Canadian Academy of Audiology
Academie Canadienne d'audiologie

Fundamentals of Vestibular Assessment
From Theory to Practice

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Land Acknowledgement

We begin this meeting by acknowledging the land on which we gather is the traditional territory of the Haudenosaunee and Anishinaabe peoples, many of whom continue to live and work here today. This territory is covered by the Upper Canada Treaties and is within the land protected by the Dish With One Spoon Wampum agreement. Today this gathering place is home to many First Nations, Metis, and Inuit peoples and acknowledging reminds us that our great standard of living is directly related to the resources and friendship of Indigenous people.

Objectives

- Introduction to Vestibular assessment
- Vestibular anatomy & physiology
- Recording techniques
- Case History
- Oculomotor testing
- Positional/positioning testing
- Caloric testing
- vHIT

Vestibular Assessment and Management

- are within the scope of practice of the Audiologist
- Advanced Competency in BC
- Inter-disciplinary team
- ENT versus Audiologist versus Physiotherapist roles

Vestibular Assessment and Management

The need:

- 35% of US adults 40 yo or older evidence of balance dysfunction based on modified Romberg
- 85% in the 80 + yo group
- 80% individuals needed sick leave and medical consultation
- 27% changed jobs, 21% gave up work, 50% reduced efficacy at work
- 57% disruption social life, 35% family difficulties, 50% difficulties traveling
- 2,6-fold increase in falls, rising to 12-fold increase if symptomatic

Agrawal, Y., BK Ward, and LB Minor. "Vestibular Dysfunction: Prevalence, Impact and Need for Targeted Treatment."
Journal of Vestibular Research-Equilibrium & Orientation, vol. 23, no. 3, 2013, pp. 113-117
H.K. Neuhauser, Epidemiology of vertigo, Curr Opin Neurol, 20(1) (2007), 40–46.
A.M. Bronstein, J.F. Golding et al., The social impact of dizziness in London and Siena, J Neurol 257(2) (2010), 183–190

Vestibular Assessment and Management

The need:

- vestibular dysfunction may be present in up to 70% of children with hearing loss
- about 20–40% have severe bilateral vestibular loss
- up to 48% of children with unilateral deafness had vestibular disorder, often ipsilateral
- significantly poorer balance function than their normal hearing peers
- children and adolescents (7-18) with HL perform significantly worse in gait tasks than hearing peers
- the higher the degree of HL, the worse the performance

Cushing, S Vestibular and balance dysfunction in the pediatric population: a primer for the audiologist. Can Aud 2014;1(4).
Sokolov, M., Gordon, K. A., Polonenko, M., Blaser, S. I., Papsin, B. C., & Cushing, S. L. (2019). Vestibular and balance function is often impaired in children with profound unilateral sensorineural hearing loss. Hearing Research, 372, 52-61.
Melo, R. d. S. (2017). Gait performance of children and adolescents with sensorineural hearing loss. Gait & Posture, 57, 109-114.

Vestibular Assessment and Management

- Although history (augmented by questionnaires) and physical examination are the initial steps in the evaluation of vertigo, the current study suggests that they should be complemented by objective testing for evaluation of inner ear origin of vertigo

  Gofrit SG, Mayler Y, Eliashar R, Bdolah-Abram T, Ilan O, Gross M.The Association Between Vestibular Physical Examination, Vertigo Questionnaires, and the Electronystagmography in Patients With Vestibular Symptoms. Ann Otol Rhinol Laryngol. 2017 Apr;126(4):315-321.

- In younger patients with vertigo, negative results on head impulse tests may not be informative

  Cohen, HS, Sangi-Haghpeykar, H, Ricci, NA, Kampangkaew J, Wlliamson, RA. Utility of Stepping, Walking, and Head Impulses for Screening Patients for Vestibular Impairments. Otolaryngology-Head and Neck Surgery Vol 151, Issue 1, pp. 131 – 136, 2016

- Bedside head impulse testing has moderate sensitivity and low positive predictive value even when performed by experienced clinicians

  Yip CW, Glaser M, Frenzel C, Bayer O, Strupp M. Comparison of the Bedside Head-Impulse Test with the Video Head-Impulse Test in a Clinical Practice Setting: A Prospective Study of 500 Outpatients. Frontiers in Neurology. 2016;7:58.

Vestibular Assessment and Management

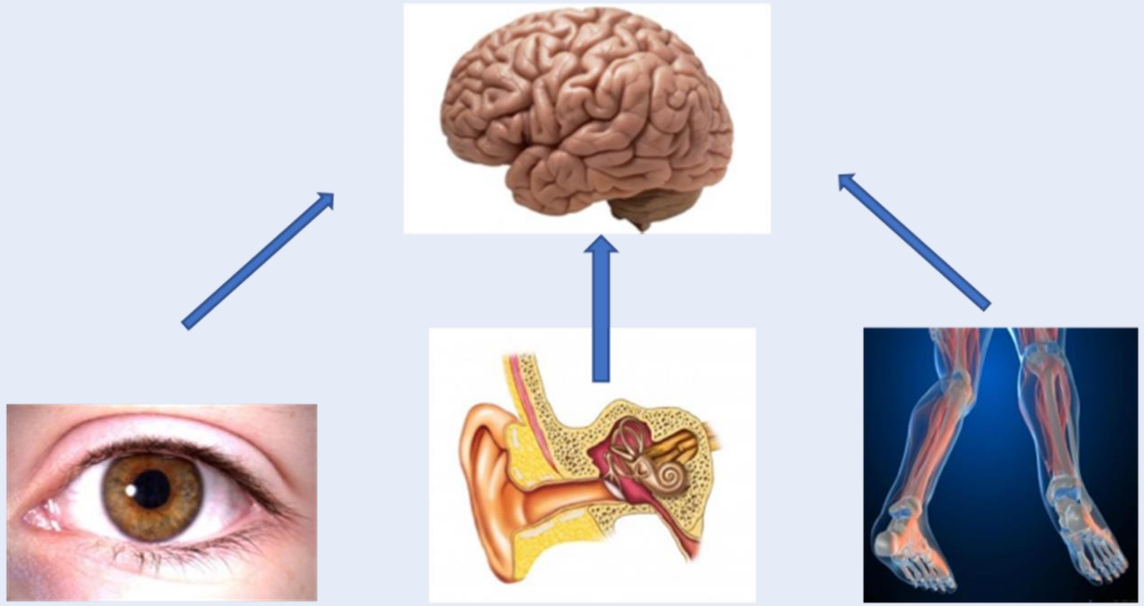
- Goal:
  - Is there a vestibular impairment?
  - Is it central or peripheral?
  - What side?
  - How much?

Targeted, effective treatments exist for vestibular disorders with well-defined pathophysiology

- Pharmacological treatment
- Surgical treatment
- Vestibular Rehabilitation Therapy

Balance and the Vestibular System

- Responsible for providing our brain with information about motion, head position, and spatial orientation
- Sense straight and rotational movements of the head



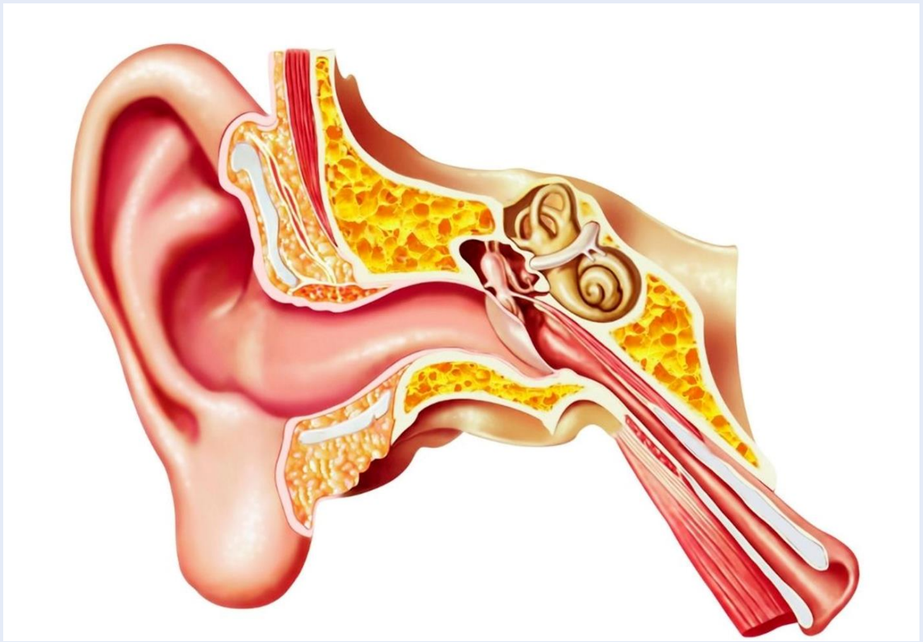
Vestibular System

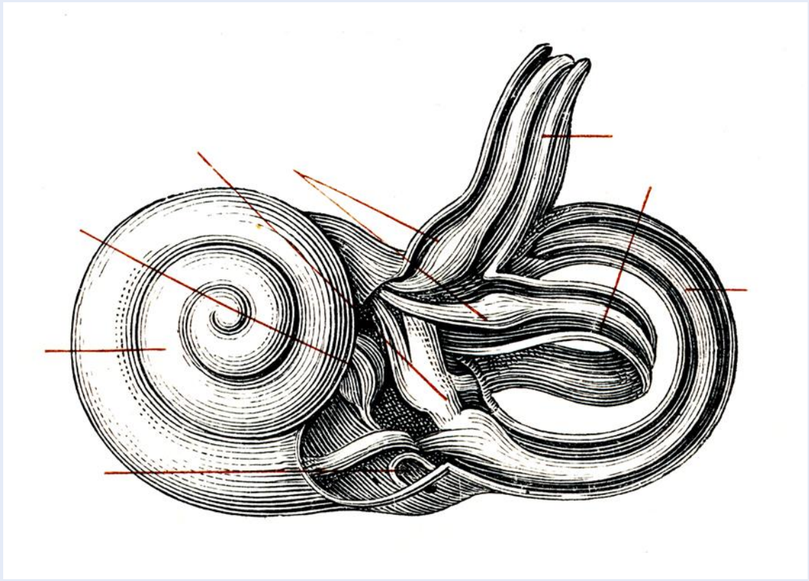
Maintains gaze stability
Objects stay clear with head movement
VOR (vestibulo ocular reflex)

Maintains postural stability
keep balance when moving in space
VSR (vestibulo spinal reflex)

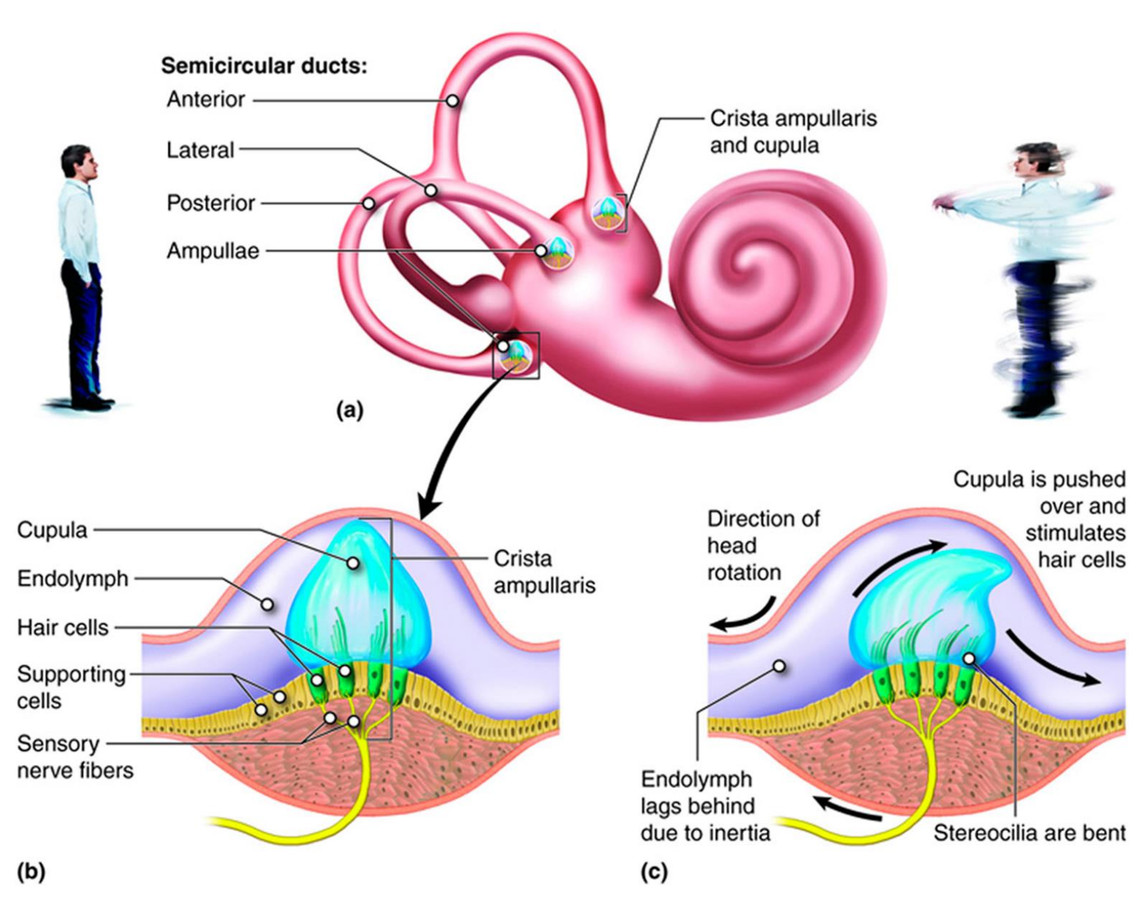
Resolves sensory conflicts
visual and somatosensory mismatches

