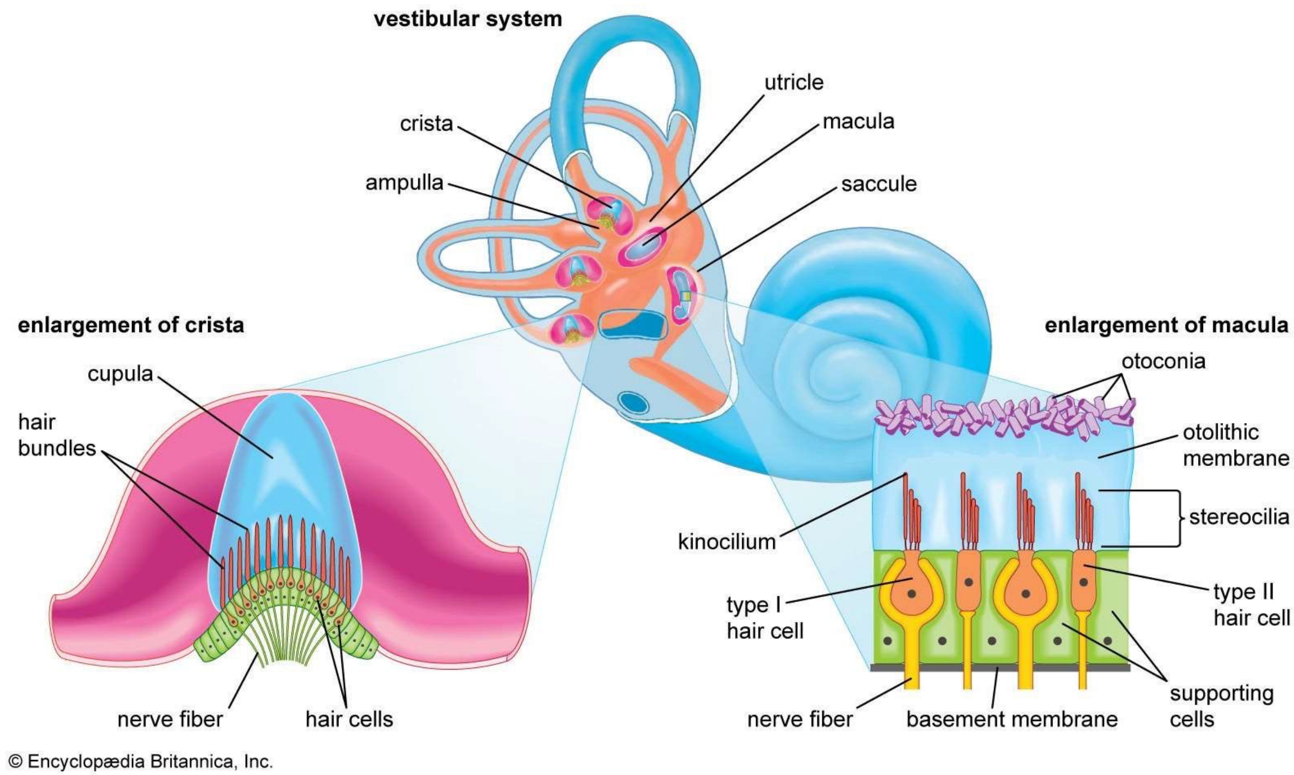
Peripheral sense organ

Semi-circular Canals

Otolith Organs



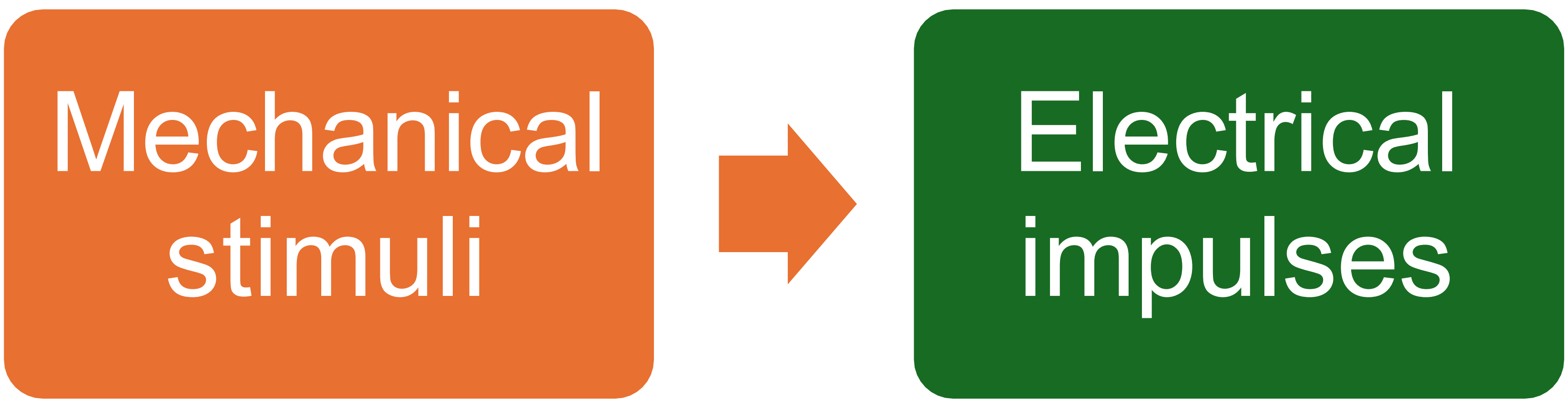
Sensory epithelium



Semicircular canal crista

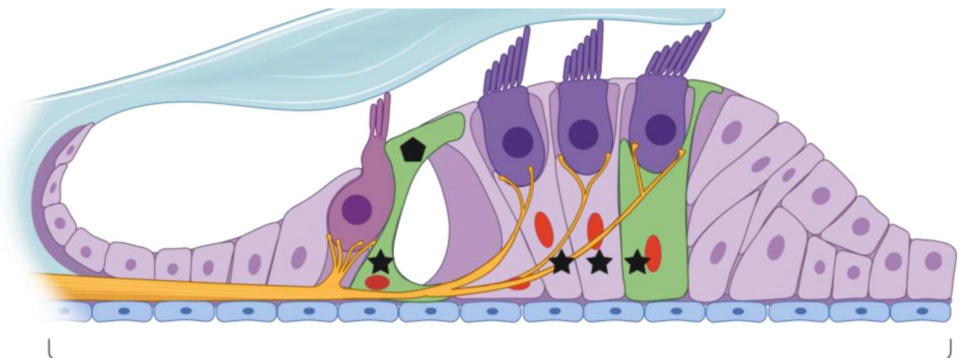
Utricular/ Saccular macula

Mechano-electric transducer

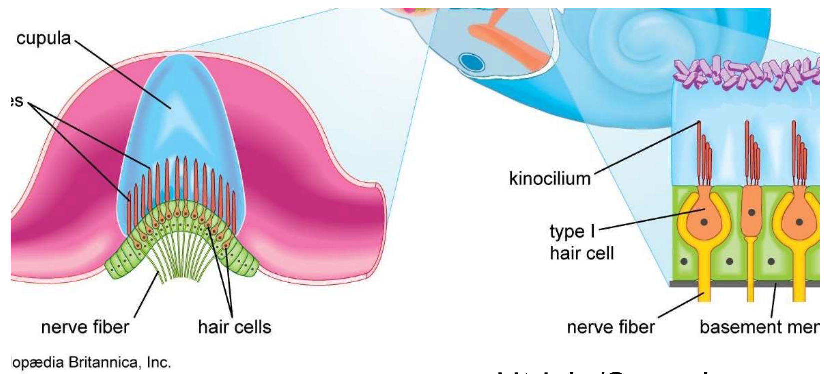


Hair cells

The functions of hair cells changes depending on where they are placed



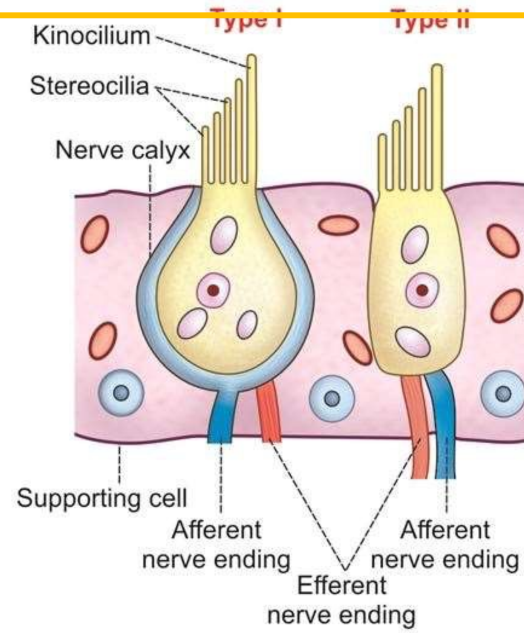
Cochlea – Hearing



Semicircular canals – Angular accelaration

Utricle/Saccule – Linear acceleration, tilt

Feature	Type 1 Hair Cells	Type 2 Hair Cells
Shape	Flask-shaped	Cylindrical-shaped
Afferent Innervation	Innervated by large, chalice-shaped afferent terminals	Innervated by multiple, bouton-shaped afferent terminals
Efferent Innervation	Indirect efferent modulation via the afferent nerve ending	Directly innervated by efferent fibers
Location in Vestibular System	Found in the central zones of the sensory epithelia	Distributed more uniformly across the sensory epithelia
Response Characteristics	More irregular response to head movements	More regular and sustained response to head movements
Synaptic Structure	Single large afferent contact (chalice-shaped)	Multiple small afferent synapses (bouton-shaped)
Role in Vestibular Function	More involved in high-sensitivity, rapid response to movement	More involved in steady-state detection of head position



Clinical application

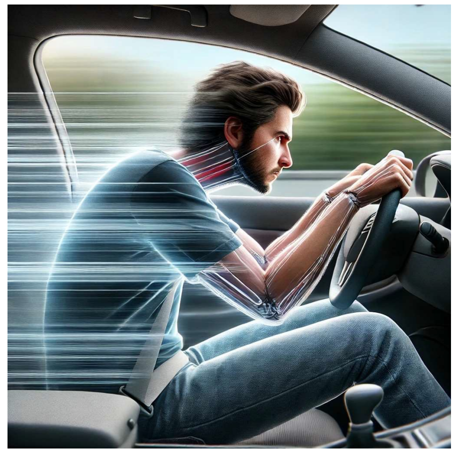
Condition	Preference for Type I Cells	Preference for Type II Cells
Vestibular Neuritis	✅ Strongly affected	❌ Less affected
Meniere's Disease	❌ Affected later	✅ Affected early
Aging (Presbyvestibulopathy)	❌ Mildly affected (late)	✅ Strongly affected
Head Trauma	✅ Strongly affected	❌ Less commonly affected
Autoimmune Inner Ear Disease	✅ Affected	✅ Affected

Forces acting on head

Linear forces	Rotational forces
• Graviational force • Translation	• Angular acceleration

Rest to movement
Acceleration

Constant speed
Velocity



Braking
Deceleration

Motion Detection:

The vestibular sensors detect changes in velocity rather than constant motion.

As the head accelerates or decelerates, the fluid in the semicircular canals lags, stimulating hair cells.

Inertial sensors

Head translations

- Surge
- Heave
- Bob

Head rotations

- Yaw
- Pitch
- Roll

	Stimulation	Inhibition
Right yaw	RLC	LLC
Left yaw	LLC	RLC
Left anterior	LAC	RPC
Right posterior	RPC	LAC
Right anterior	RAC	LPC
Left posterior	LPC	RAC

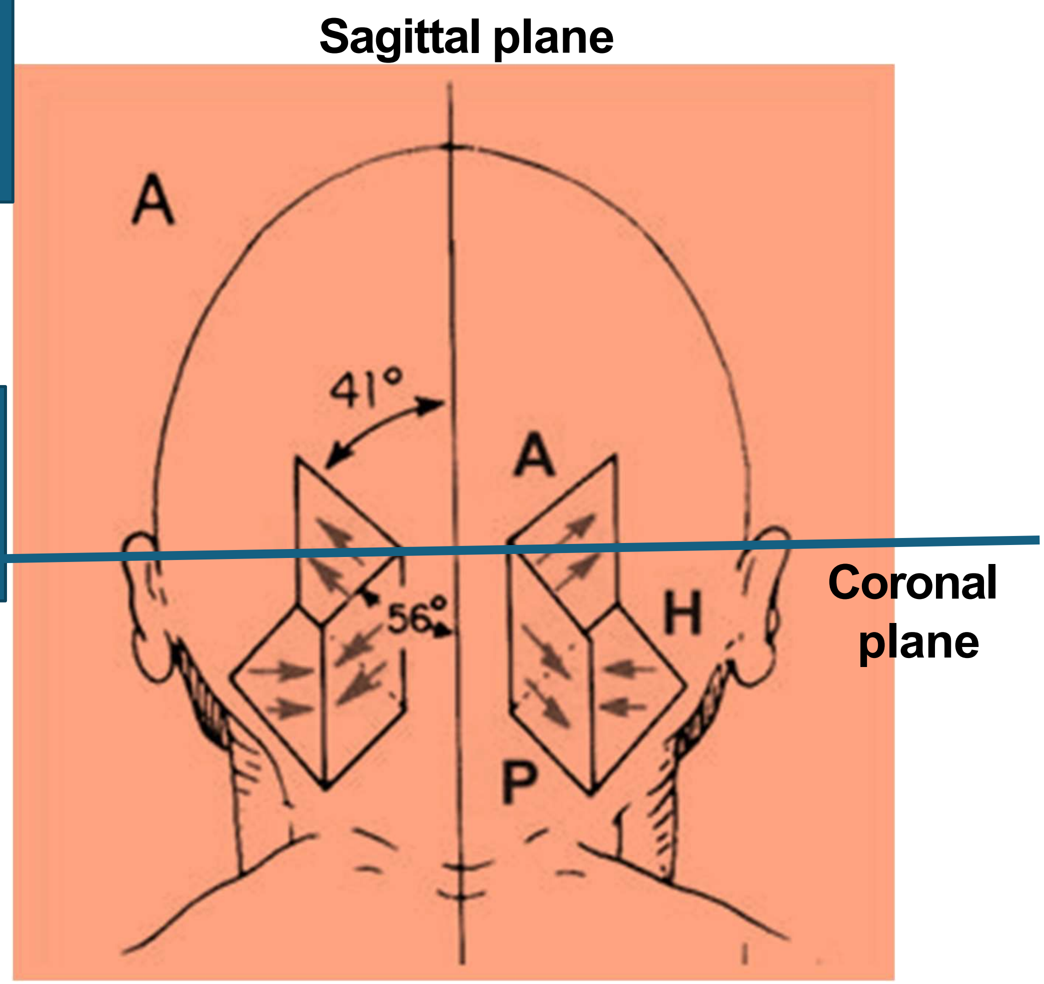
Semicircular canal planes

- LARP
- RALP
- Horizontal

The anterior canal is nearer to sagittal (pitch) plane than the posterior canal.