Vestibular System





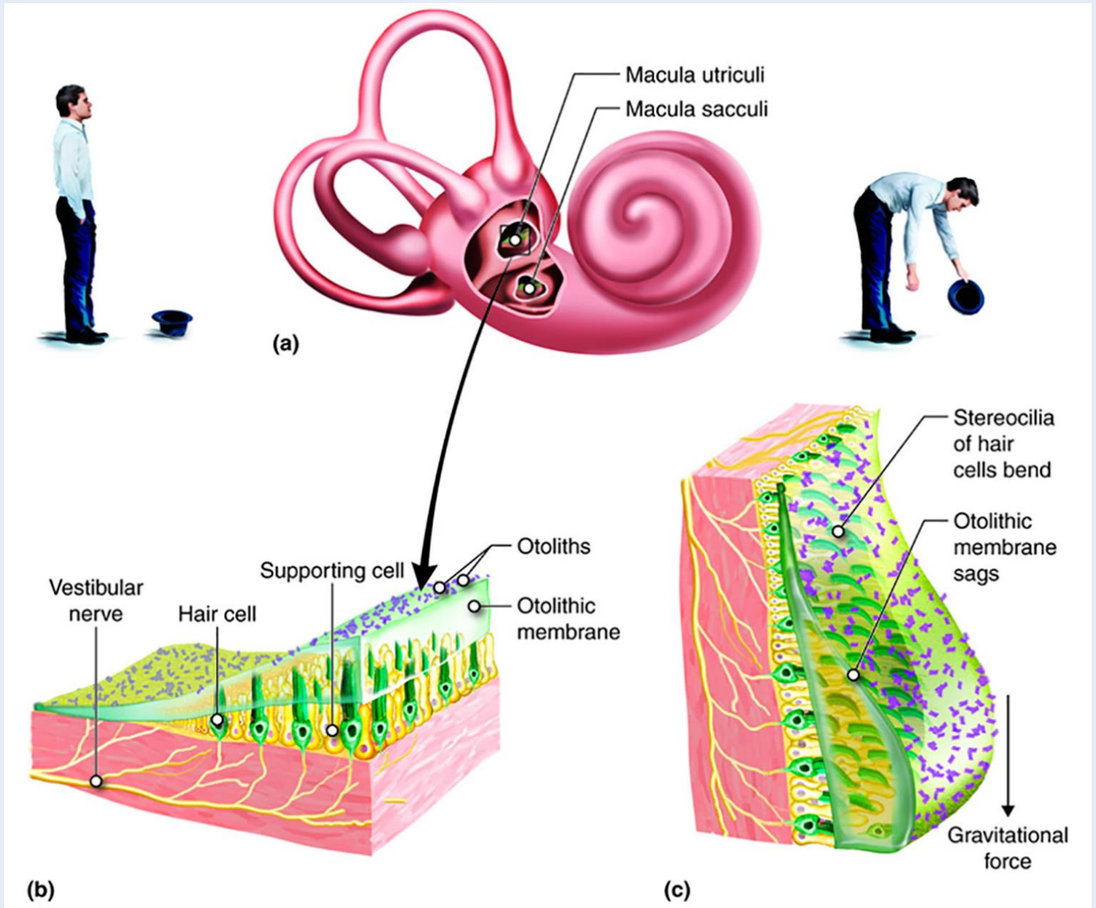
Vestibular System



Semicircular Canal Pairs:

- Right and left horizontal canals
- Left anterior and right posterior semicircular canals (LARP)
- Right anterior and left posterior semicircular canals (RALP)

Vestibular System



The Otolith Organs:
Respond to linear head movements in all planes

- up and down
- side to side
- back and forth

Vestibular Assessment

- Case History:
  - complex and difficult to describe symptoms
  - long history; several, often conflicting opinions from professionals
  - keep on track but LISTEN
  - focus on the sequence of events and symptoms
  - questionnaires/consult letters

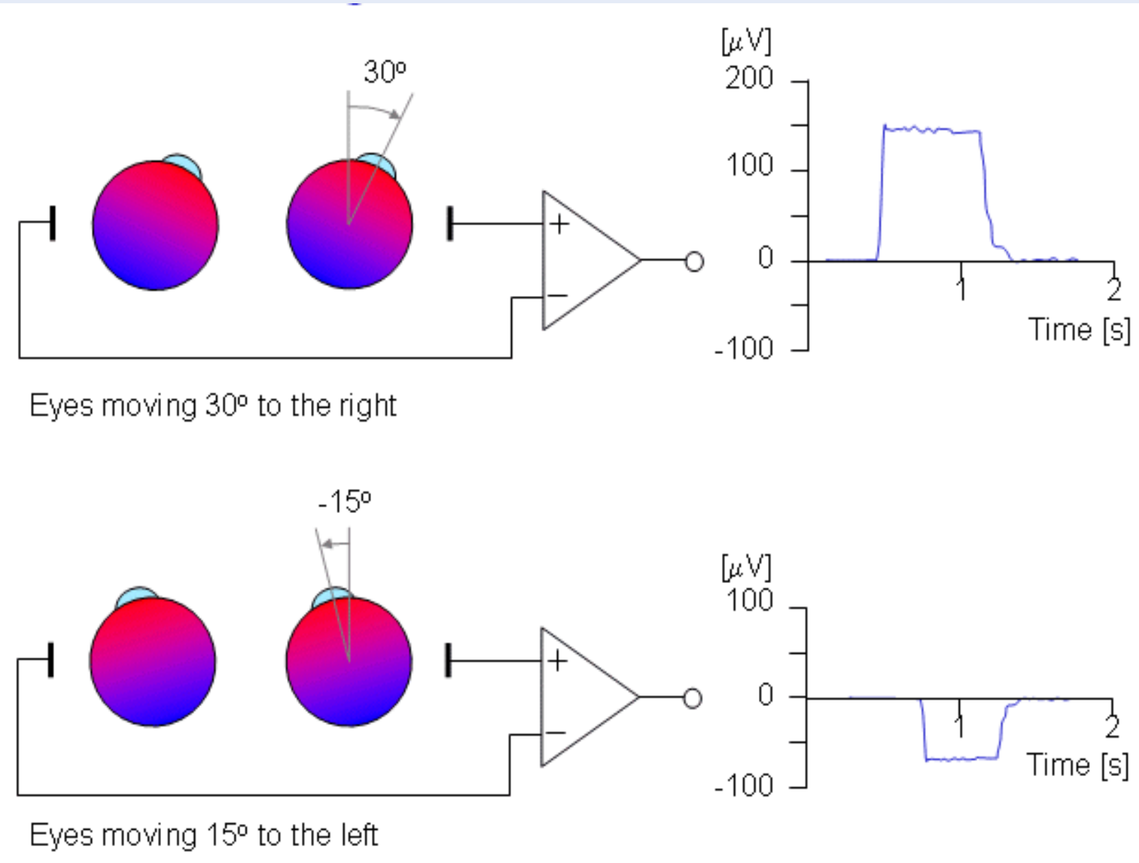
Vestibular Assessment

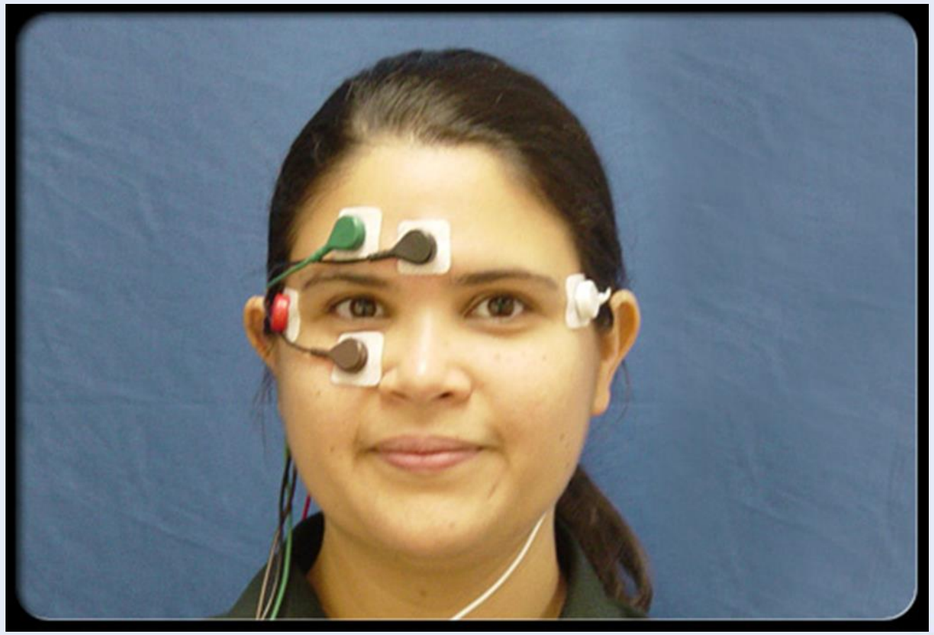
- important aspects to obtain:
  - type of dizziness
  - duration and frequency of dizziness
  - triggering/exacerbating and alleviating factors
  - accompanying symptoms
  - medical history
  - medications/drugs

Eye movement recording techniques

- Eletro-oculography (EOG) / eletronystagmography (ENG)
- Videorecording techniques
- Scleral search coil techniques

EOG / ENG
Corneo-retinal potential

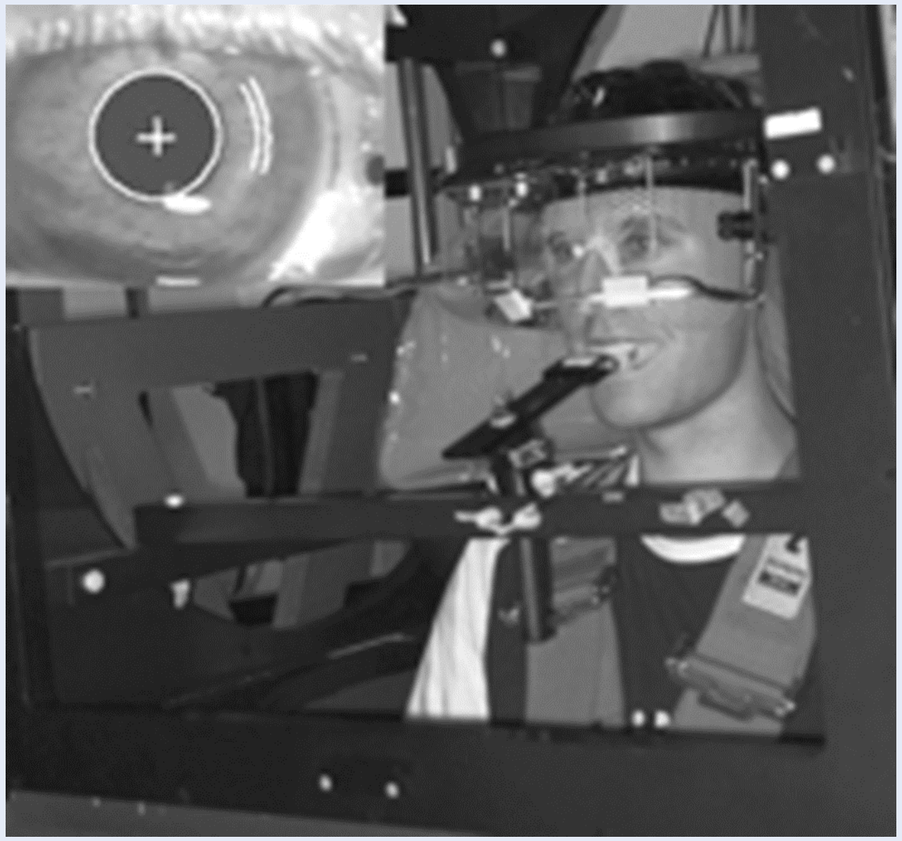




Videorecording (VNG)

- camera mounted on goggles
- dark-pupil system
- light-tight + infrared LED → recordings without fixation
- resolution = camera frame rate (200Hz+ currently)

Scleral Search Coil



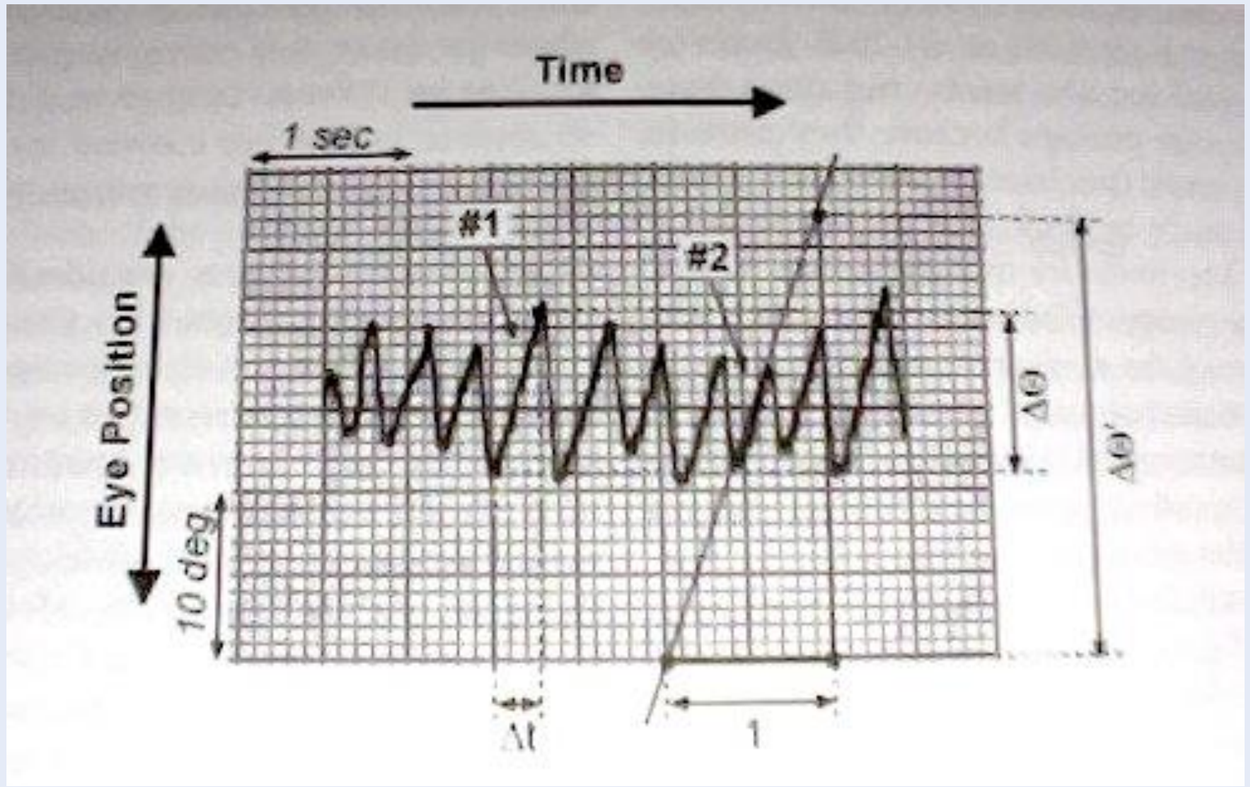
- contact lenses with wire coil + magnetic field
- uncomfortable
- high spatial and temporal resolution
- research