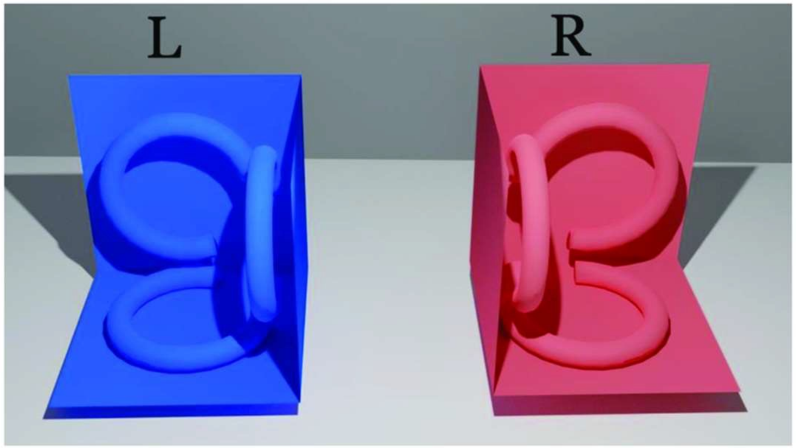
The posterior canal is nearer to coronal (roll) plane than the anterior canal (34^0 vs 49^0)

Orientation of canals



The canals are nearly orthogonal

- **Positional testing variability**: Misalignment can influence the accuracy of vestibular tests, slightly affecting results.



The vestibular system is described using a **pendulum model with critical damping** consisting of three elements

Component	Explanation	Example/Analogy

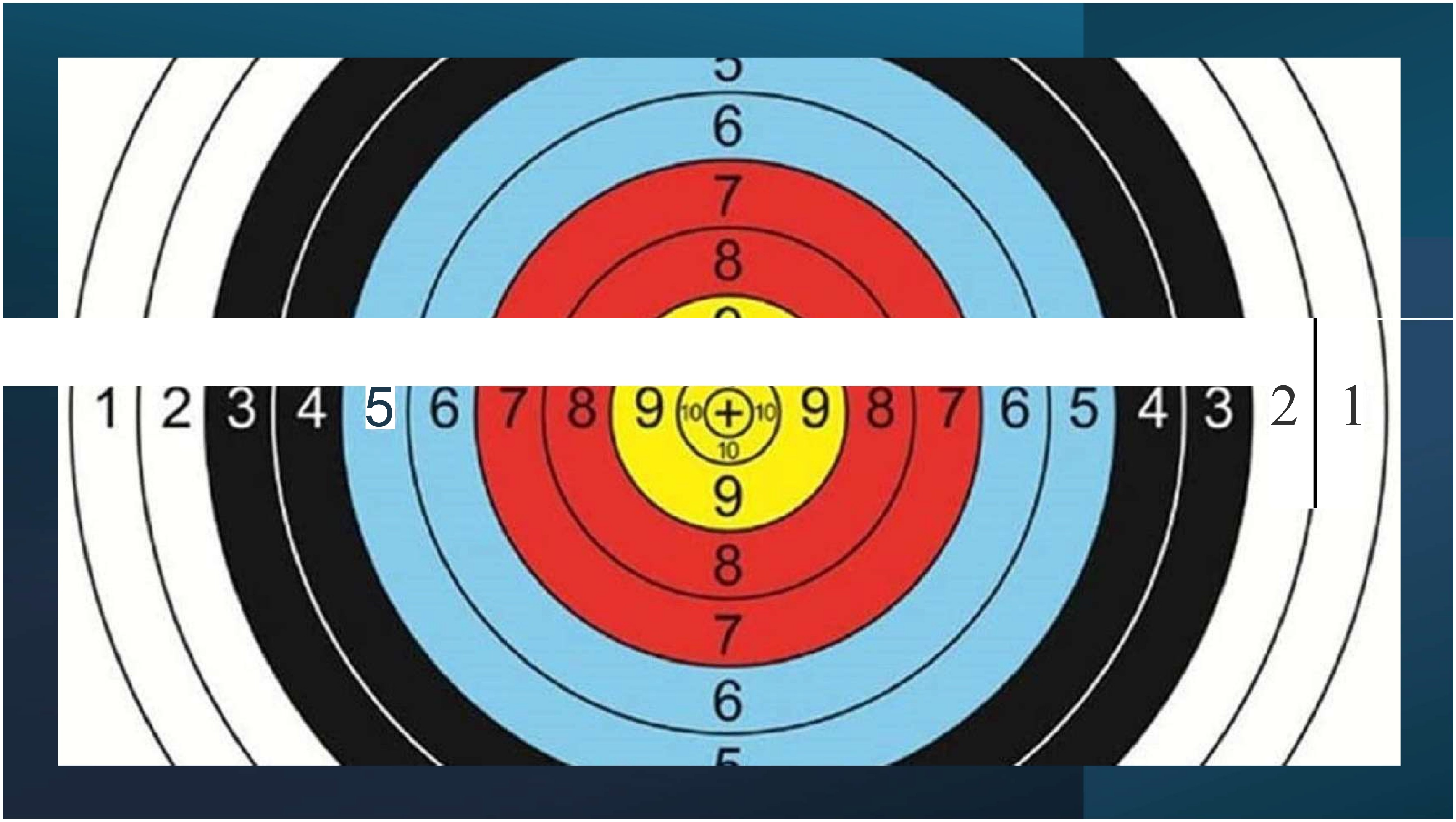
Head movement velocity and response of cupula

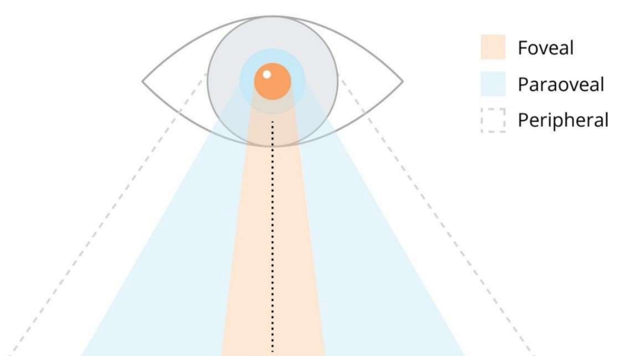
Dynamics of cupula during head movements

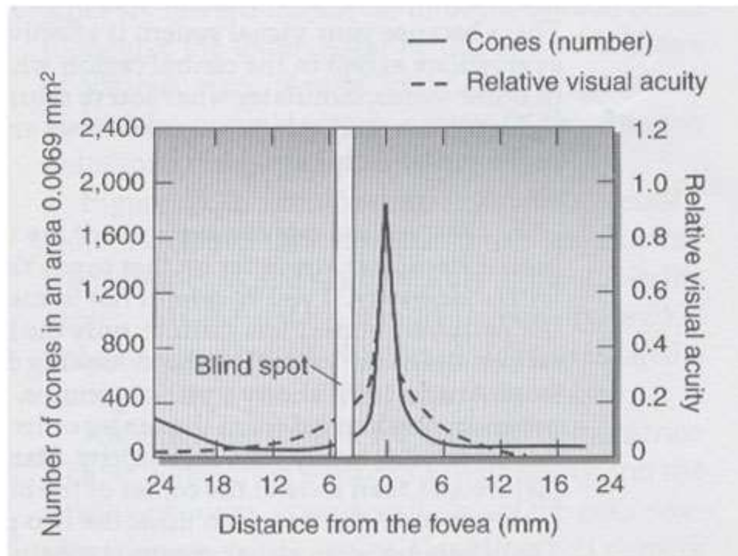
Head Movement	**Cupula Behavior**	**Response Type**
Slow	Loose (**elasticity** dominates)	Responds to **acceleration**
Moderate	Balanced by fluid thickness (**viscosity** dominates)	Responds to **speed**
Fast	Stiffens due to resistance (**inertial forces** dominate)	Responds to **position**

Head	Right	VOR	Left
Membranous labyrinth	Right	Endolymph movement can be predicted from the eye movements	Left
Endolymph	Left		Right
Eyes	Left		Right




1 2 3 4 5 6 7 8 9 10 9 8 7 6 5 4 3 2 1

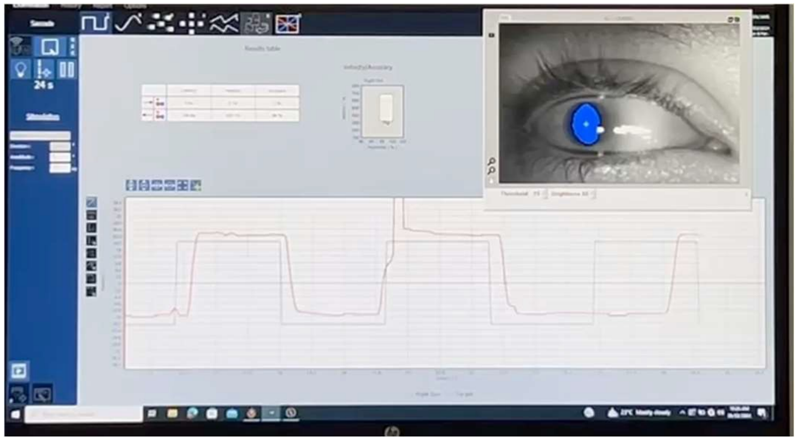

Foveal
Paraoveal
Peripheral


Cones (number)
Relative visual acuity
Number of cones in an area 0.0069 mm²
2,400
2,000
1,600
1,200
800
400
0
Blind spot
1.2
1.0
0.8
0.6
0.4
0.2
0
Relative visual acuity
24 18 12 6 0 6 12 16 24
Distance from the fovea (mm)

Functional classes of eye movements

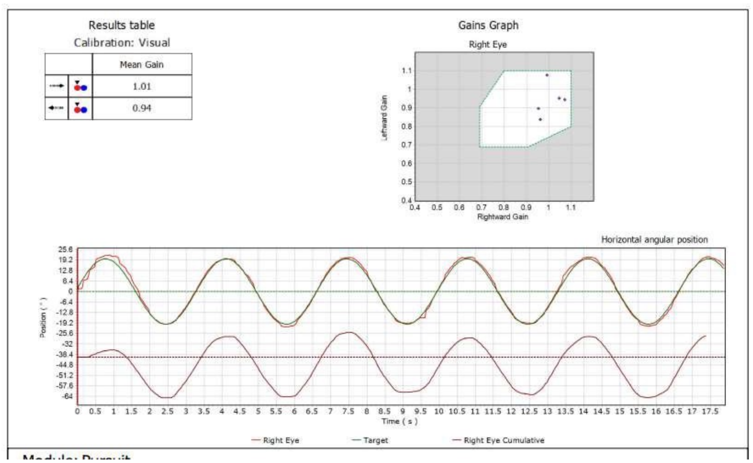
Saccade

Bring images of objects of interest onto the fovea



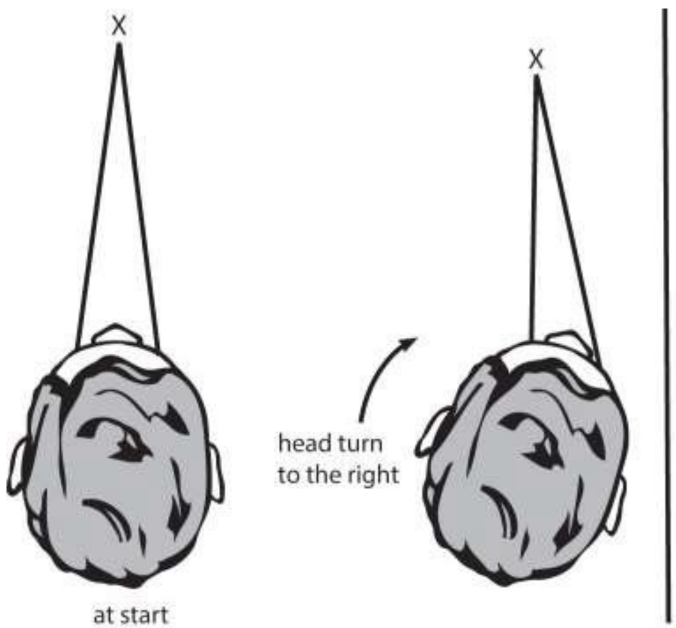
Smooth pusuit

Holds the image of a small moving target on the fovea



Vestibulo-ocular reflex

Reflex- Equal and opposite eye movements

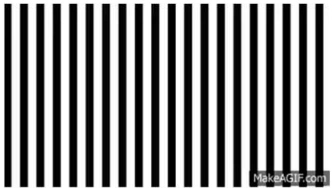


Optokinetic reflex

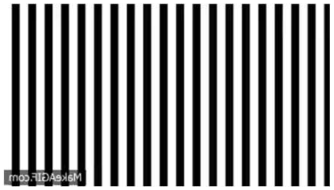
Predictable head or object movements

Stimulus

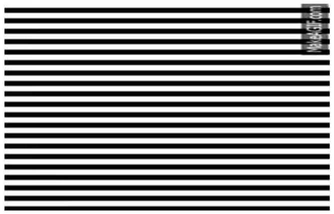
Left to right



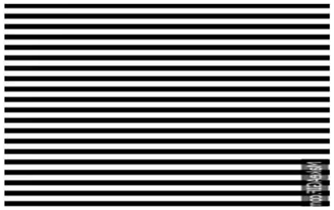
Right to left



Bottom to up



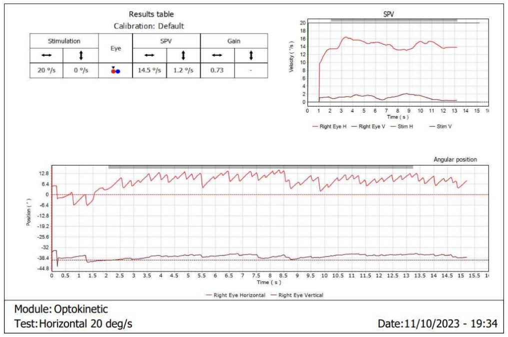
Up to bottom



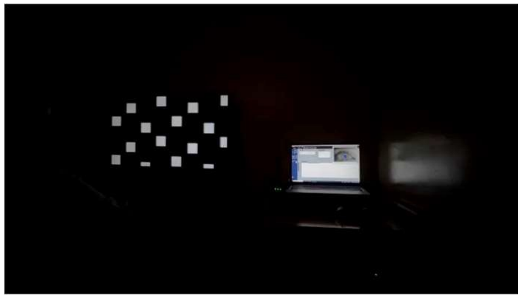
Nystagmus

Left beating

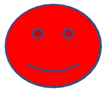
Right beating



Downbeating

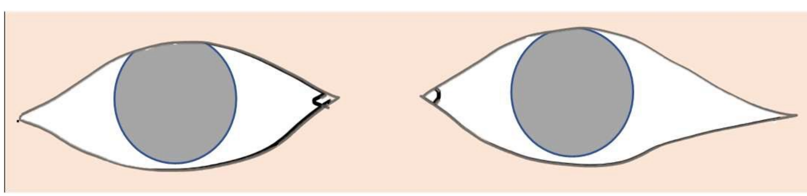


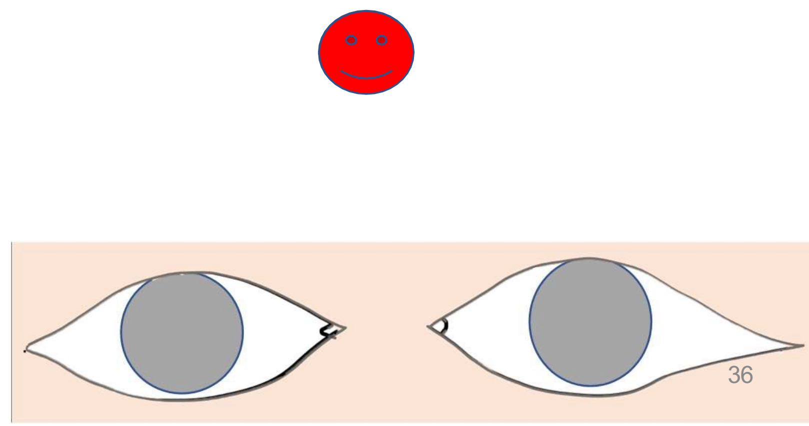
Upbeating



Vergence

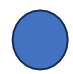
Depth perception





Visual fixation

To inhibit unwanted saccades



Functional classes of eye movements

Smooth pursuit | Saccades
OKR | VOR
Vergence | Visual Fixation

Bring images of objects of interest onto the fovea

Holds the image of a small moving target on the fovea

Holds images of the visual world steady on the retina during brief head rotations or translations

Holds images of the visual world steady on the retina during sustained head rotation or translations

Moves the eyes in opposite directions so that images of a single object are placed or held simultaneously on the fovea of each eye

Holds the image of a stationary object on the fovea by minimizing ocular drifts

Gaze-shifting

Gaze-stabilization

Saccades

Smooth pursuit

VOR

OKR

Vergence

Visual Fixation

Conjugate

Saccades

Smooth pursuit

VOR

OKR

Visual Fixation

Dys-conjugate

Vergence

Foveal

Saccades

Smooth pursuit

OKR- Larger noticeable visual patterns

Vergence

Visual Fixation

Retinal

VOR

OKR-Wider visual field

Can inhibit

Saccades

Smooth pursuit

VOR

OKR

Vergence

Visual Fixation

	Voluntary	Reflexive	
Saccades	Volitional	Reflexive	Quick phase of OKN, VOR Reflex visual, Reflex auditory
Smooth pursuit	Modification	Initiation	
VOR		Yes	
OKR		Yes	
Vergence	For near and far adjustment	Visual response depth changes	
Visual Fixation	To choose the target	To maintain the image on the fovea	

Vestibular mediated

Shorter latency (<15 ms)

Fatigable

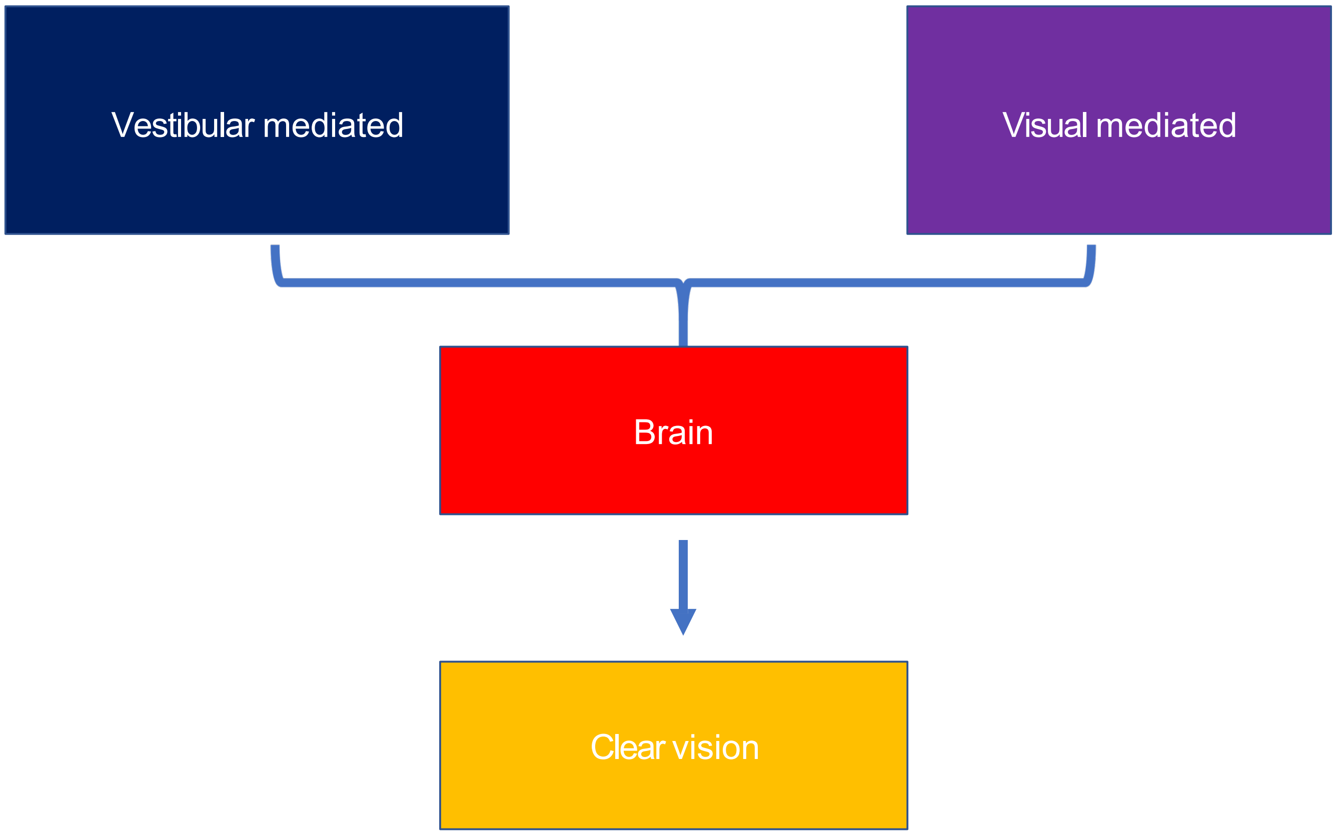
- VOR

Visual mediated

Longer latency (>70 ms)

No fatigue

- Saccades
- Smooth pursuit
- OKR
- Vergence
- Visual Fixation


Vestibular mediated
Visual mediated
Brain
Clear vision

Vestibular System Function- 5 Integration with other Sensory systems

Vision

The vestibular system helps determine the position of the head relative to gravity and movement.
It allows the brain to understand how the body is oriented in space, whether standing, sitting, or moving.

Proprioception

Vestibular system

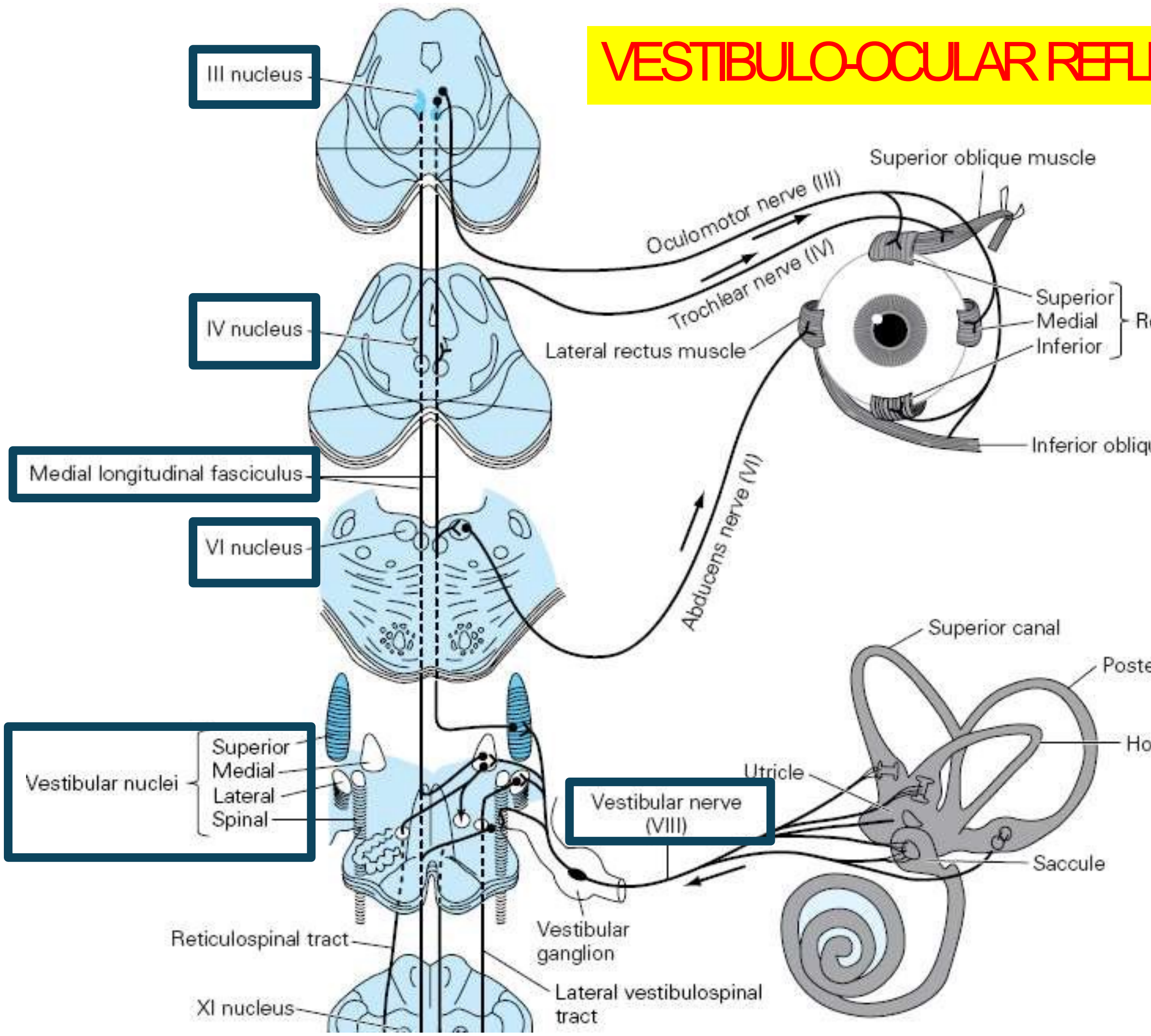
	Vestibular input	Neck proprioception	Body proprioception	Vision
Gaze stabilization	Vestibulo-ocular reflex	Cervico-ocular reflex	Somato-sensory feedback	Smooth pursuit Visuo-vestibular interactions
Head stabilization	Vestibulo-collic reflex	Cervico-collic reflex	Somato-sensory feedback	Visual feedback
Posture stabilization	Vestibulo-spinal reflex	Cervico-spinal reflex	Somato-sensory feedback	Visual feedback

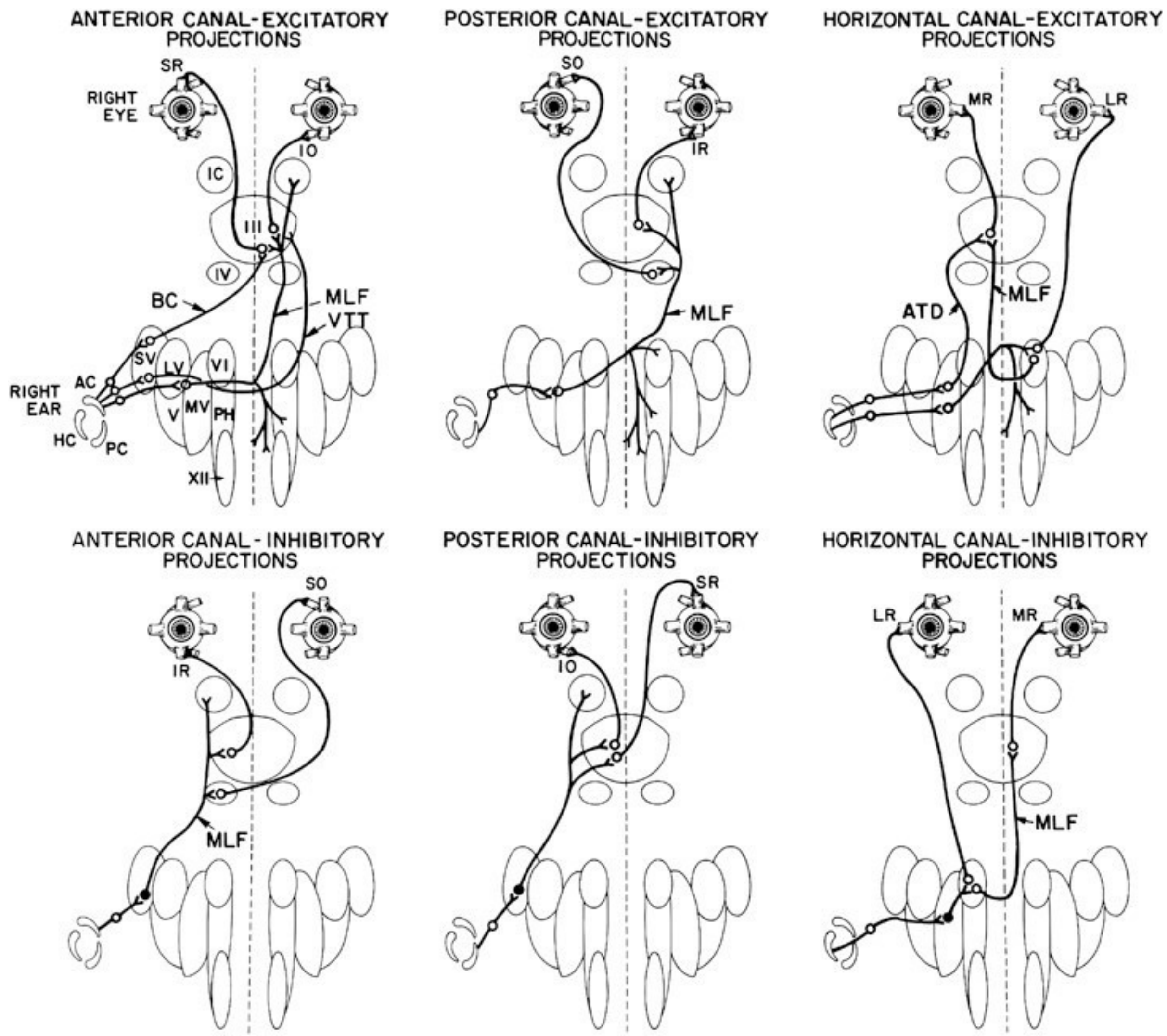
Vestibulo-Ocular Reflex (VOR):