Understanding the recordings

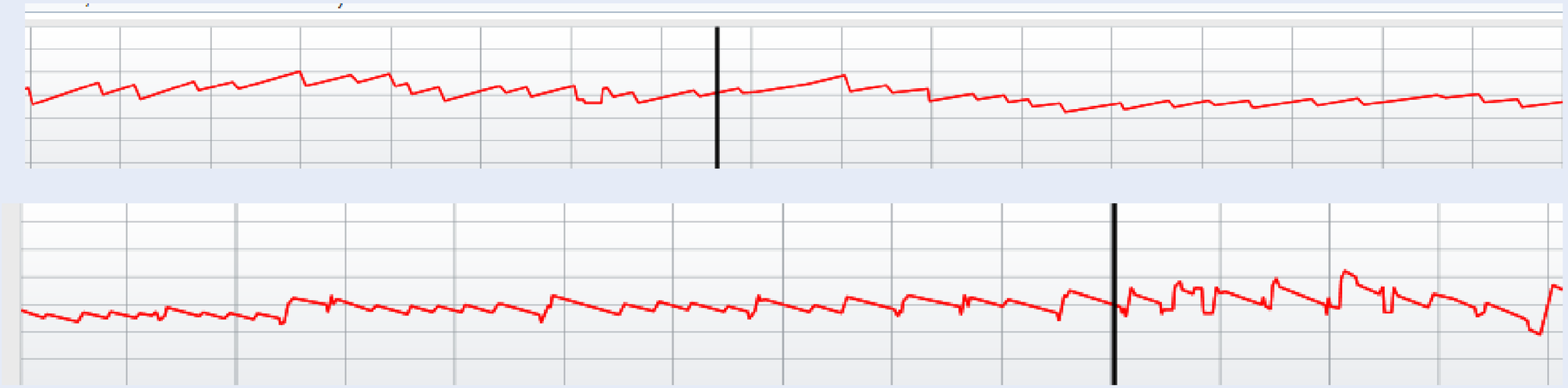
- Eye movements with and without fixation
- Eye movements (saccadic, tracking, nystagmus
- Nystagmus: physiological, congenital, acquired (visual, vestibular, central)
- Normal vestibular physiology: bilateral symmetrical constant firing

Understanding the recordings

- direction given by fast phase (ocular)
- velocity measured on slow phase (vestibular)



Understanding the recordings



- right + upwards
- left - downwards

VNG - oculomotor testing

- gaze stability
- saccade testing
- smooth pursuit tracking
- optokinetic nystagmus

Gaze stability

- ability to maintain gaze stable without generating eye movements
- center (primary), right, left, up and down
- with/without fixation
- abnormal can be peripheral or central

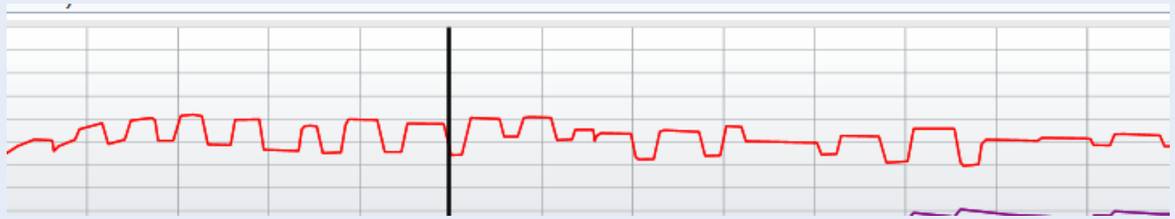
Gaze stability

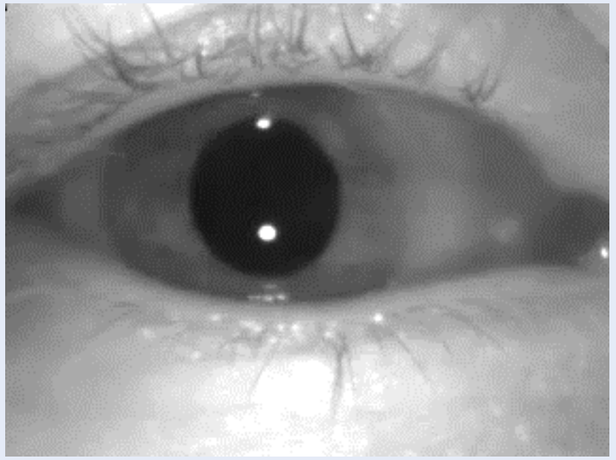
PERIPHERAL	CENTRAL
spontaneous with fixation in acute stage	acute or chronic lesion - persistent
direction fixed with horizontal component (> neural activity)	direction fixed or changing; pure vertical or torsional
follows Alexander’s Law	rarely horizontal in primary
enhanced with fixation removed	enhanced with fixation present + rebound
enhanced with head shake	vertical ny post head shake
straight slow phase	decrease speed of slow component

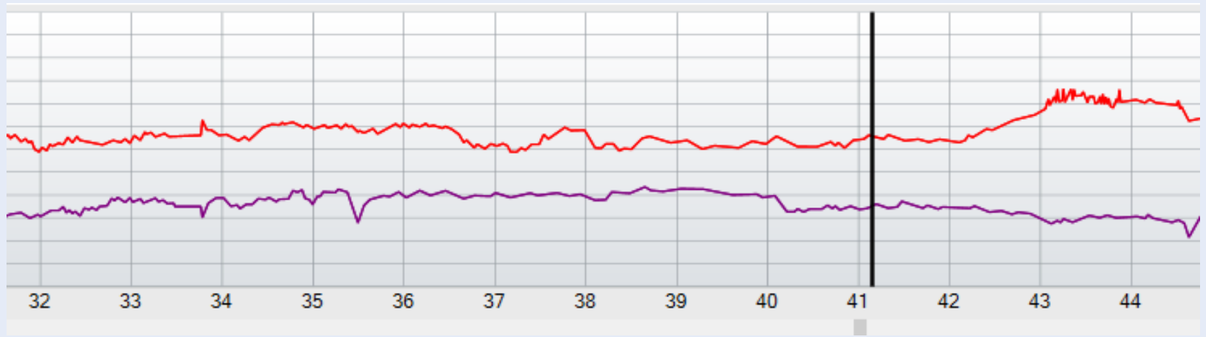
Gaze stability

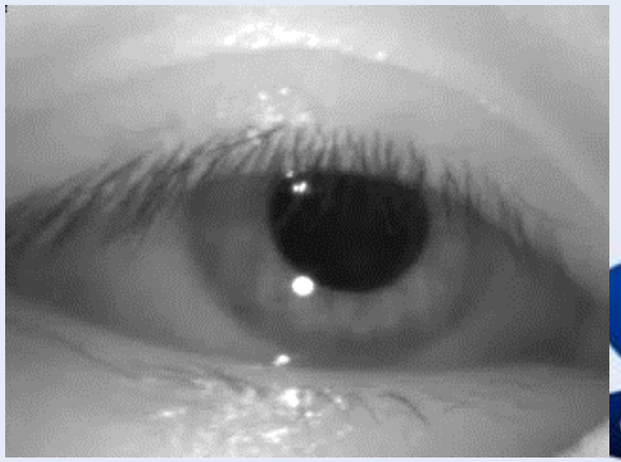
- square wave jerks: 0.5 to 5°; 20 - 30 per minute in normals; if more = cerebellar or upper motor neuron
- macro square wave jerks: 5 to 15°; brainstem or cerebellum
- macro saccadic oscillations: both directions; cerebellum
- ocular flutter / opsoclonus: no intersaccades interval; brainstem or cerebellum

Gaze stability









Saccade testing

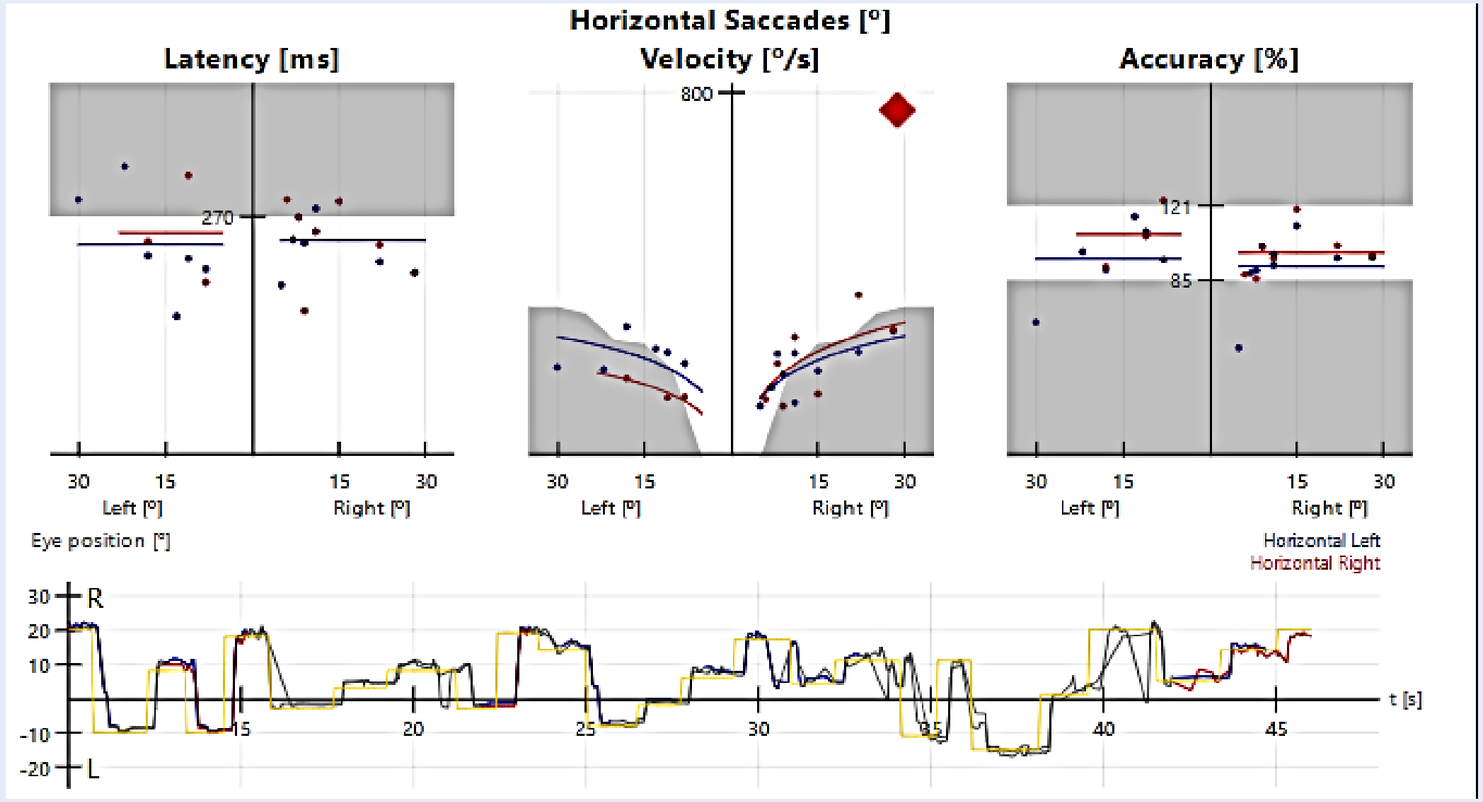
TEST

- sudden rapid eye movements
- fixed or random
- individual eye recording
- latency, velocity, accuracy

INTERPRETATION

- never peripheral
- posterior cerebellum and various brainstem areas, cerebral hemispheres
- fatigue, medications, drowsiness
- MS, intranuclear ophthalmoplegia, Parkinson’s

Saccade testing



Visual pursuit

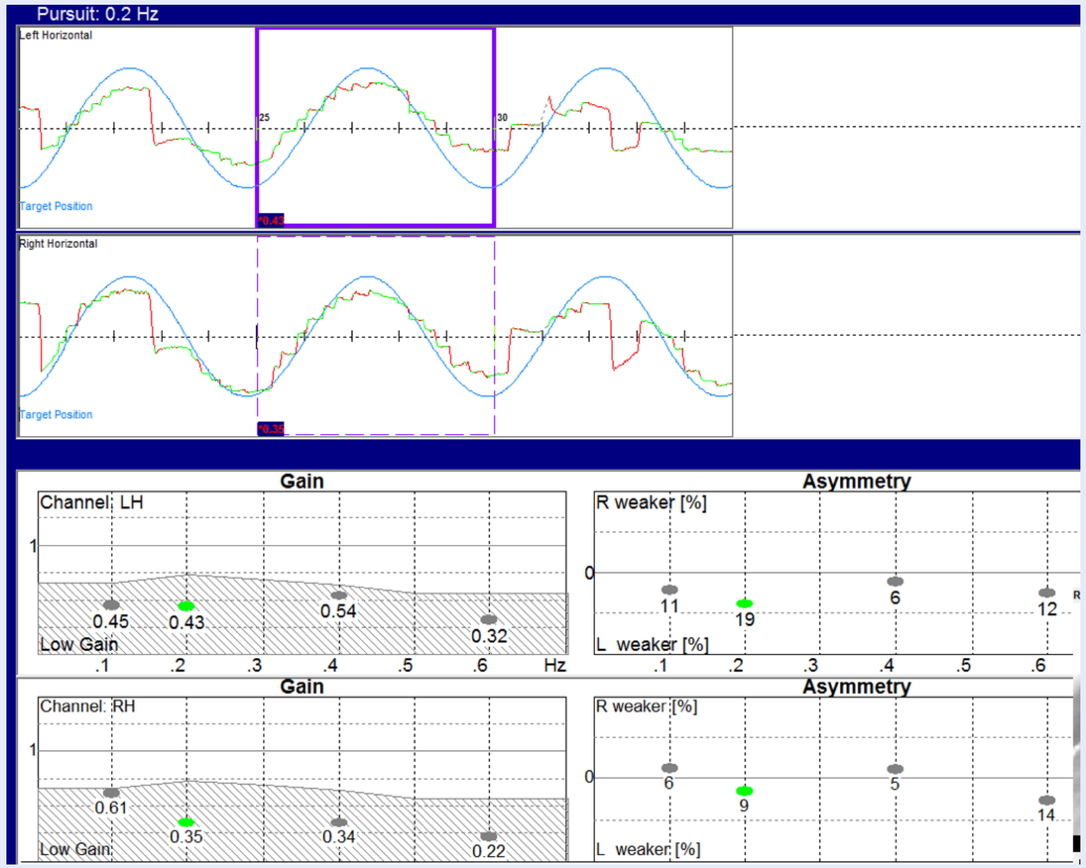
TEST

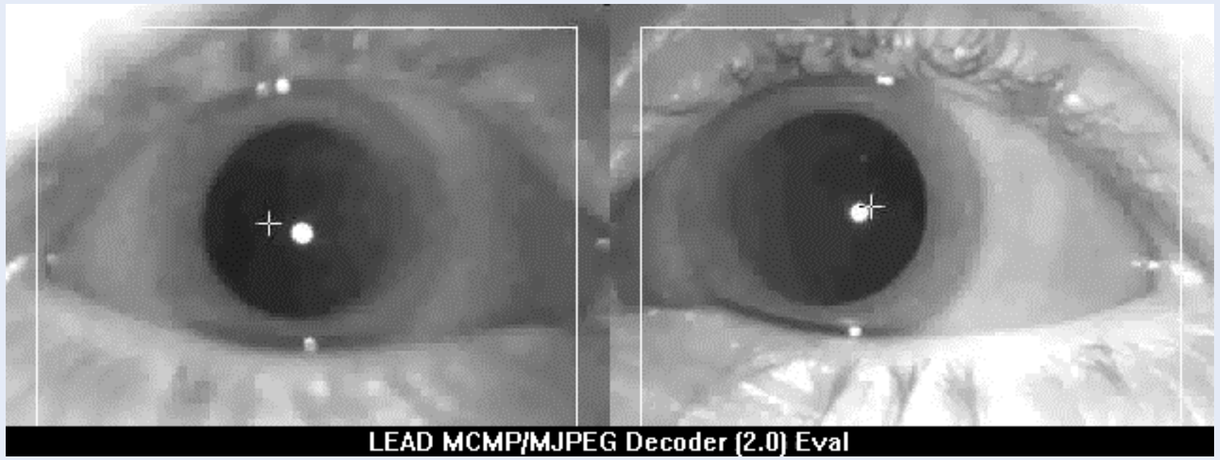
- tracking the target smoothly
- age sensitive norms
- gain, symmetry, (phase)

INTERPRETATION

- cerebellum (paraflocculus of the vestibulocerebellum)
- pontine nuclei of brainstem
- cortex

Visual pursuit





Optokinetic nystagmus

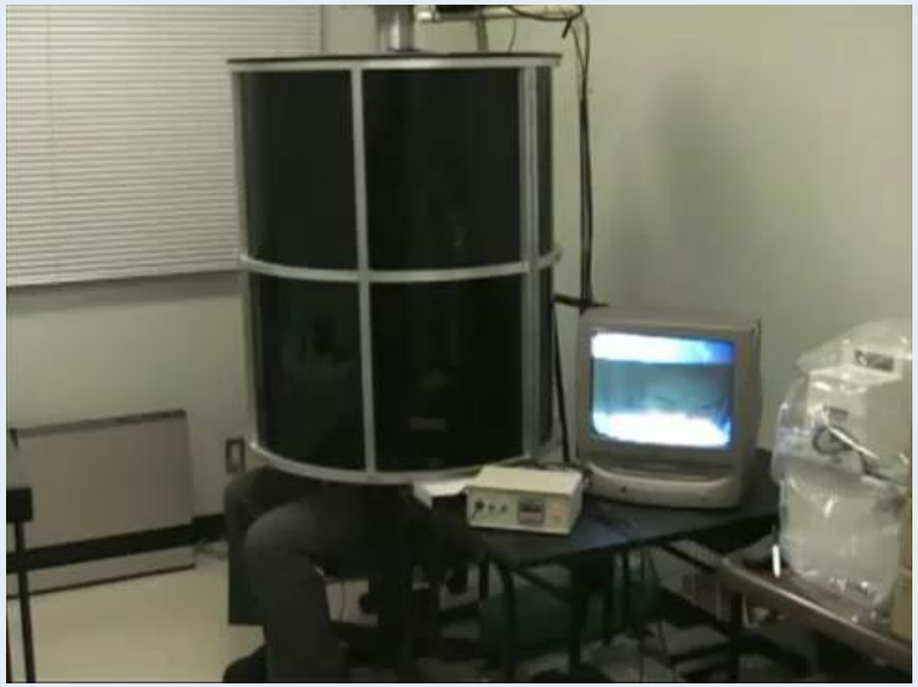
TEST

- nystagmus produced by moving objects
- 80 - 90% visual field - light bar?
- gain, symmetry
- influenced by peripheral lesions

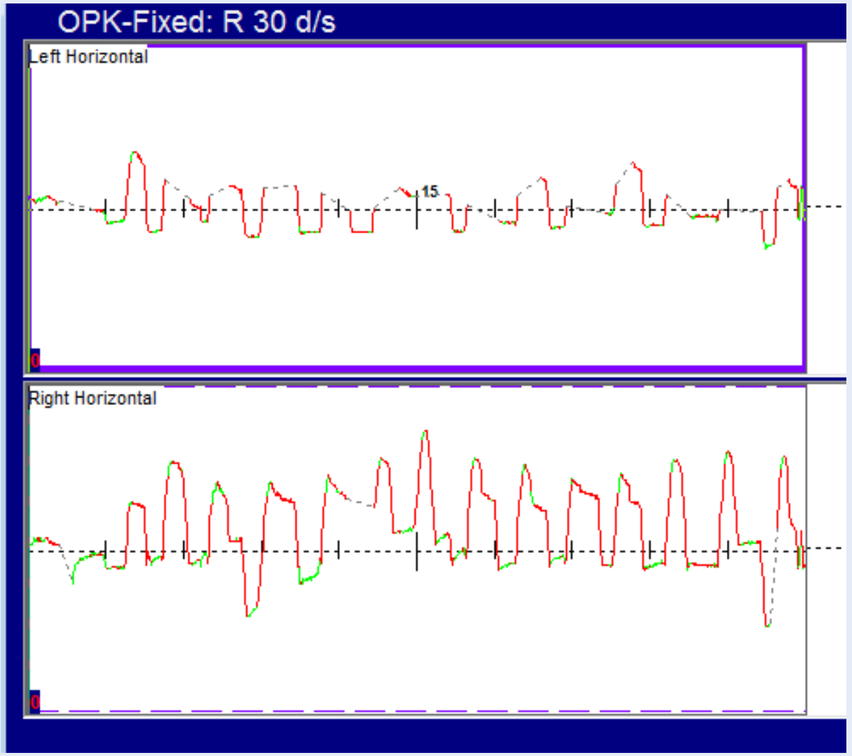
INTERPRETATION

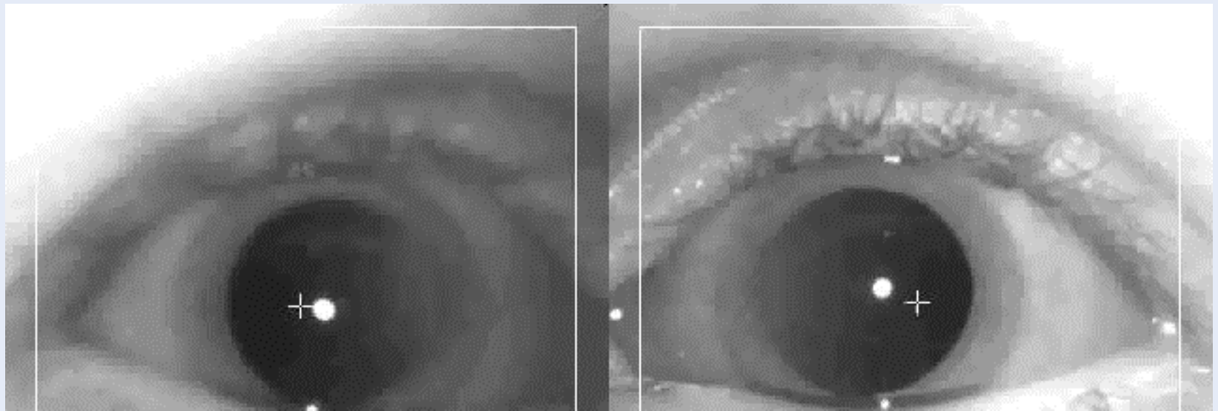
- cerebellum/brainstem areas
- unlikely abnormal (central) when saccades + pursuit are normal
- use OKAN: ny without fixation after OPK stim for 30 sec = velocity storage system - vestibular nuclei

Optokinetic nystagmus



Optokinetic nystagmus





It is time to practice!

Positional and Positioning testing

Positional/positioning testing

- Positioning tests: active transition from one position into another
- Positional tests: head remains static
- Nystagmus
  - Presence
  - **Direction**
  - Duration
  - Latency (onset)
  - Slow phase velocity
  - Fatigability
- Associated symptoms – vertigo, dizziness, nausea

Positional testing

- Positional Body Test
- slow-phase velocity > 5°/s
- spv < 6 °/s persistent in 4 or more positions
- spv < 6 °/s sporadic in all positions
- direction changing within a given head position (indicates central involvement)
- *** Vertical nystagmus

Positioning testing - BPPV

- Dix-Hallpike maneuver
  - Fully supported
  - Side lying maneuver

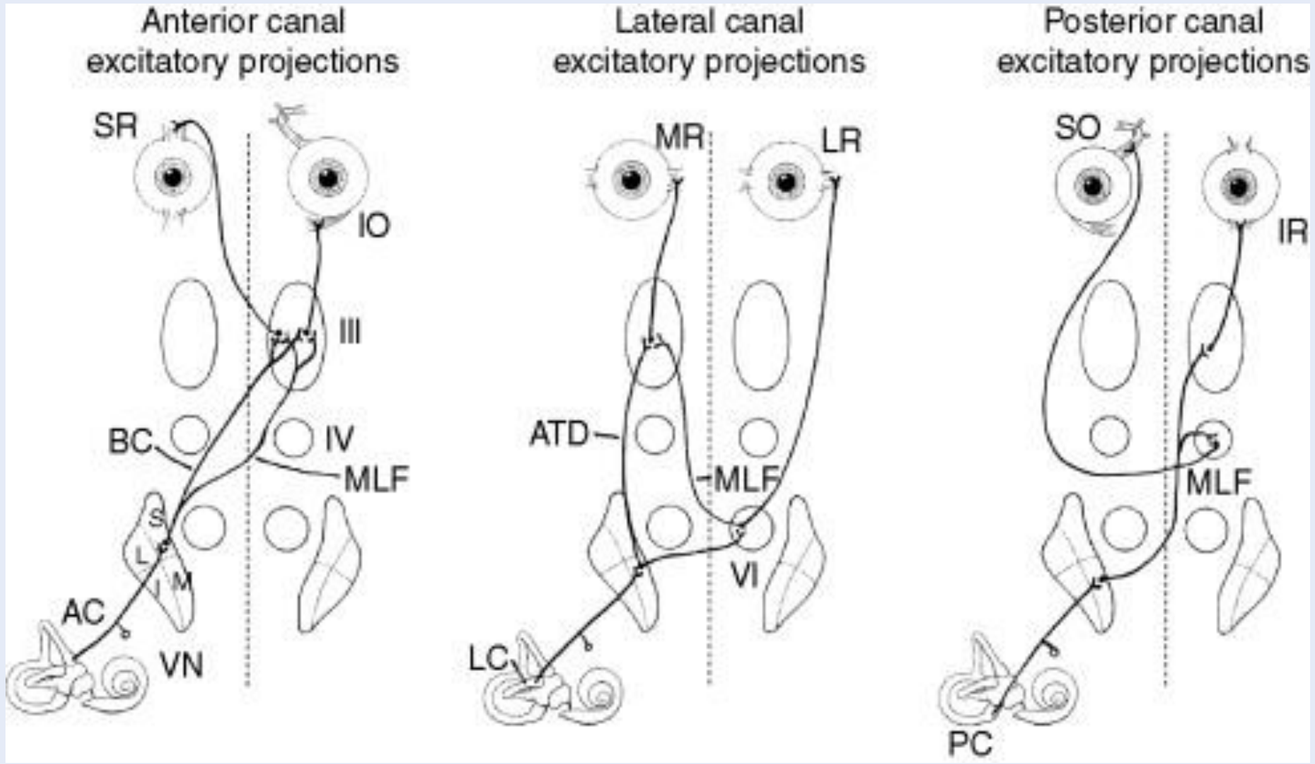
	Posterior canal	**Anterior canal**
RIGHT	Right torsional up	Left torsional down
LEFT	Left torsional up	Right torsional down

Positioning testing - BPPV

- Supine head roll

	RIGHT	LEFT
canalithiasis (transient delayed onset)	Geotropic, Stronger on right ear down	Geotropic, Stronger on left ear down
cupulolithiasis (persistent immediate onset)	Ageotropic, Stronger on left ear down	Ageotropic, Stronger on right ear down

How does it work?