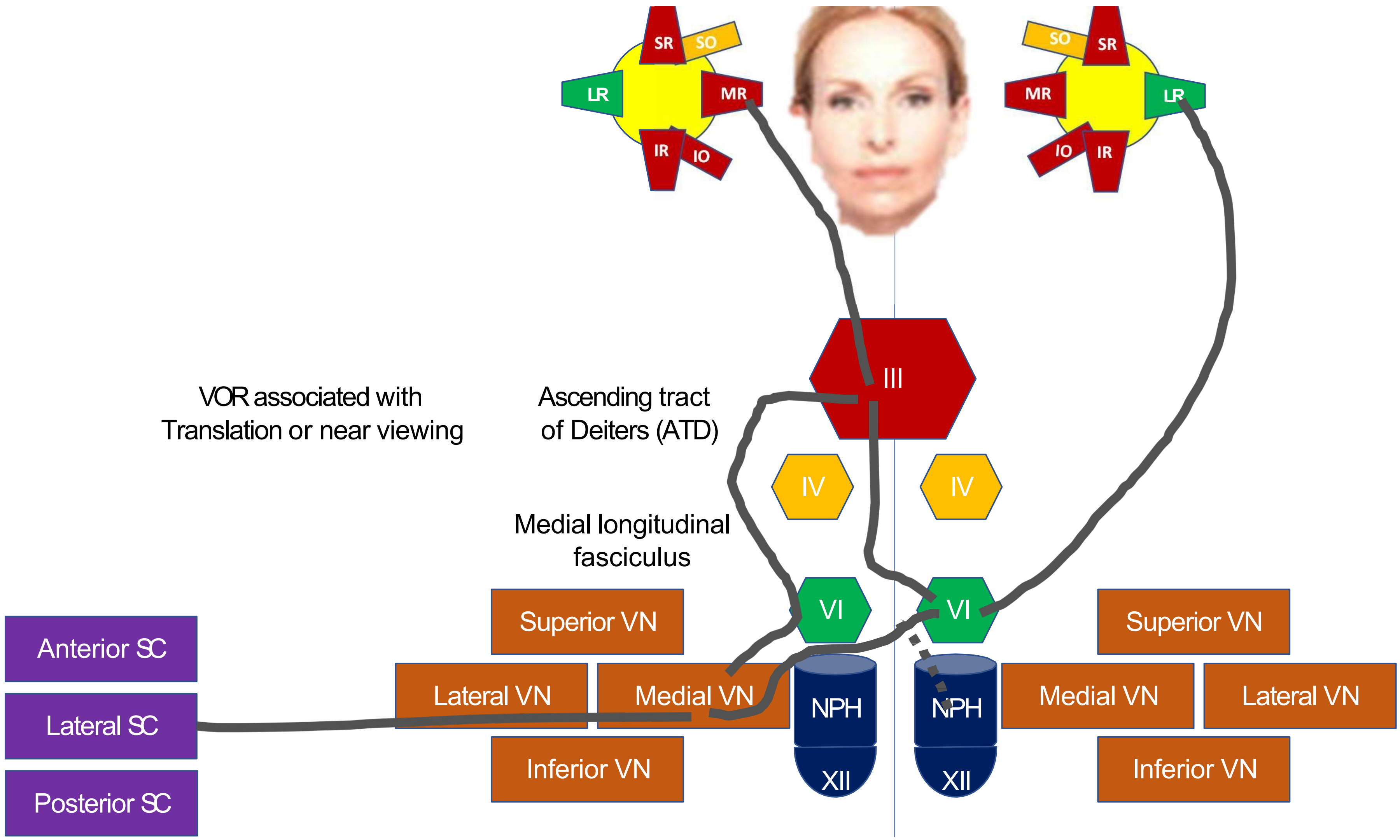
This reflex **stabilizes vision during head movements** by coordinating eye movements in the opposite direction, ensuring clear and stable visual perception.

The VOR is a **key diagnostic tool** in neuro-otology, connecting the labyrinths with eye muscles via fast brainstem pathways

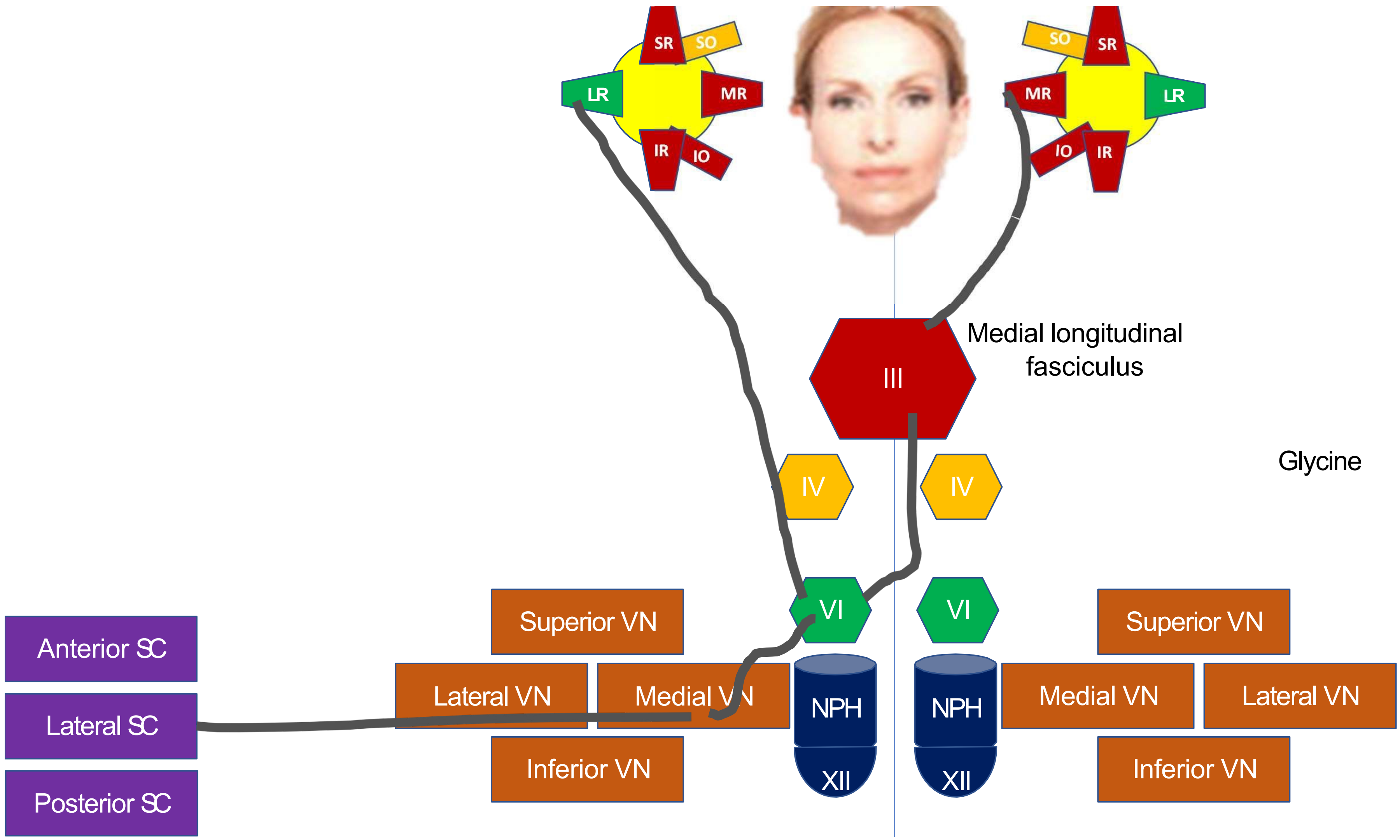
VESTIBULO-OCULAR REFLEX




ANTERIOR CANAL-EXCITATORY PROJECTIONS
SR
RIGHT EYE
IO
IC
III
IV
BC
MLF
VTT
SV
AC
RIGHT EAR
LV
VI
V
MV
PH
HC
PC
XII
POSTERIOR CANAL-EXCITATORY PROJECTIONS
SO
IR
MLF
HORIZONTAL CANAL-EXCITATORY PROJECTIONS
MR
LR
ATD
MLF
ANTERIOR CANAL-INHIBITORY PROJECTIONS
SO
IR
MLF
POSTERIOR CANAL-INHIBITORY PROJECTIONS
SR
IO
HORIZONTAL CANAL-INHIBITORY PROJECTIONS
LR
MR
MLF



SR
SO
LR
MR
IR
IO
SO
SR
MR
LR
IO
IR
VOR associated with
Translation or near viewing
Ascending tract
of Deiters (ATD)
III
IV
IV
Medial longitudinal
fasciculus
VI
VI
Anterior SC
Lateral SC
Posterior SC
Superior VN
Lateral VN
Medial VN
Inferior VN
NPH
XII
NPH
XII
Superior VN
Medial VN
Lateral VN
Inferior VN

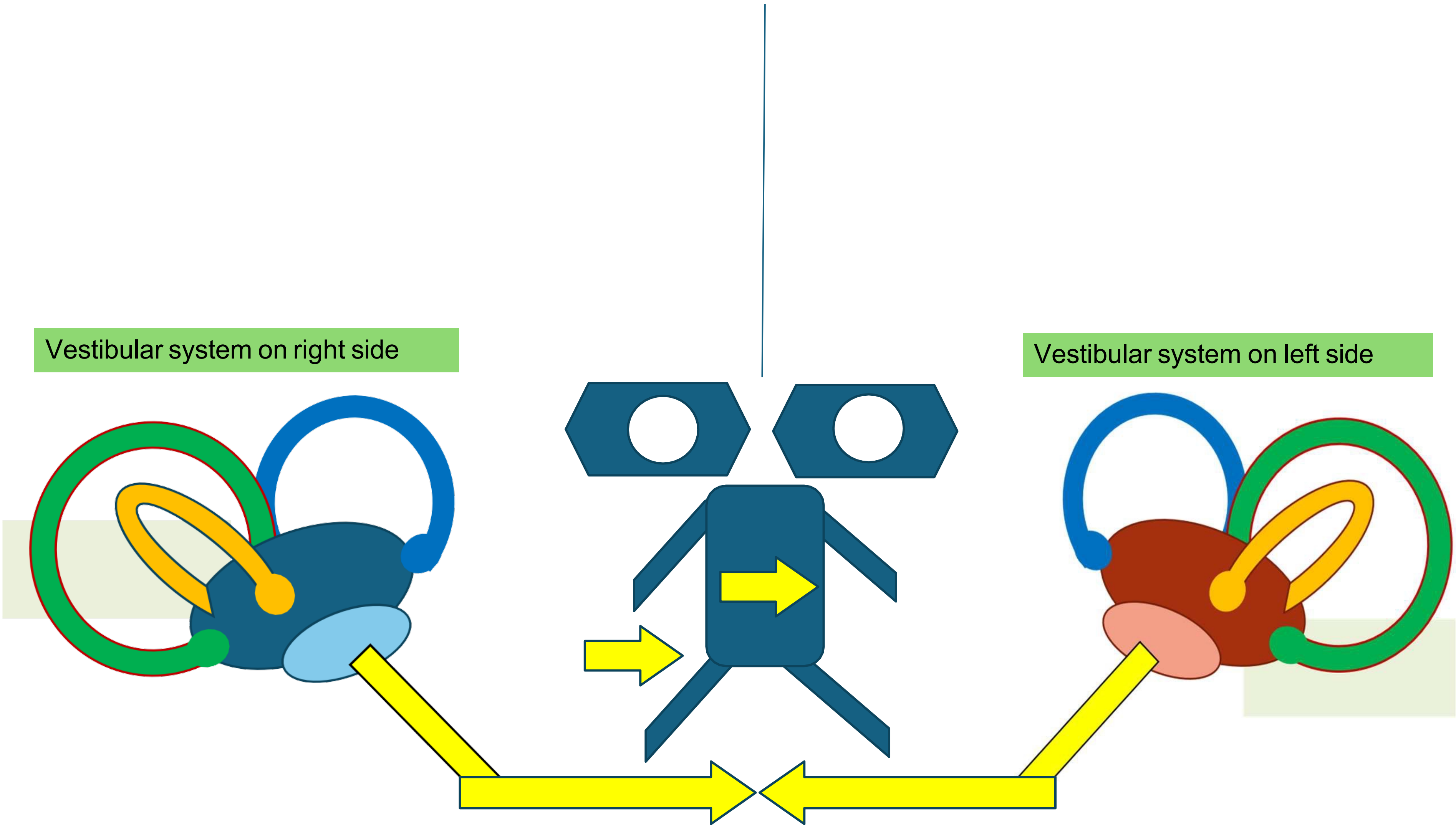


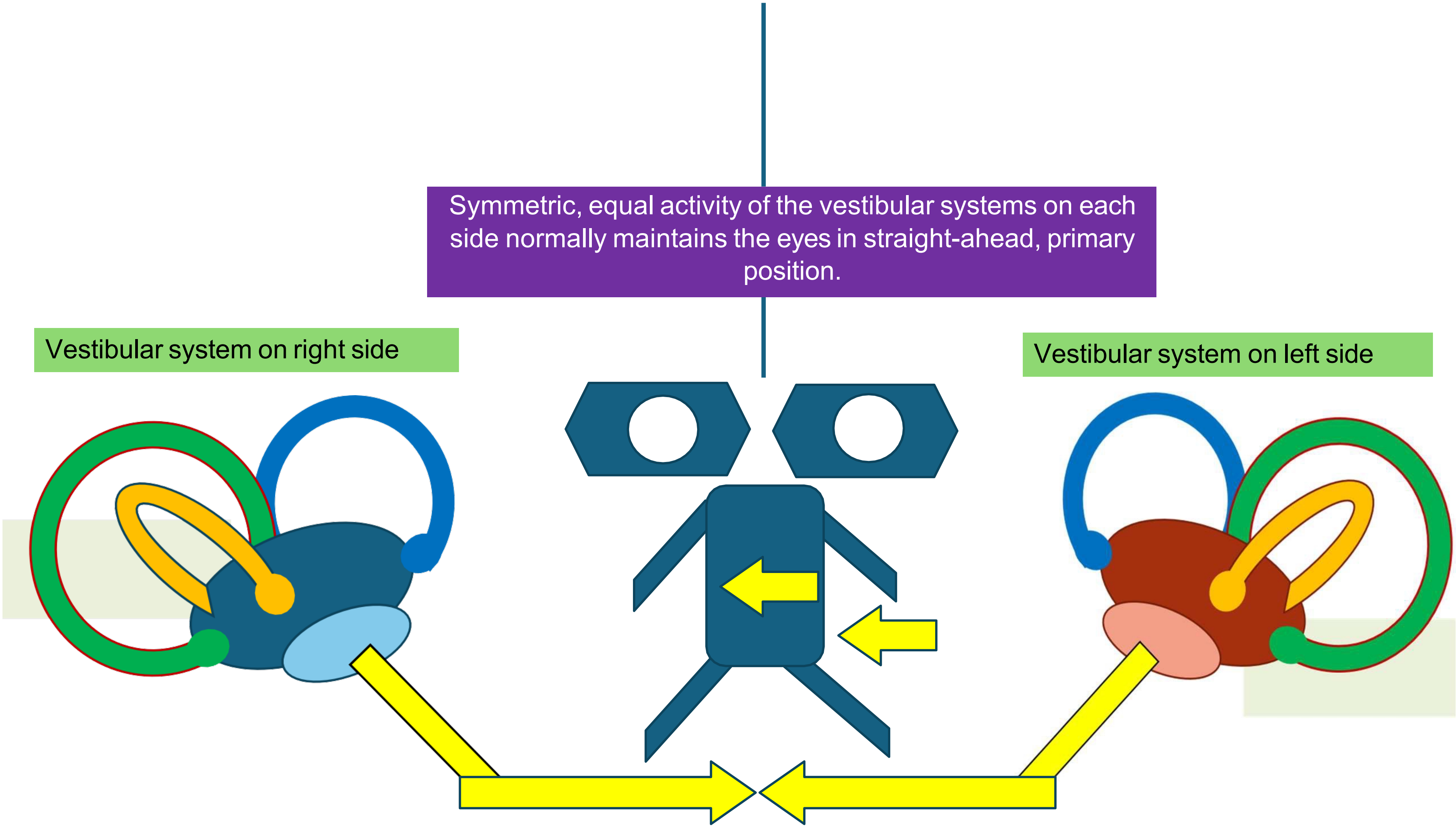
SR
SO
LR
MR
IR
IO
SO
SR
MR
LR
IO
IR
Medial longitudinal fasciculus
III
Glycine
IV
IV
VI
VI
Anterior SC
Lateral SC
Posterior SC
Superior VN
Lateral VN
Medial VN
Inferior VN
NPH
XII
NPH
XII
Superior VN
Medial VN
Lateral VN
Inferior VN