What is BPPV?

- Benign Paroxysmal Positional Vertigo
- Most common cause of vertigo of vestibular origin
- Calcium carbonate crystals (otoconia) dislodge from otoliths into one or more semicircular canals
- Free floating = canalithiasis
- Adhered to the cupula = cupulolithiasis
- Vast majority posterior canal
- About 15% lateral canal
- Very low occurrence anterior canal

} choice of canalith repositioning maneuver

Peripheral or central?

Lee SH and Kim JS

Table 2. Clinical and differential features of benign paroxysmal positional vertigo (BPPV) versus central paroxysmal positional vertigo (CPPV)

	BPPV	CPPV
Latency	Usual (shorter in HC-BPPV)	Unusual
Duration of attack	Usually less than 60 seconds (longer in HC-BPPV)	Variable, usually longer than BPPV
Direction of nystagmus	Torsional/vertical (PC/AC-BPPV) and horizontal (HC-BPPV); compatible with the stimulated canal plane	Pure vertical (usually downbeat) or pure torsional; not attributable to the stimulated canal plane; possibly mimics BPPV pattern*
Fatigability	Usual (possibly rare in HC-BPPV)	Unusual
Nausea and vomiting	Rare on single precipitating maneuver; not uncommon after several maneuvers; usually associated with intense nystagmus	Frequent even on single precipitating maneuver; not necessarily associated with intense nystagmus
Mechanism	Debris moving in semicircular canal	Damage to central otolith–ocular pathways
Natural course	Spontaneous recovery within several weeks in 70-80%	Spontaneous recovery within weeks possible
Associated neurological signs and symptoms	None	Often cerebellar and other oculomotor signs; possibly none
Brain imaging	Normal	Cerebellar lesions (common in dorsal vermis, nodulus, dorsolateral to the fourth ventricle); cerebellar atrophy; craniocervical anomaly; possibly normal (VBI)

*Apogeotropic nystagmus is common. Other BPPV patterns are also possible.
AC: anterior canal, PC: posterior canal, VBI: vertebrobasilar insufficiency.

Canalith repositioning maneuvers

- Posterior canal
  - Epley maneuver
  - Semont
  - Gans
  - Half somersault (Foster)
- Lateral canal
  - Barbeque roll
  - Gufoni
- Anterior canal
  - Deep Head Hanging – Yacovino

It is time to practice!

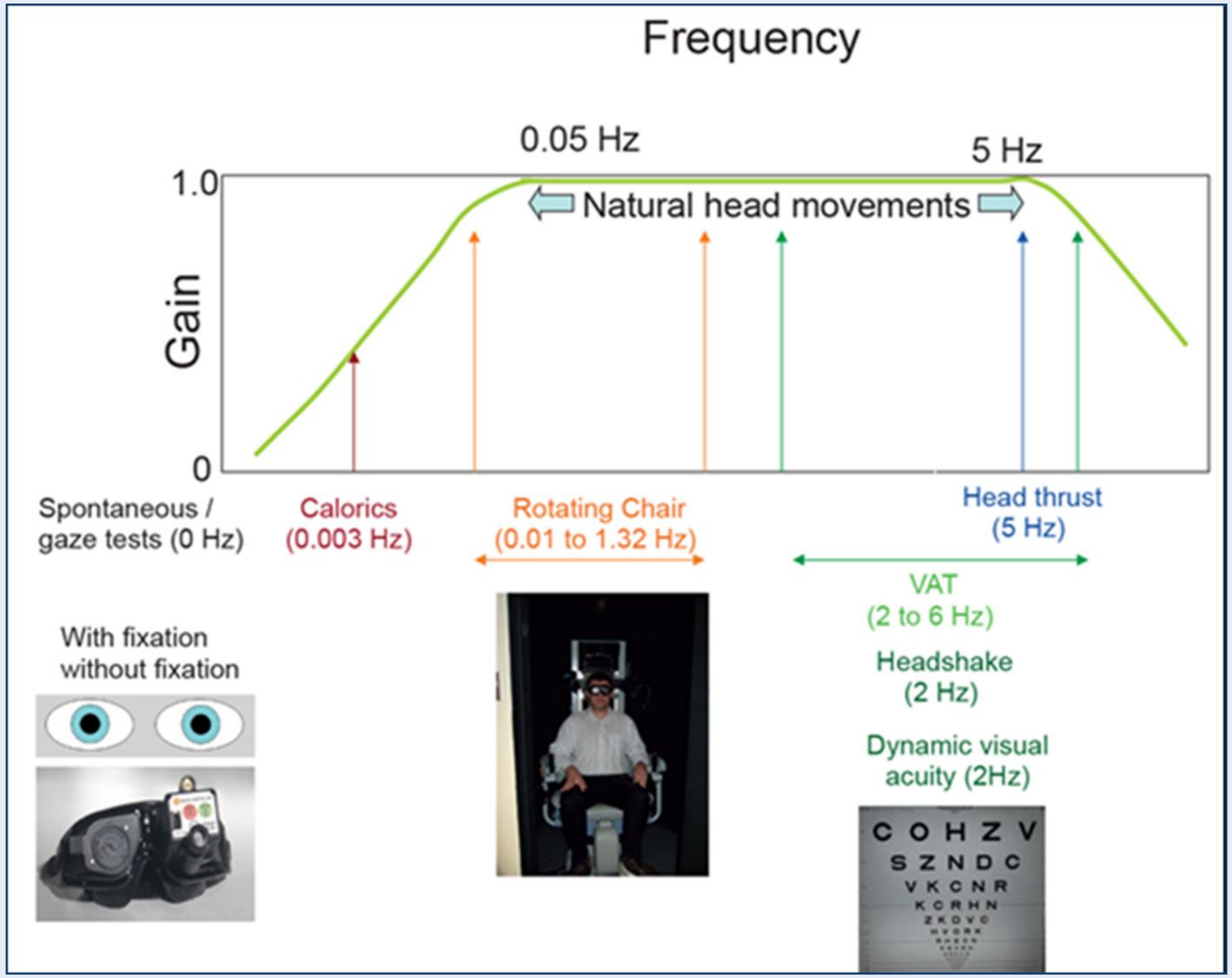
Caloric Testing

Caloric testing

- temperature gradient ear canal transferred to horizontal semicircular canal
- supine/semi-reclined patient
- warm = excitatory
- cool = inhibitory
- COWS

- influenced by ear canal + TM + middle ear
- comparison within patient R/L
- only horizontal canal
- low frequency (0.003 Hz)
- Aphysiological: head movements 0.1 to 3 Hz
- NOT comfortable - patient’s age

Caloric testing

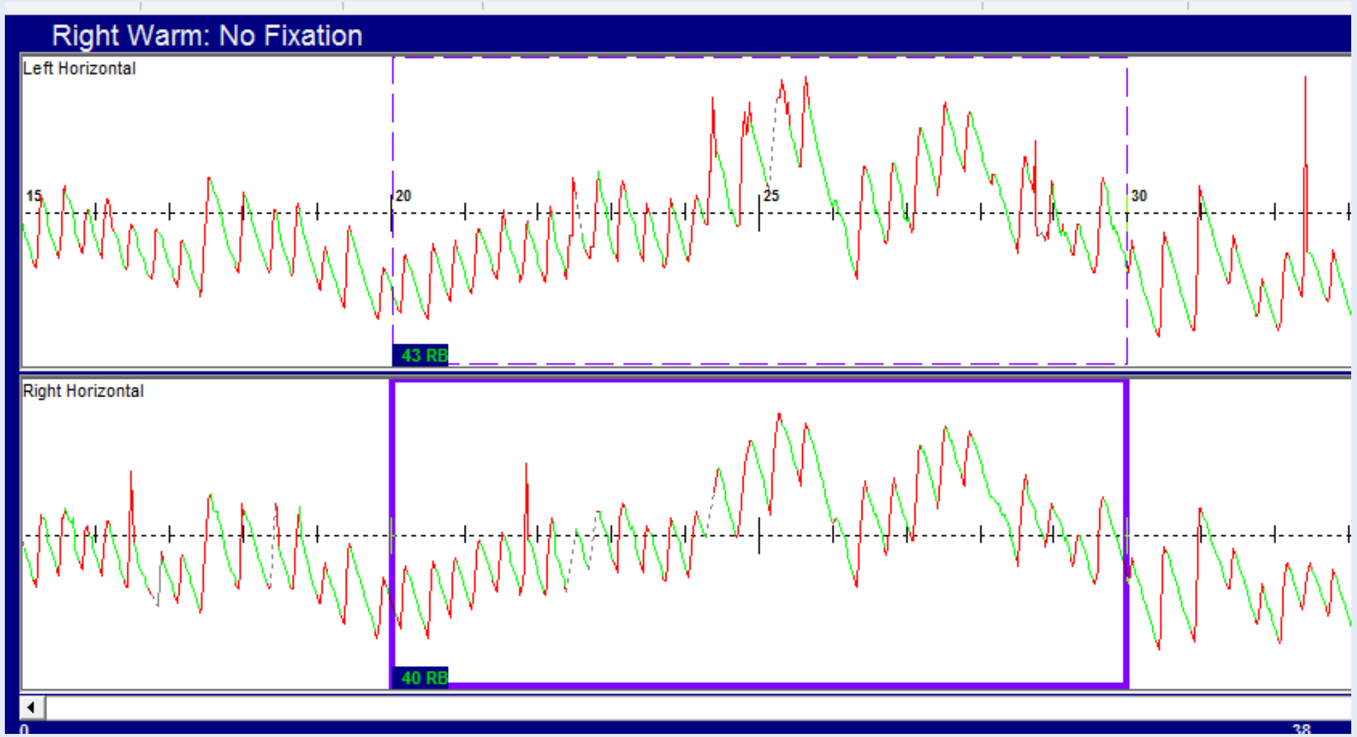


Caloric testing

- water X air
- air 50°C / 24°C - 60 sec
- open X closed loop (disuse)
- water + open loop
- 44°C / 30°C - 250 ml - 30 sec

- pre-caloric ny/spontaneous ny without fixation
- mental tasking
- observe peak slow phase velocity (+/- 30 sec)
- observe decline responses
- fixation = cerebellar flocculus + “will”
- 3 - 5 minutes interval

Caloric testing



Caloric testing

- irrigation order - warm (either ear - suspected?)
- cool - needed?
- Ice cold: not needed if you have vHIT
- monothermal warm VNG:
  - warm monothermal asymmetry below 15%
  - warm slow phase velocities > 8°/sec bilaterally

Lightfoot, G., Baker, F., Belcher, K., Kennedy, V., Nassar, G. and Tweedy, F. (2009) The derivation of optimum criteria for use in the monothermal caloric screening test. *Ear and Hearing*, Vol 30, No 1, Pages 54 - 62.