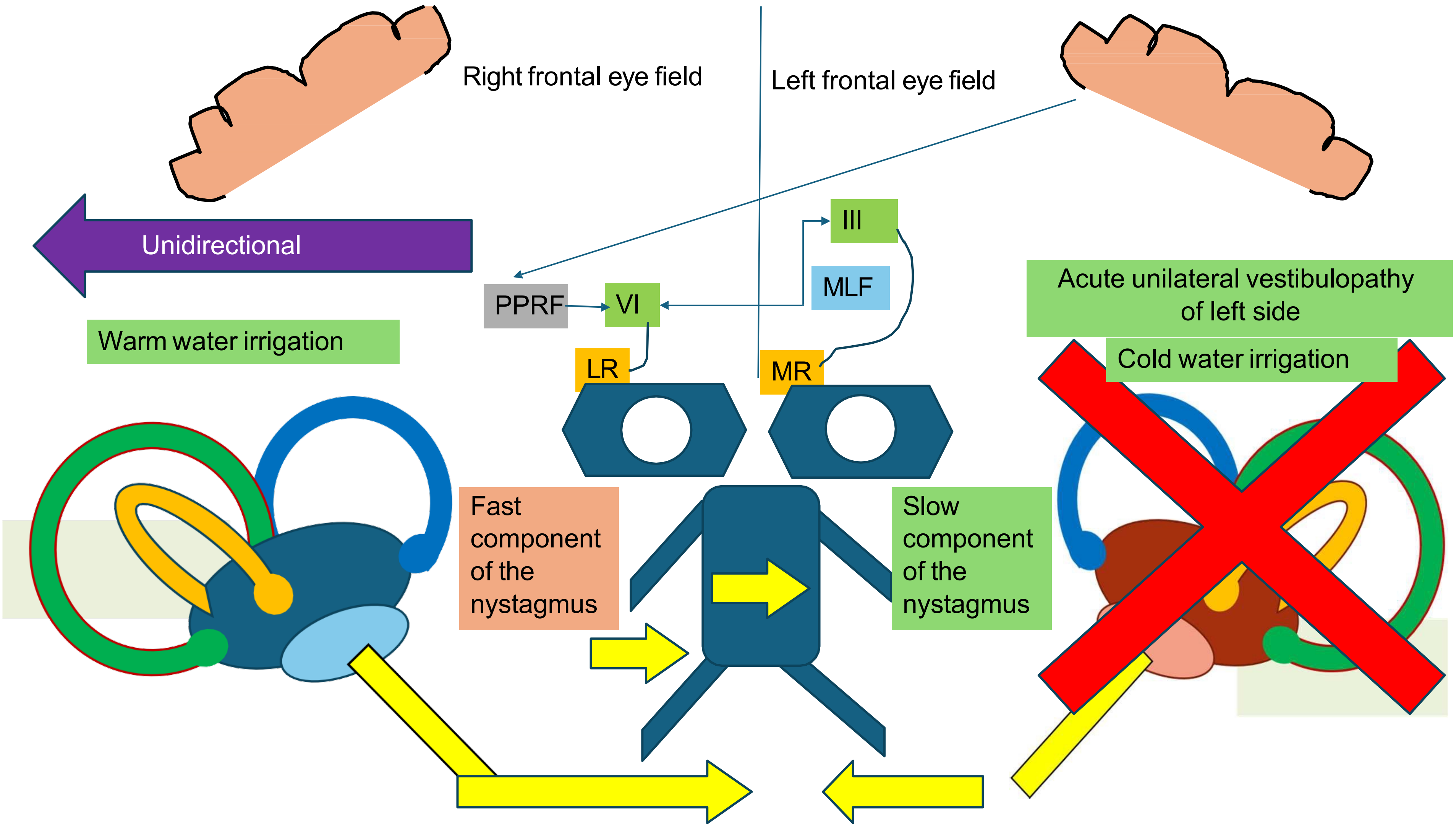
Vestibular System Function- Coordination of Eye Movements

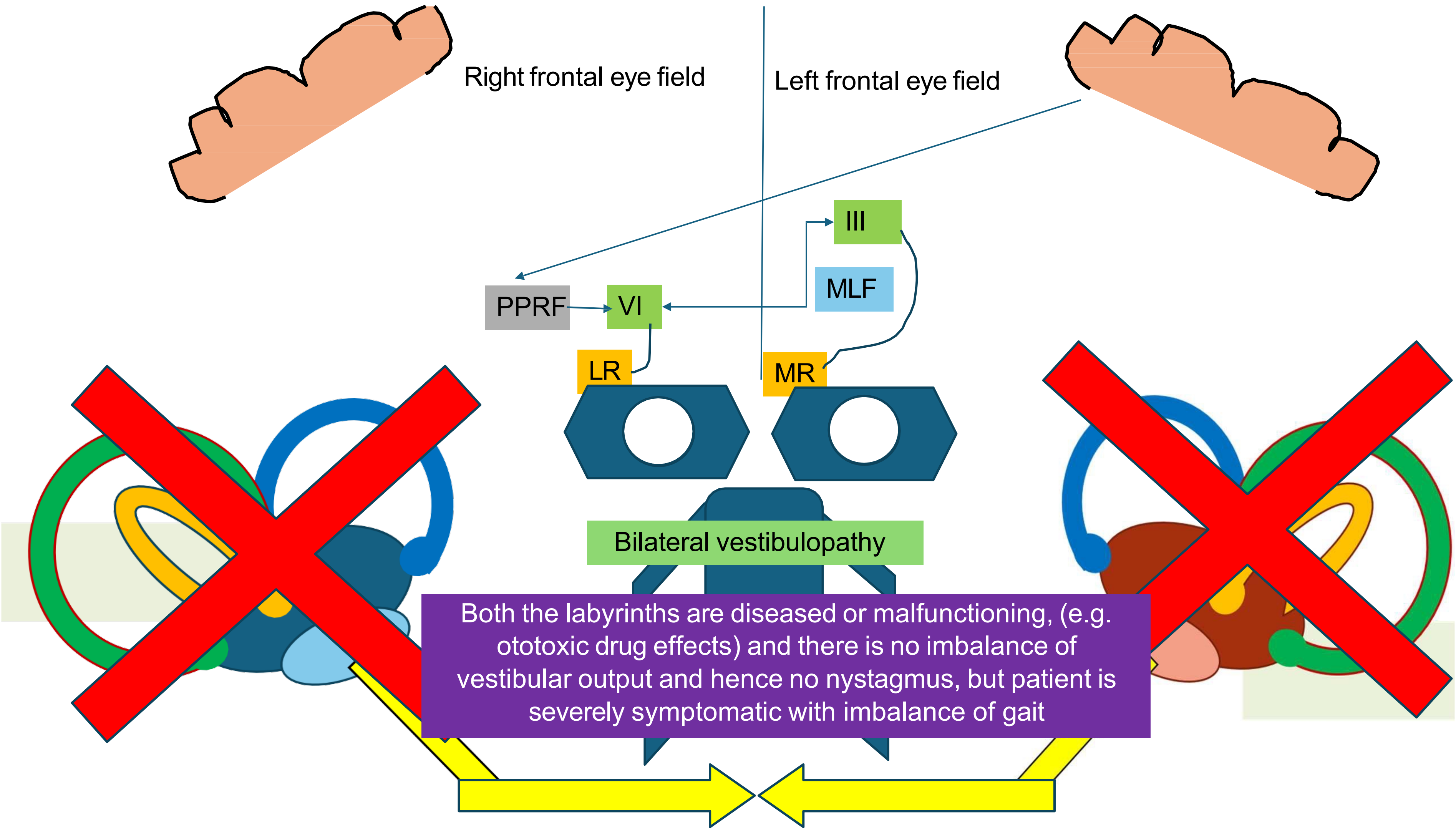
- The system works to coordinate eye movements with head movements to maintain a stable gaze, particularly during rapid head motions.

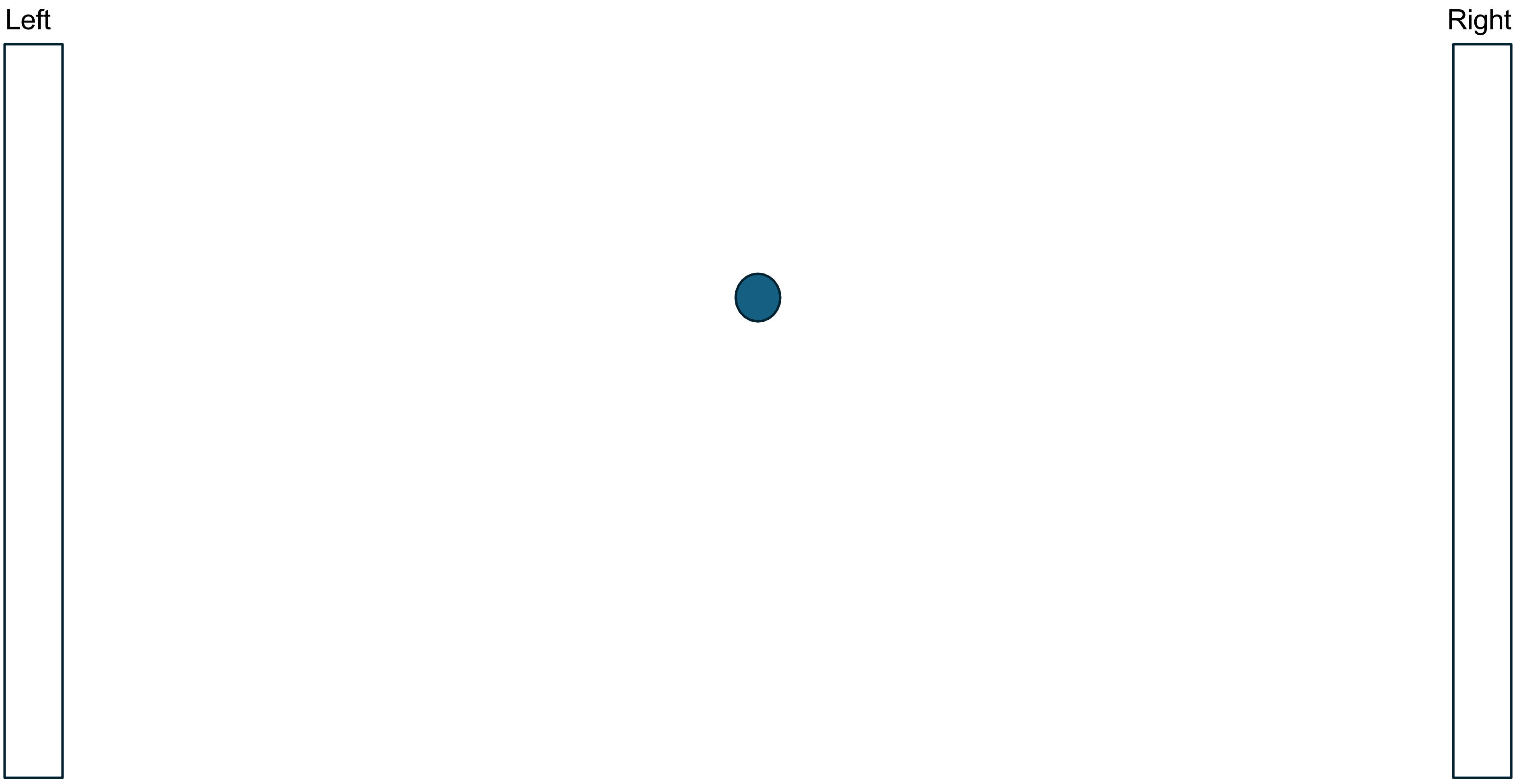

itself to the ground and
push.

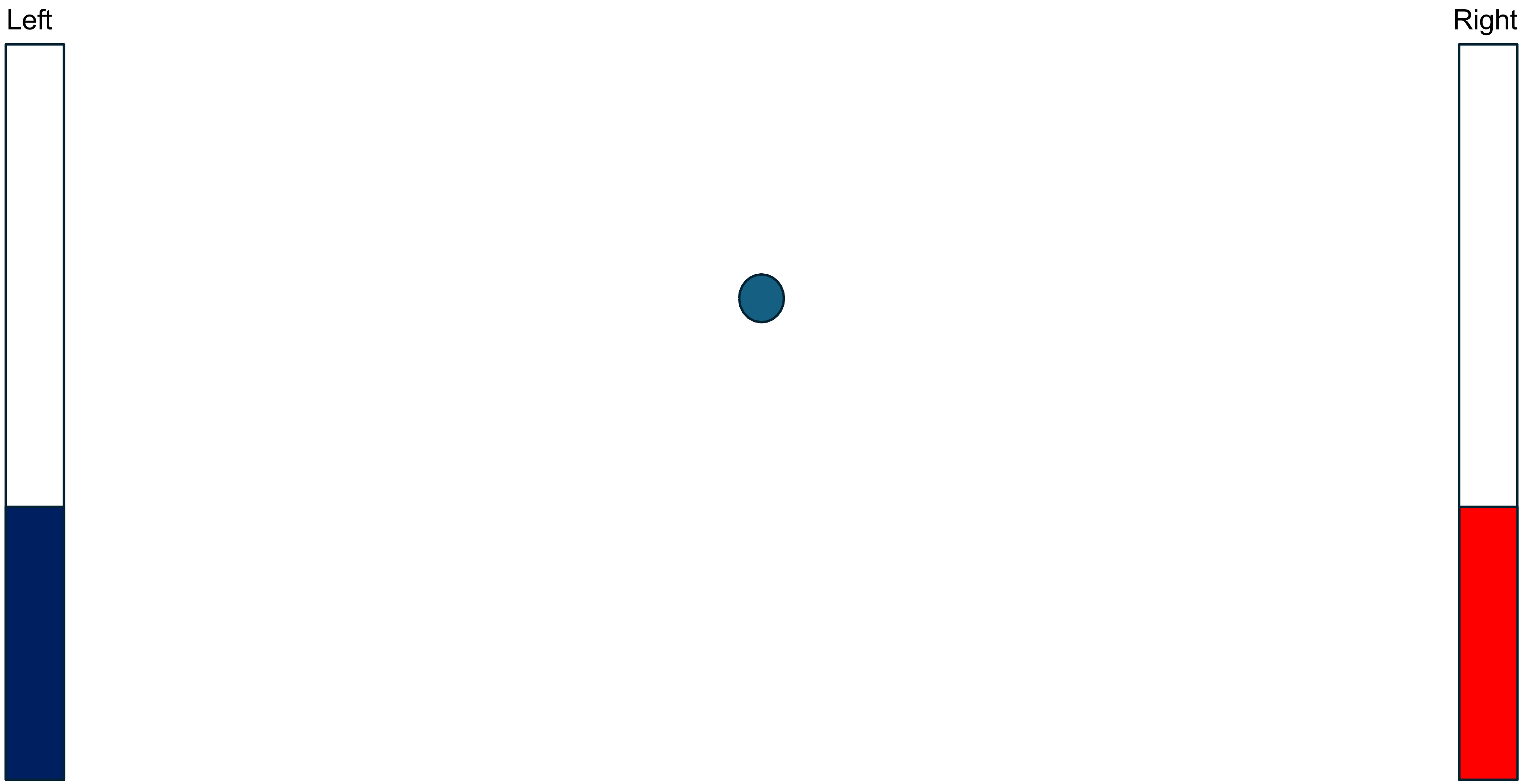

Vestibular system on right side
Vestibular system on left side

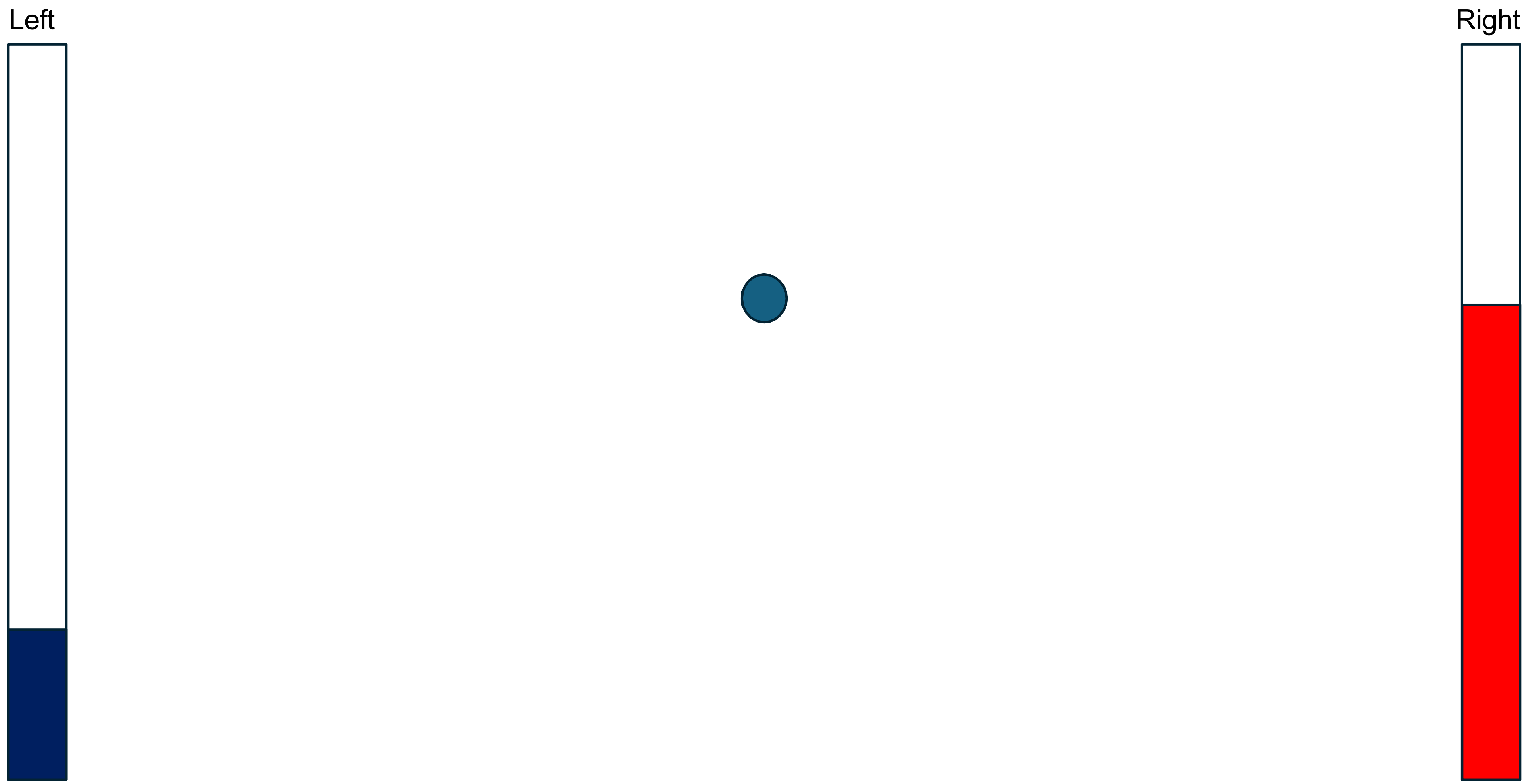

Symmetric, equal activity of the vestibular systems on each side normally maintains the eyes in straight-ahead, primary position.
Vestibular system on right side
Vestibular system on left side


Right frontal eye field
Left frontal eye field
Unidirectional
III
MLF
PPRF
VI
Acute unilateral vestibulopathy of left side
Warm water irrigation
LR
MR
Cold water irrigation
Fast component of the nystagmus
Slow component of the nystagmus

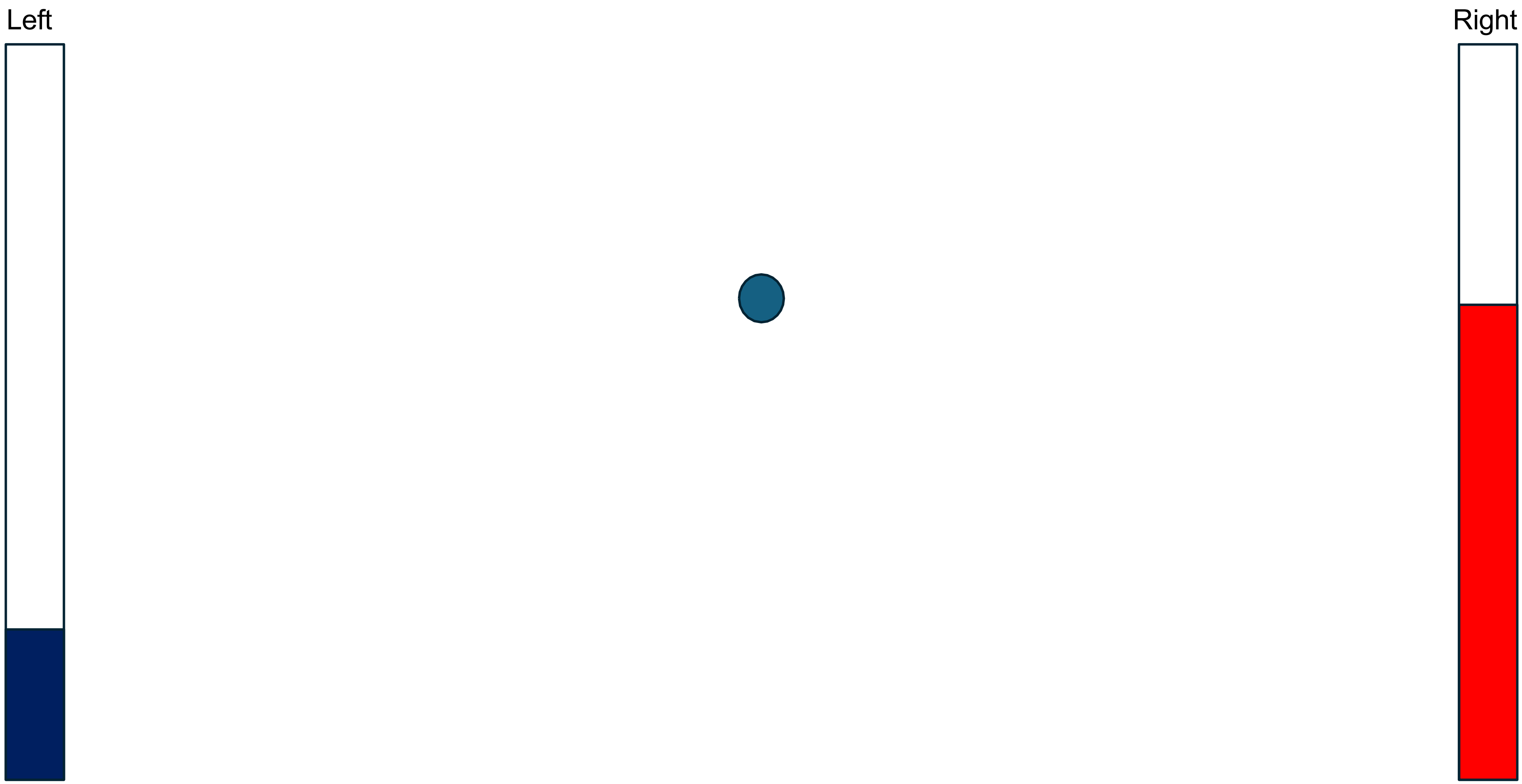

Right frontal eye field
Left frontal eye field
III
MLF
PPRF
VI
LR
MR
Bilateral vestibulopathy
Both the labyrinths are diseased or malfunctioning, (e.g. ototoxic drug effects) and there is no imbalance of vestibular output and hence no nystagmus, but patient is severely symptomatic with imbalance of gait