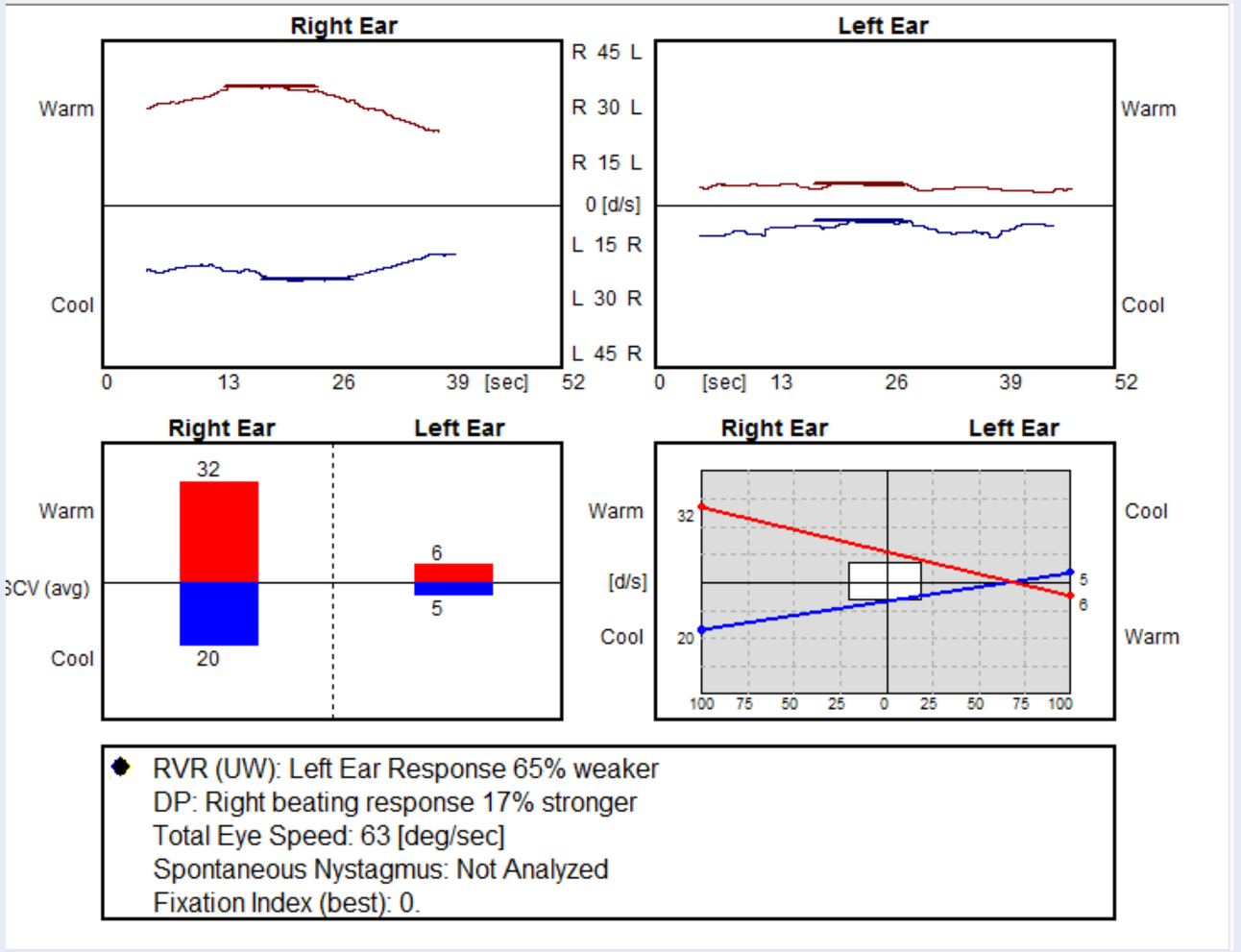
Caloric testing

- Symmetry - UNILATERAL WEAKNESS
- monothermal: $\frac{\text{higher - lower}}{\text{higher + lower}}$
- bithermal: Jongkees

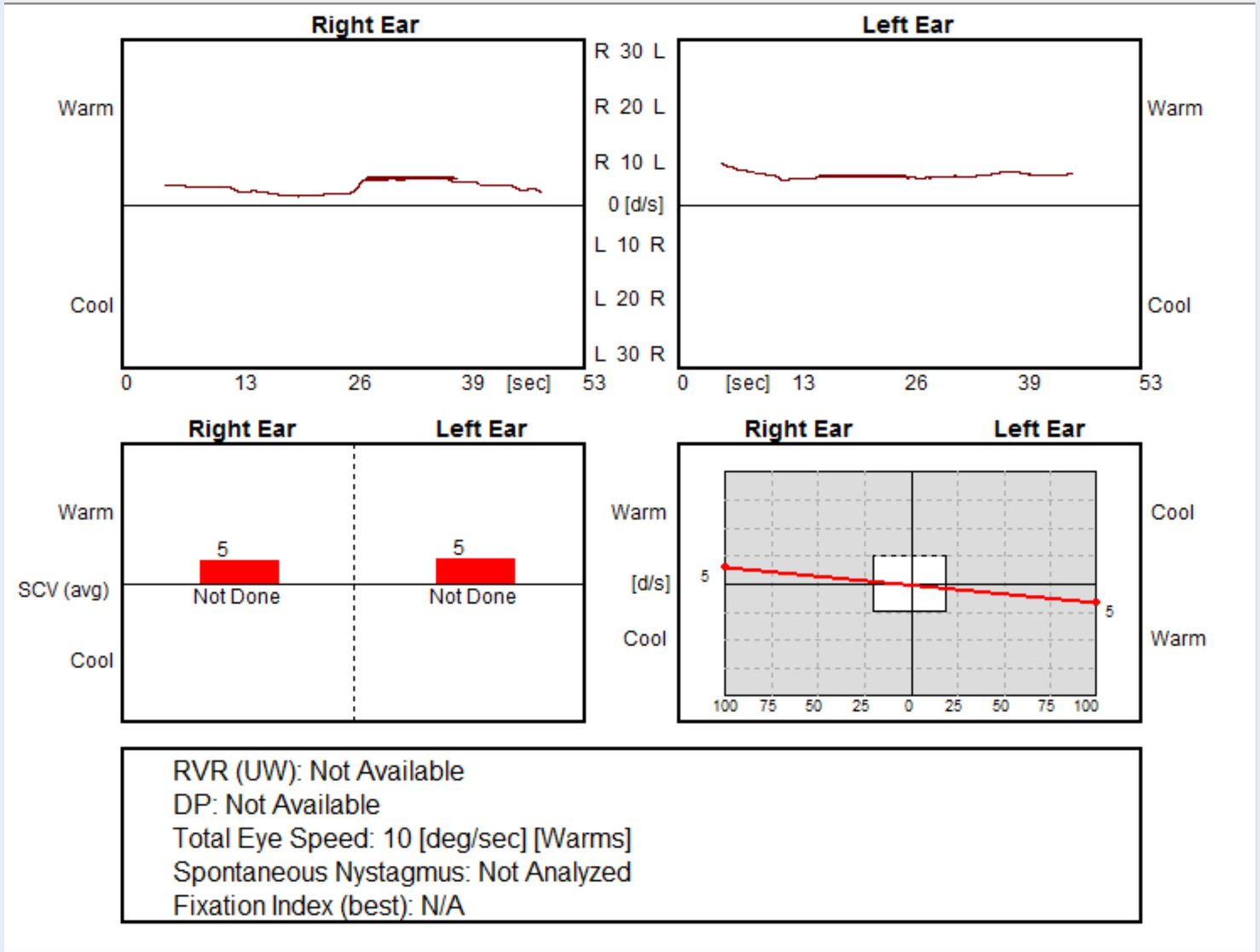
$$\frac{(WR + CR) - (WL + CL)}{WR + CR + WL + CL} \times 100\%$$

- normal limit = 20 - 23% - conservative

Caloric testing



Caloric testing



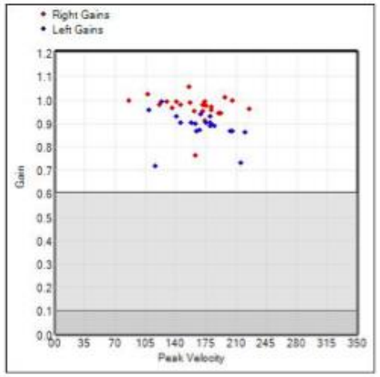
RVR (UW): Not Available
DP: Not Available
Total Eye Speed: 10 [deg/sec] [Warms]
Spontaneous Nystagmus: Not Analyzed
Fixation Index (best): N/A

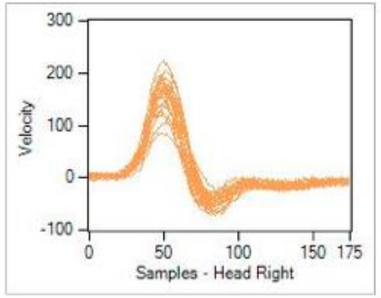
Caloric testing

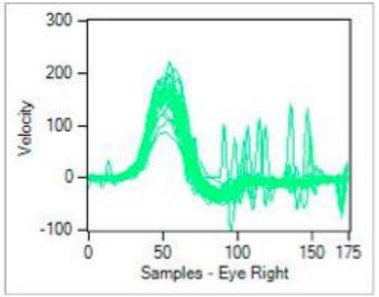
- bilateral caloric hypofunction does not mean bilateral complete vestibular loss
- other tests (rotary chair; vHIT)
- consistent symptoms - oscillopsia

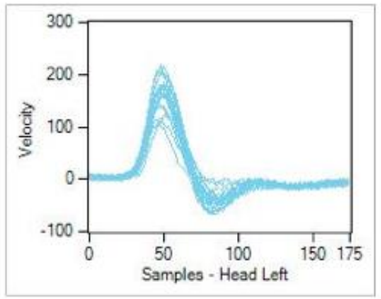
vHIT

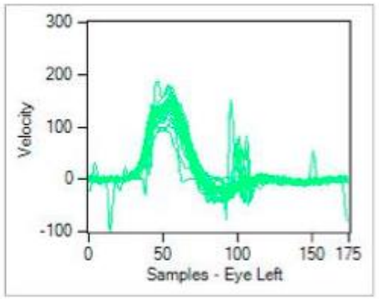
Impulse Test:	31/08/2012 9:39 AM
Test Operator:	Default Administrator
Right Gains:	Mean = 0.96
	σ = 0.03
Left Gains:	Mean = 0.87
	σ = 0.06







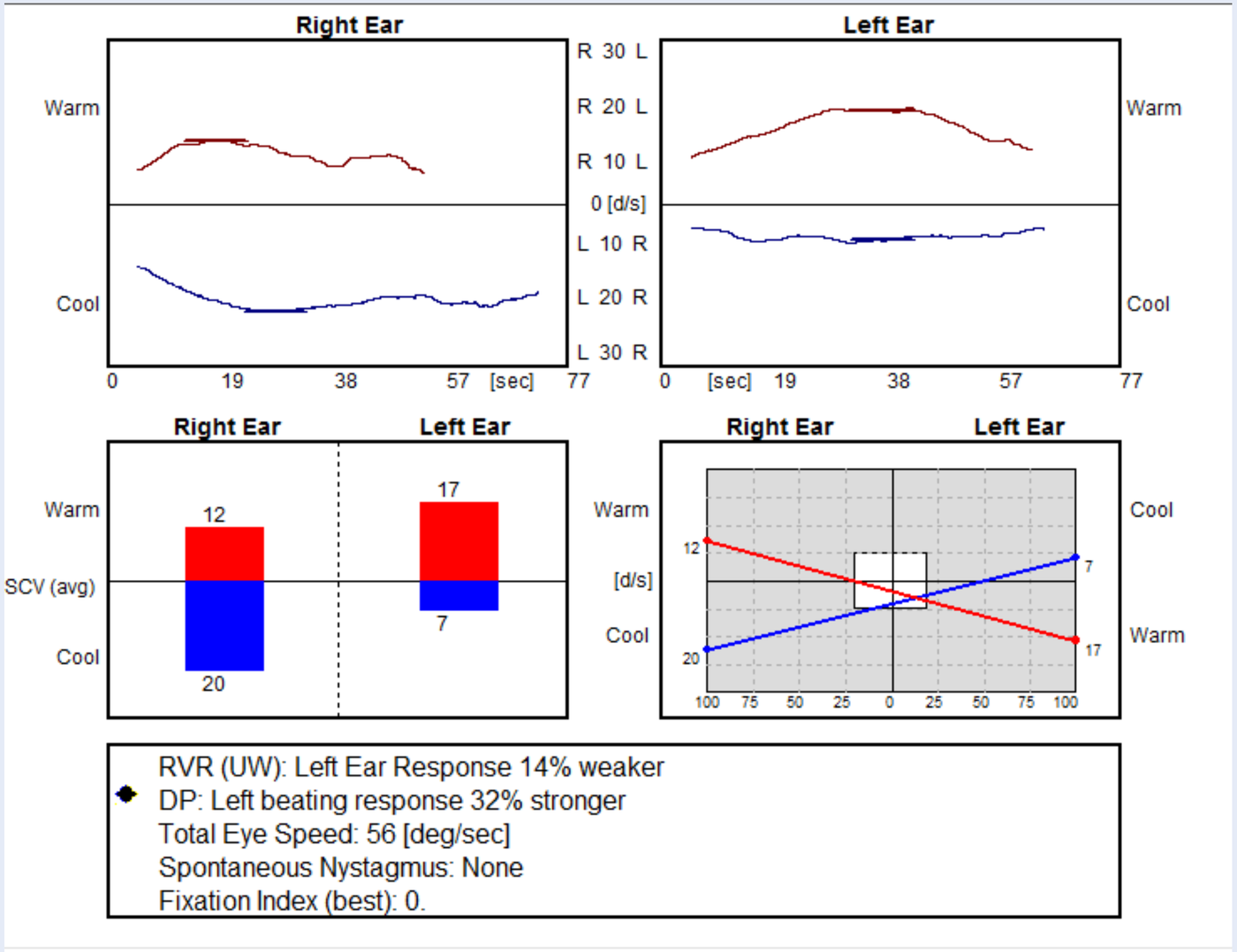




Caloric testing

- Symmetry: DIRECTIONAL PREPONDERANCE
- Jongkees $\frac{(WR + CL) - (WL + CR)}{WR + CR + WL + CL} \times 100\%$
- Halmagyi et al., 2000 - DP as a result of spontaneous ny versus isolated DP (30% in clinic)
- “while an isolated DP is rare (1%) it does exist”
- about half were peripheral; 5% central