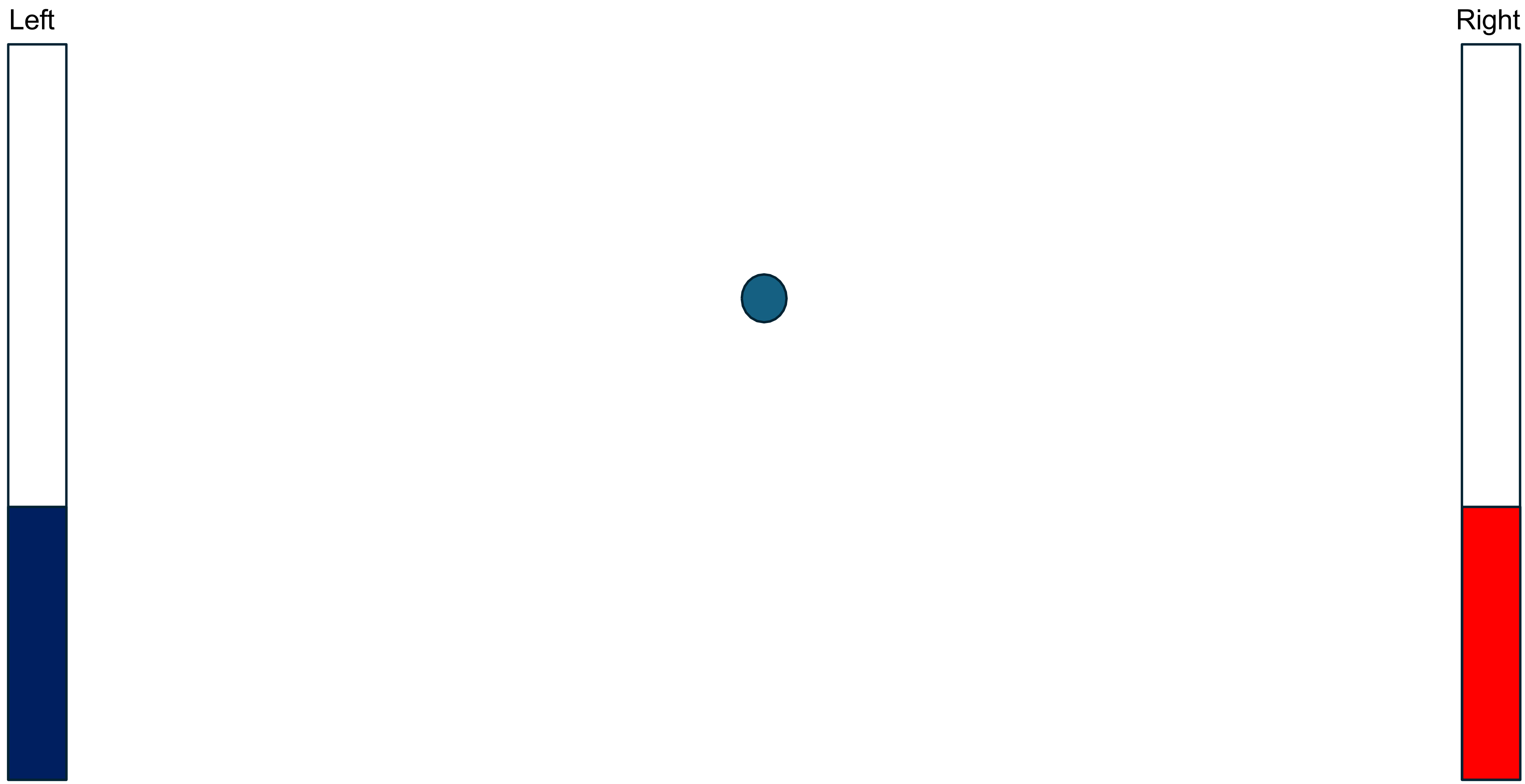

Left
Right


Left
Right



Left
Right


Left
Right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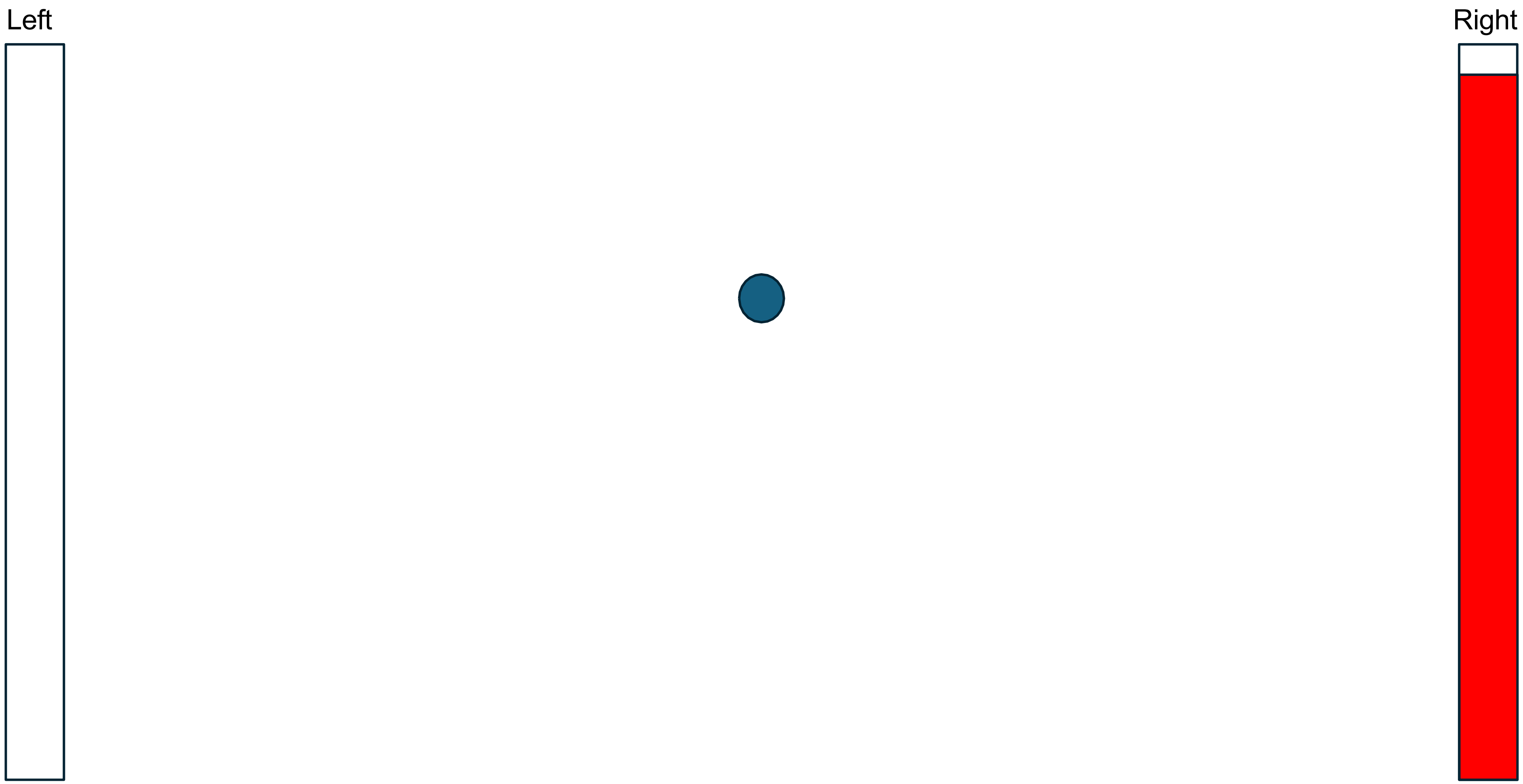
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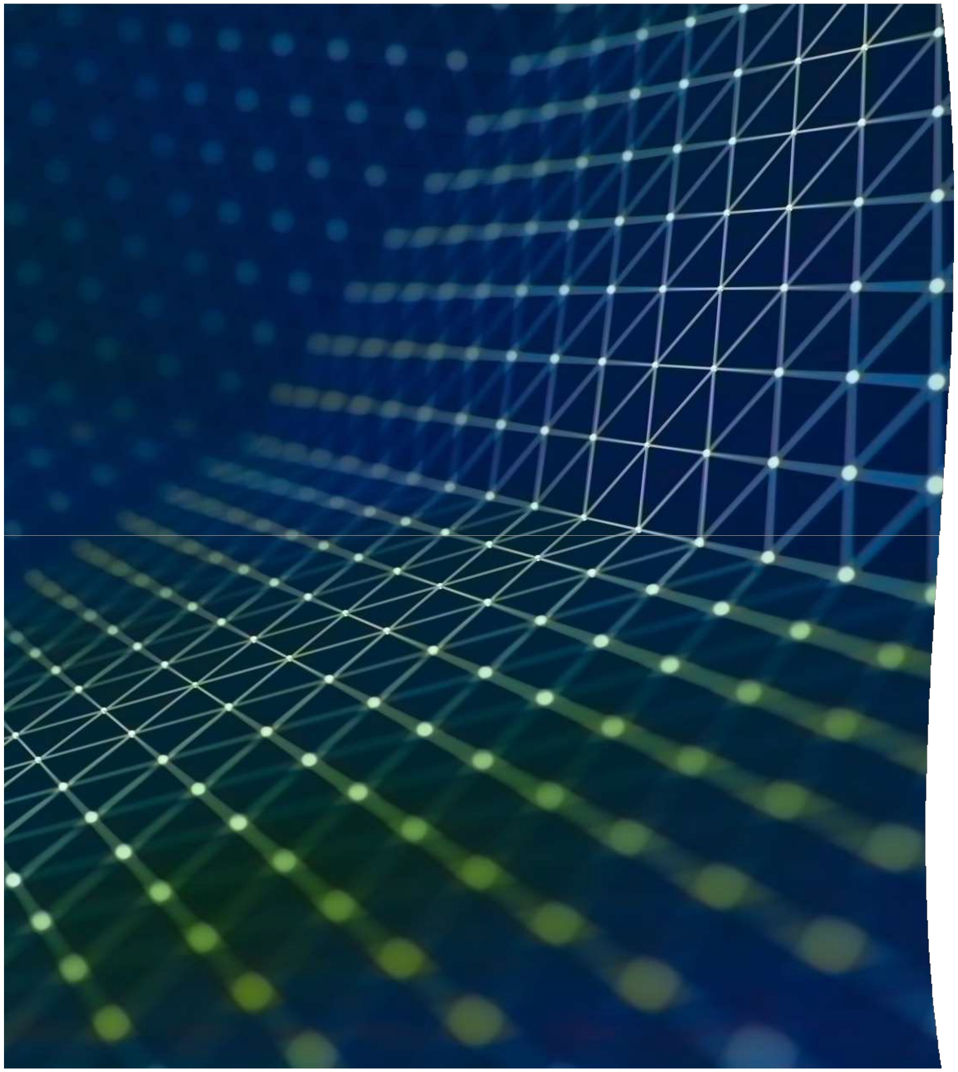
Head impulse test

The head impulse test (HIT) assesses the function of the vestibulo-ocular reflex (VOR), which links the vestibular system and the oculomotor muscles.

There are two versions of the test:

- **Clinical Halmagyi's Test (cHIT)** or bedside head impulse test
- **Video Halmagyi's Test (vHIT)** or video head impulse test



Bedside HIT

Developed by Gabor M. Halmagyi and Ian S. Curthoys in 1988 – The head impulse test (HIT) was created to assess the function of the semicircular canals during fast head rotations.

The bedside HIT involves the patient fixating on **a stationary target** (such as the tester's nose) while the tester moves the patient's head rapidly to both sides.

The head movements used in HIT are **high-velocity, low-amplitude, and unexpected** to effectively stimulate the lateral semicircular canals.

In addition to horizontal head movements, the test can also assess **anterior and posterior semicircular canals** by moving the head in different planes.

1. In normal subjects, the vestibulo-ocular reflex (VOR) produces **compensatory eye movements** during head movements.

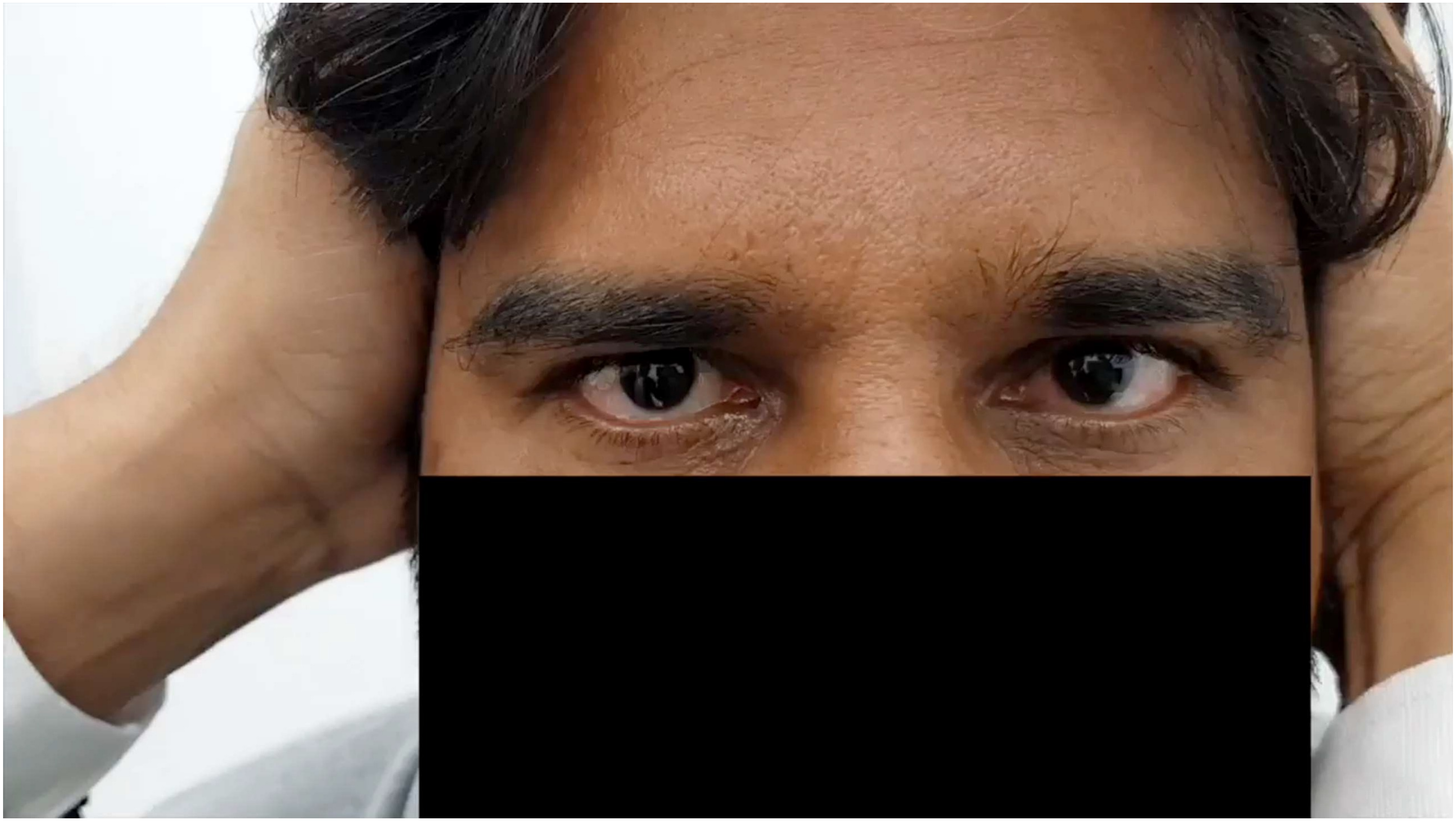
2. The eyes move in the **opposite direction of the head** at approximately the same velocity.

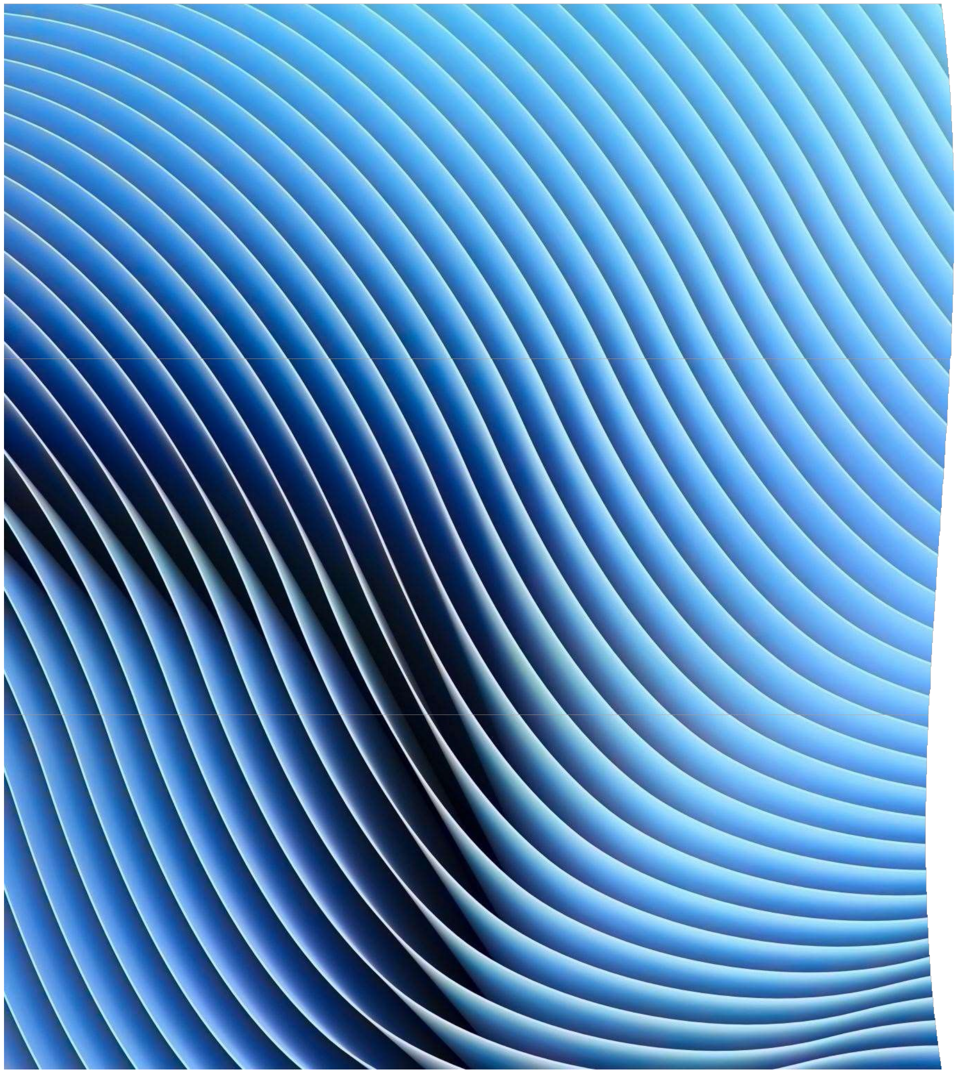
3. When the head moves to the right, the eyes move to the left, and vice versa.