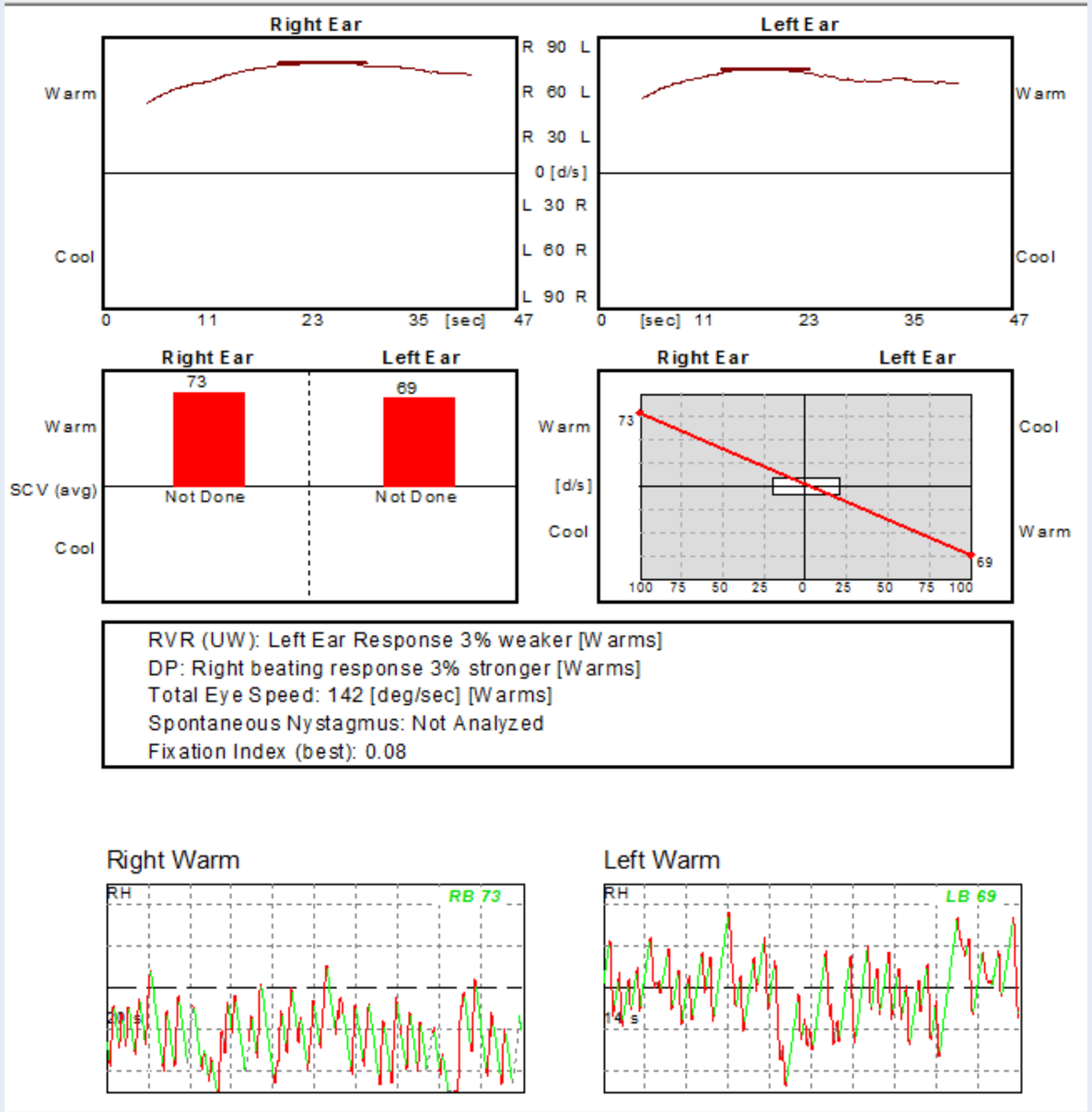
Caloric testing



Caloric testing

- hyperactive responses
  - 70 - 80°/sec each irrigation ***
  - loss of VOR inhibitory function - vestibular nuclei
  - peripheral? unilateral?

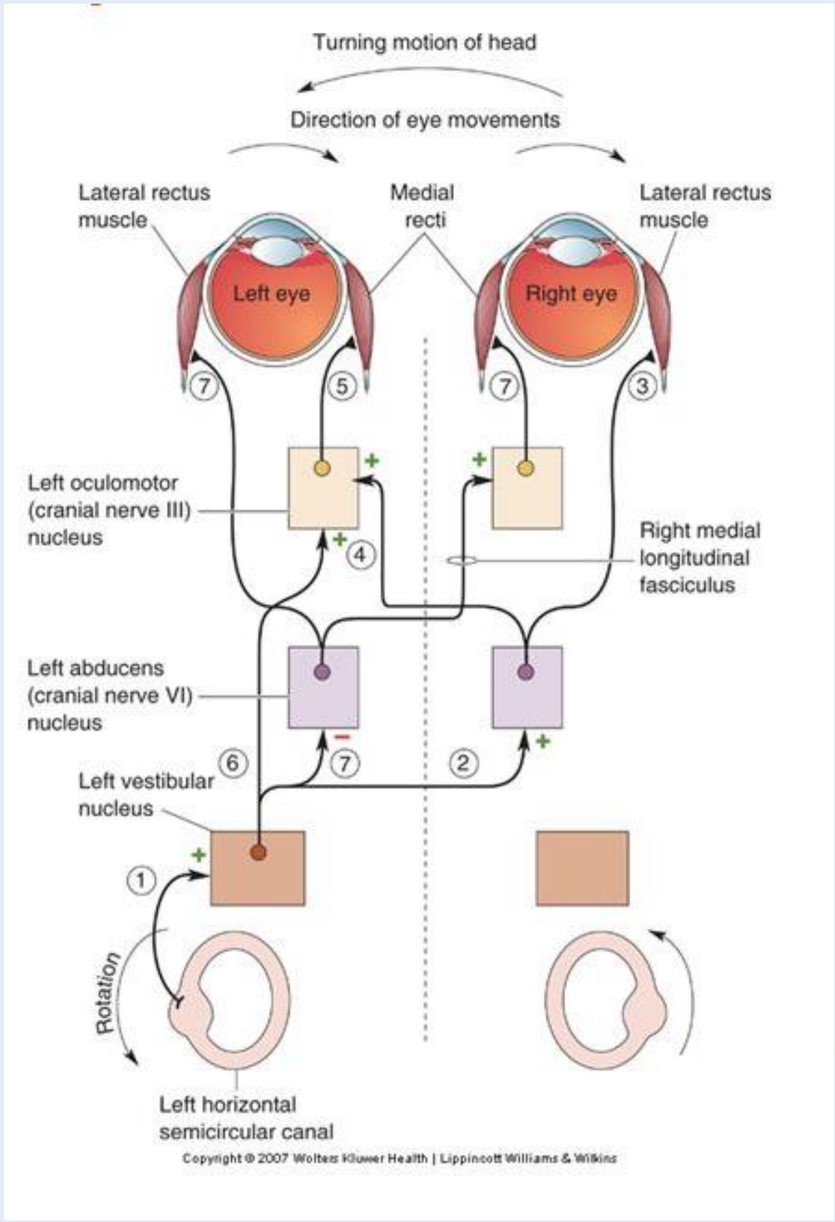
Caloric testing



Video Head Impulse Test (vHIT)

What is it?

- Objective measure of the vestibulo-ocular reflex (VOR)
- Maintain image stable with head is rotated
- Head rotation → equivalent eye movement in the opposite direction
- Abnormal input → abnormal eye movement = corrective saccade to achieve result



Head Impulse Test

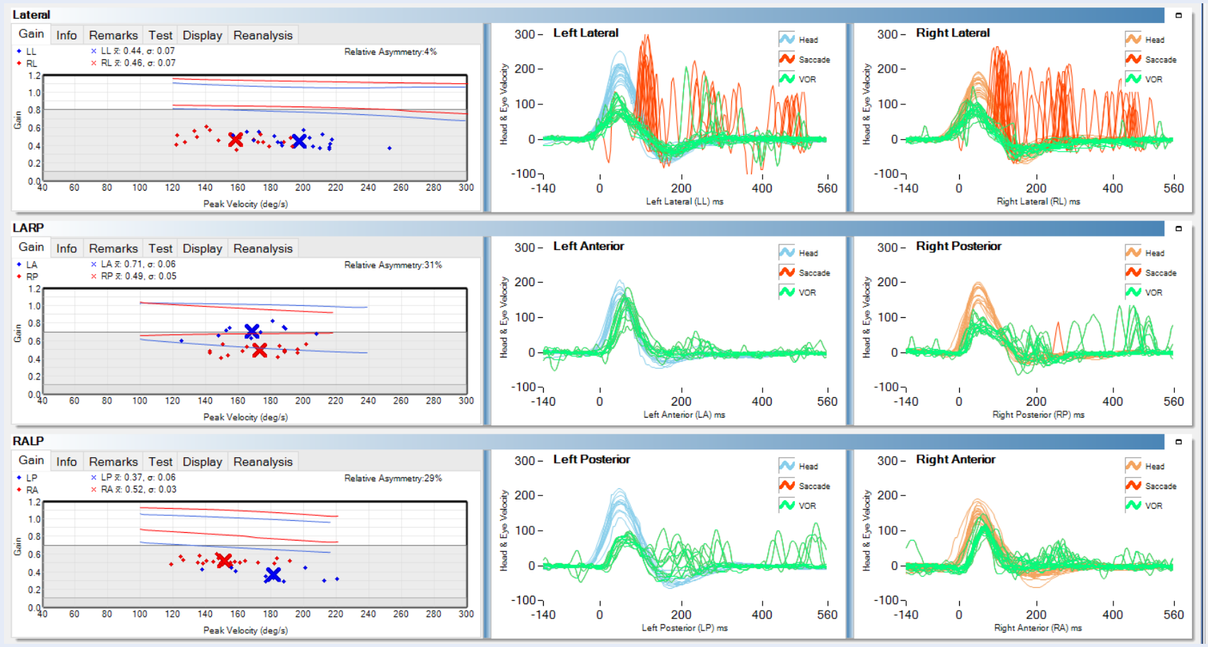
- First described by Halmagyi and Curthoys in 1987 – individual with bilateral Vestibular Schwannomas surgically removed
- Low acceleration head movements → smooth compensatory eye movements
- Fast small unpredictable head turns (15˚, 100˚/s) → could not generate eye movements = eye goes with head
- Visual system generates corrective saccades
- Covert or overt

Clinical to video Head Impulse

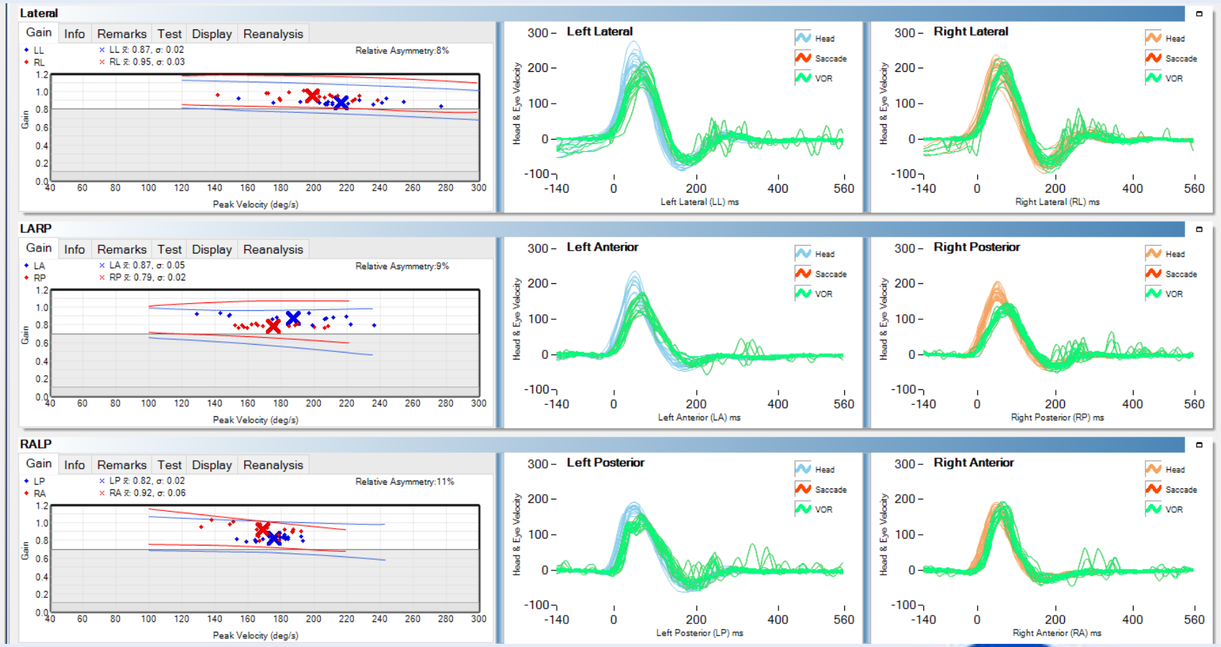
Bedside head impulse testing has moderate sensitivity and low positive predictive value even when performed by experienced clinicians

Yip CW, Glaser M, Frenzel C, Bayer O, Strupp M. Comparison of the Bedside Head-Impulse Test with the Video Head-Impulse Test in a Clinical Practice Setting: A Prospective Study of 500 Outpatients. Frontiers in Neurology. 2016;7:58.