4. This reflex makes it appear as if the **eyes remain stationary** in space.

5. The patient’s eyes stay focused on a target, such as the examiner’s nose, **despite head movement.**

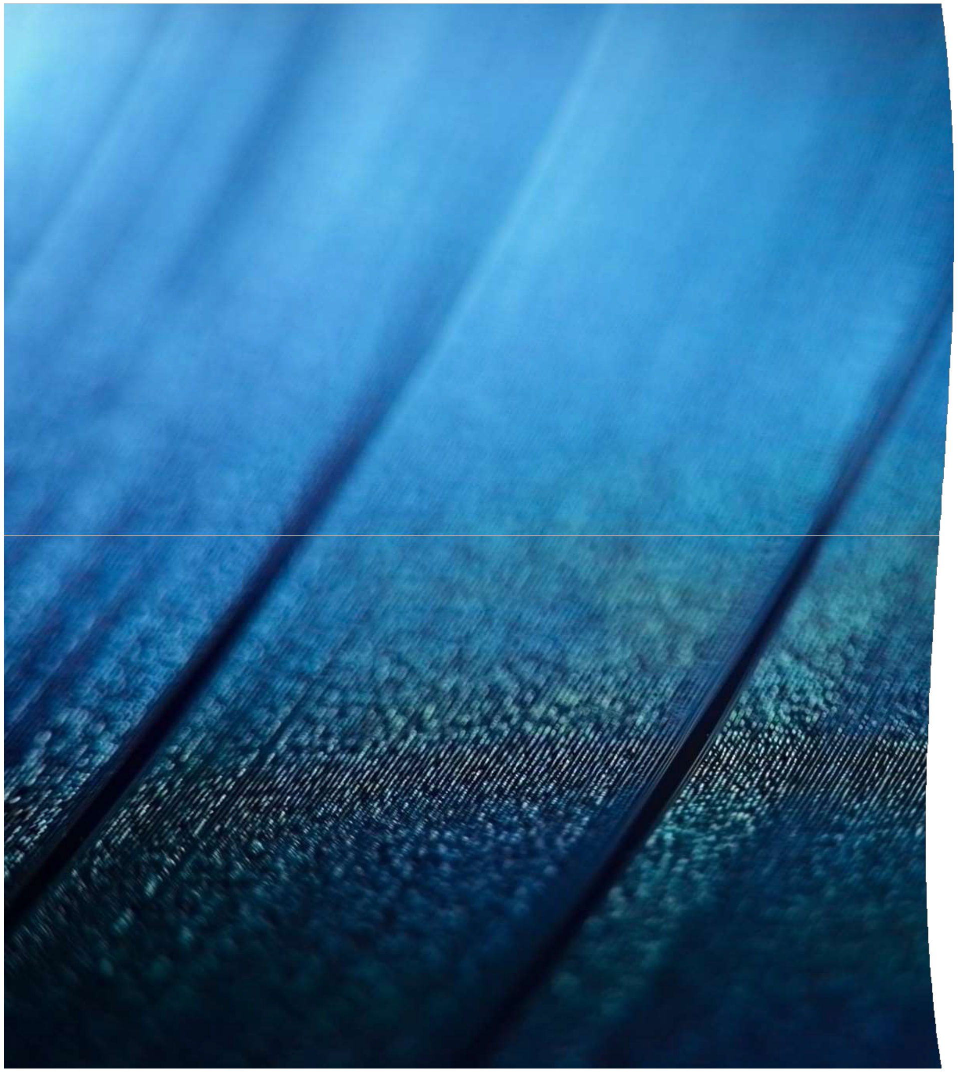
1. In patients with **unilateral vestibular lesions**, the VOR function is reduced on the affected side.
2. When the head is moved toward the damaged side, the eyes fall short of the target.
3. The patient needs to make a corrective eye movement, known as a **catch-up saccade**, to refocus on the target.





4. The catch-up saccade helps to bring the eyes back to the target after the initial failed movement.

5. This abnormal eye response is a sign of vestibular dysfunction on the affected side.



Catch-up saccaades

1. There are two types of catch-up saccades:

- **overt saccades**
- **covert saccades.**

2. **Overt saccades** occur after the head stops moving and are visible to the naked eye, making them detectable in the bedside HIT.

3. **Covert saccades** occur during head movement, are very fast, and are not visible to the naked eye.

Limitations of bedside HIT

The absence of overt saccades does **not guarantee** the normal function of the Vestibulo-Ocular Reflex (VOR).

The bedside head impulse test (HIT) **cannot detect covert saccades**, limiting its diagnostic capability.

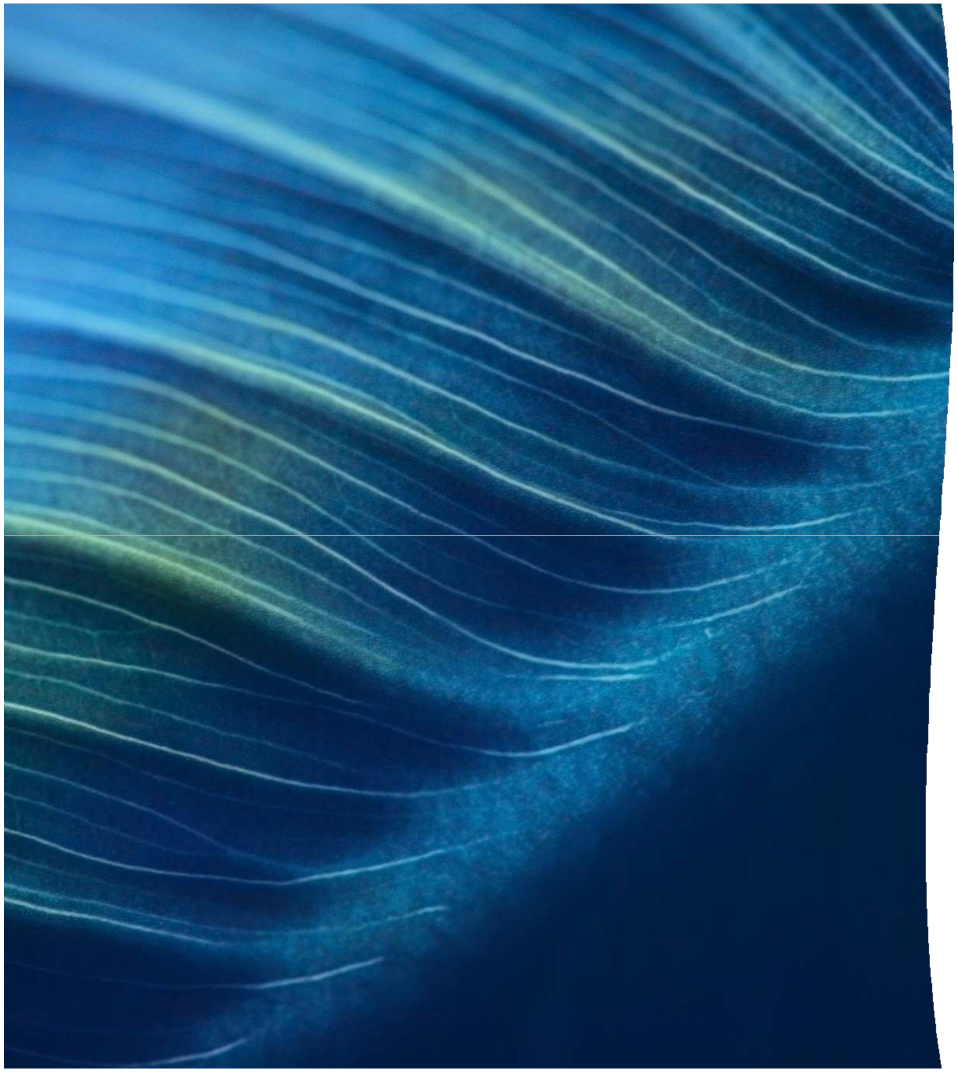
The bedside HIT is **most useful in acute stages of vestibular dysfunction** when overt saccades are more likely to be observed.

All

Partial vestibular deficits and monitor **compensation strategies**.

None

Intermediate response



Video head impulse test

Developed by **Erik Ulmer** to measure functional deficits in a continuous range.

The video head impulse test (vHIT) is a **quantitative method** for assessing the vestibulo-ocular reflex (VOR).

vHIT uses **high-speed cameras to record both the overt and covert saccades**

Can assess VOR gain Ratio of Head velocity/Eye velocity

Can identify partial vestibular impairments

Helpful in monitoring compensation methods and directing rehabilitation efforts

The vHIT provides **feedback** on the clinician's head impulses, ensuring improved testing accuracy.

vHIT has been validated against the **scleral search coil**, the gold standard for measuring eye movements, but vHIT is **non-invasive and more practical** for clinical use.

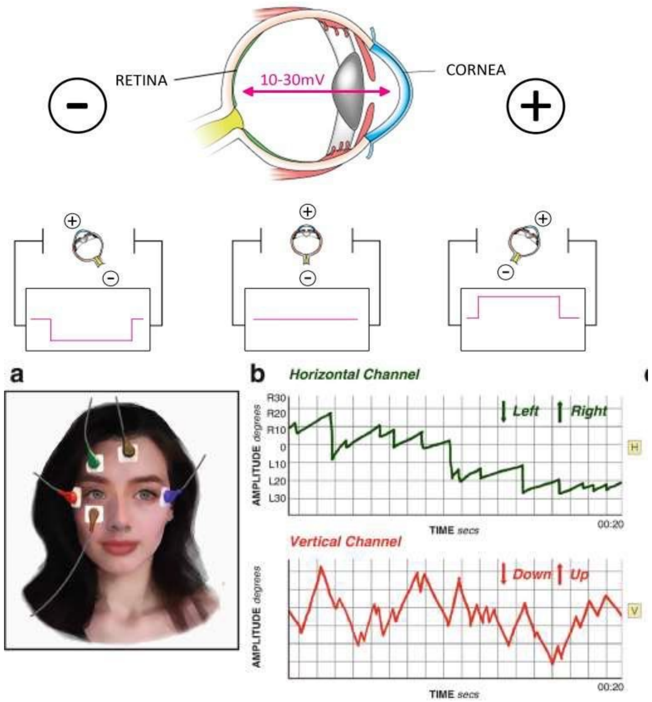
2.Principles and Methods of Ocular Recording in vHIT

- Systems for Eye Movements Analysis
- The vHIT: Two Principles of Acquisition
- Remote Camera-Based Systems
- Head Mount-Based Systems
- Comparing Technologies

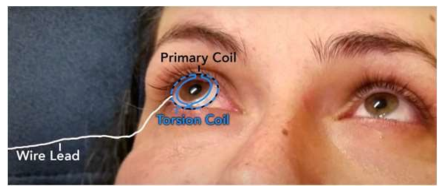
Clinical methods

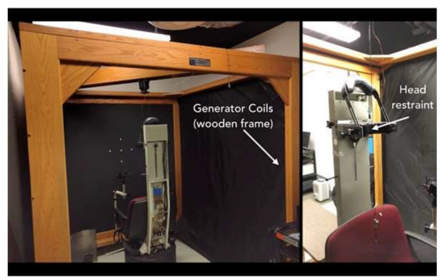
Video-oculography – Eye movements
Video-nystagmography- Nystagmus

Electro-nystagmography



Scleral search coil





Video-nystagmography

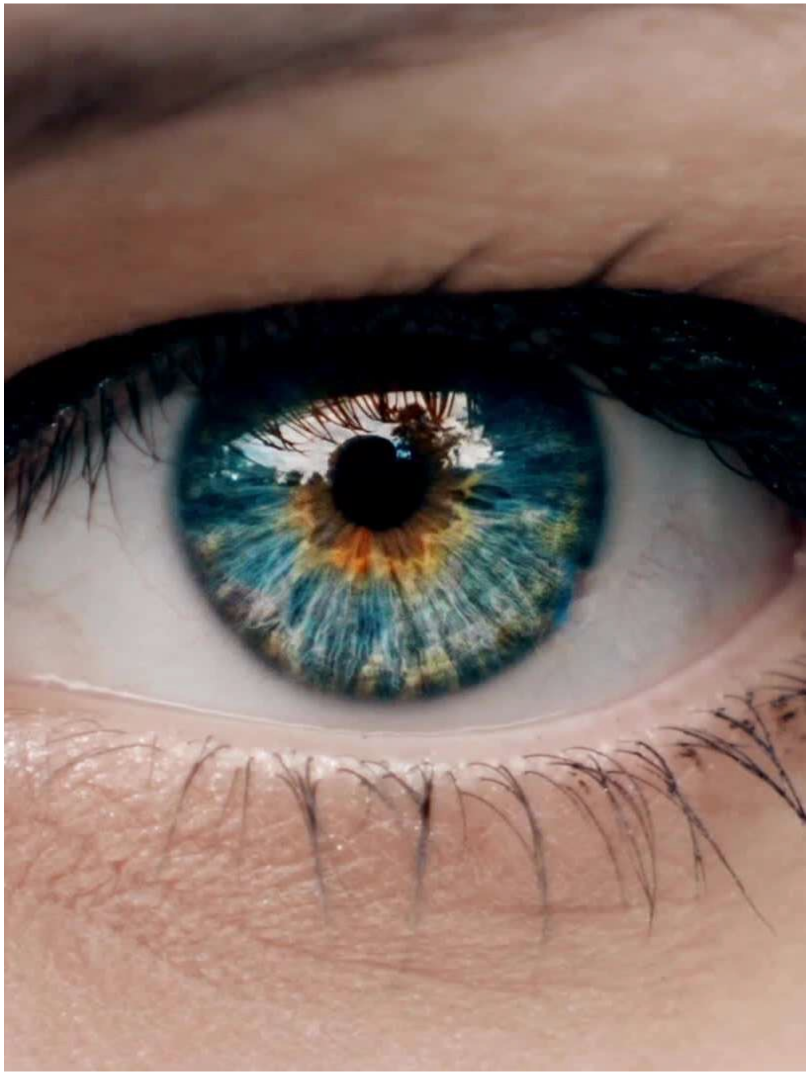
Video-Oculography

Video-recording
Eye movement graphs

Practical and easy

Comparison of Eye Movement Recording Techniques

Feature	Electro-nystagmography (ENG)	Video-nystagmography (VNG)	Scleral Search Coil (SSC)
Method	Measures electrical potential generated by eye movement	Tracks eye movement with a video camera	Tracks eye movement with a magnetic field and coil placed on the sclera
Accuracy	Moderate	High	Highest
Portability	High	Moderate	Low
Cost	Moderate	Moderate	High
Data captured	Primarily horizontal and vertical eye movements	Horizontal, vertical, and torsional eye movements	All eye movements (horizontal, vertical, torsional, and 3D rotations)
Limitations	Susceptible to electrical interference, requires skin contact with electrodes	Limited by camera resolution and field of view, requires good head stabilization	Requires specialized equipment and expertise, invasive procedure (placing coil)
Applications	Assessing vestibular function, diagnosing nystagmus, monitoring for neurological conditions	Similar to ENG, plus evaluation of gaze instability and smooth pursuit	Research on eye movement control, studying vestibular function in detail



Objective of vHIT

- The purpose of the video Head Impulse Test (vHIT) is to measure the **Vestibulo-Ocular Reflex (VOR) gain**, which is the ratio of eye velocity to head velocity during a head impulse.
- A normal, functional VOR should produce a gain close to **1** (eye movement velocity = head movement velocity).

Minimum Requirements for vHIT Systems

Accurate

head velocity measurement

Accurate

eye velocity measurement

Two Types of vHIT Systems

- **Remote camera-based systems**
  - • Uses a fixed camera to capture the patient's head and eye movements.
  - • Software analyzes the video using **Eye-Tracking** and **Head Pose Estimation** algorithms to calculate velocity and position.
- **Head mount-based systems**
  - • Consists of a head-mounted device with an integrated accelerometer and infrared camera.
  - • The accelerometer measures head velocity, while the camera measures eye velocity from reflections on a silver mirror.
  - • Software combines both inputs to calculate VOR gain.