Video Head Impulse Test

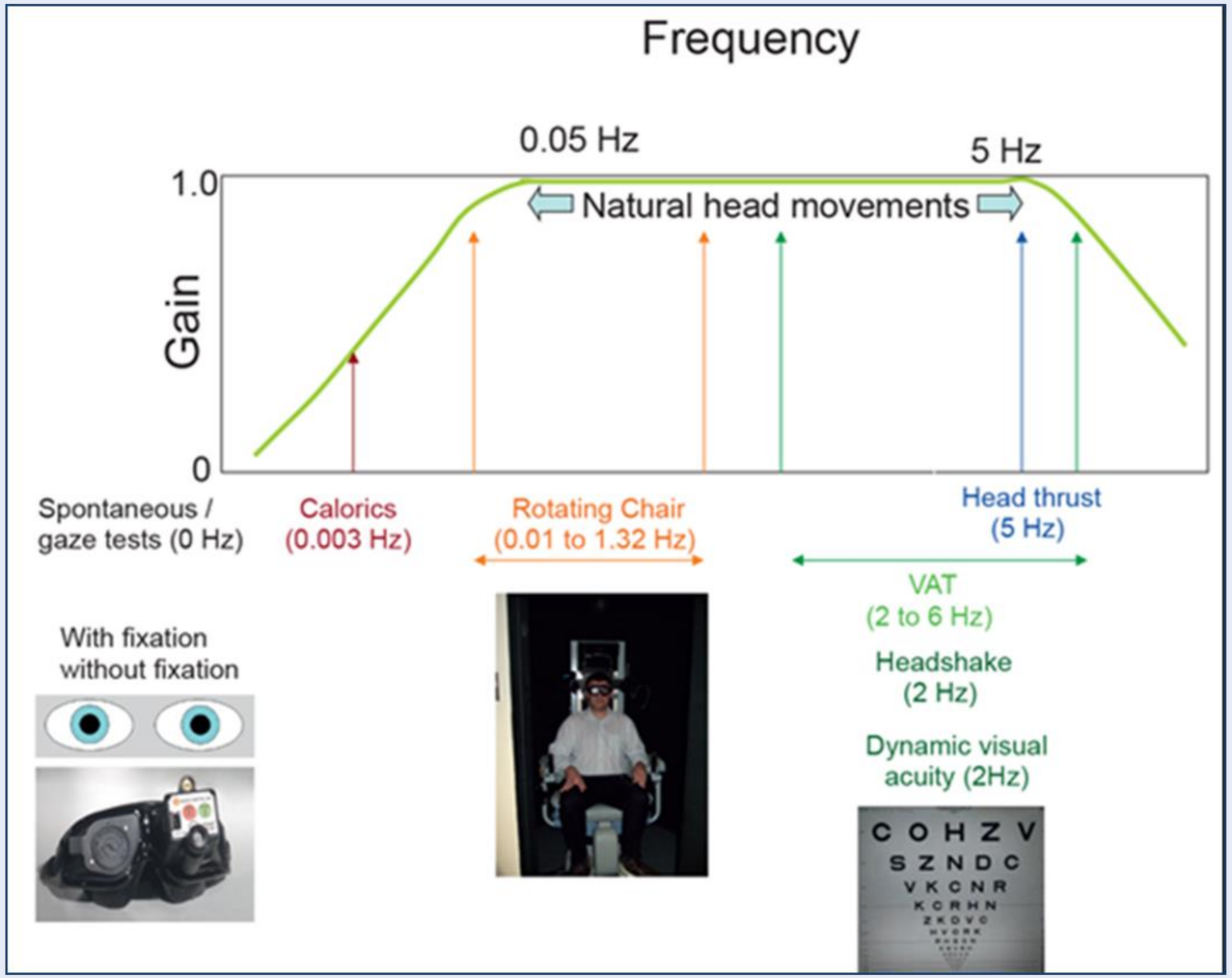


MD, bilateral SNHL



DF, PPPD

What does it assess?



Special attention to

- Tightly fitting strap
- Calibration – pupil tracking
- Instruction - gaze
- Head movement technique – hand placement, no overshoot,
- small amplitude, plane of stimulation, unpredictable, speed
  - Lateral: 120 - 300°/s
  - Verticals: 100 - 240 °/s
- Differences in equipment

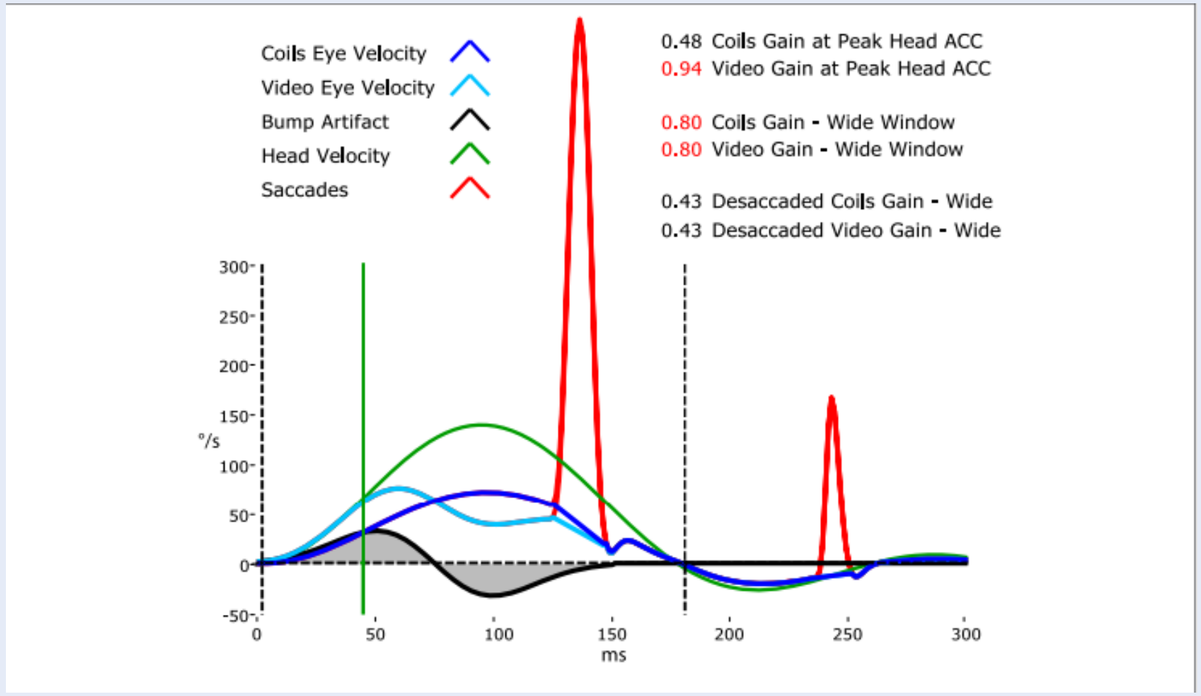
Contraindications

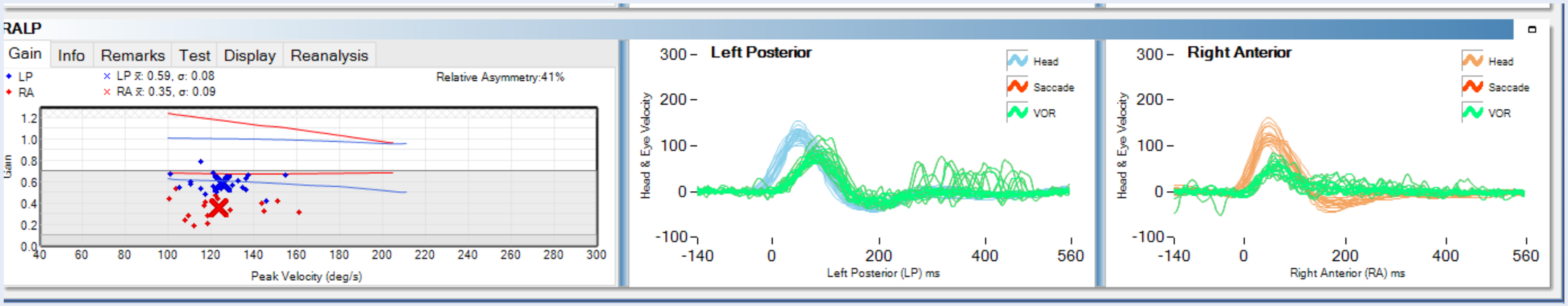
- Neck issues – trauma/fractures, immobility, pain
- Vision - Right eye (ICS Impulse)
- Cervical artery dissection

❖Following instructions

Interpretation

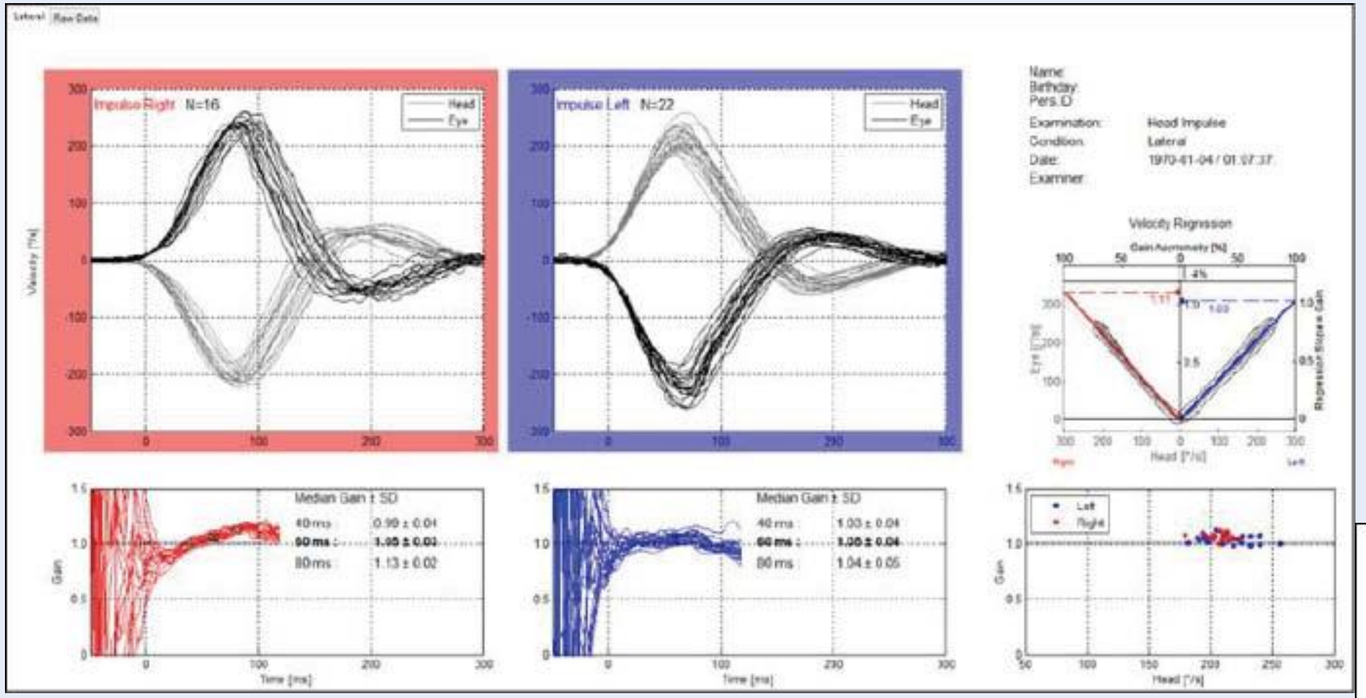
- Gain

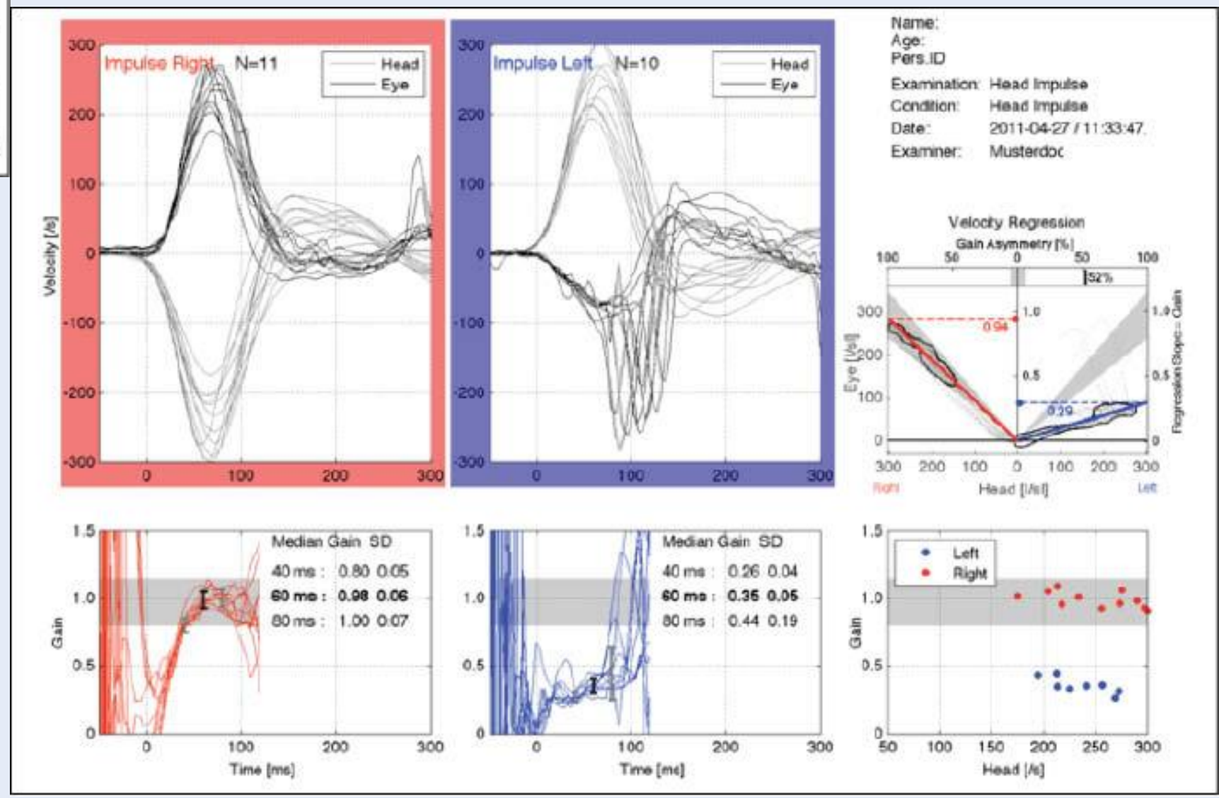




Interpretation

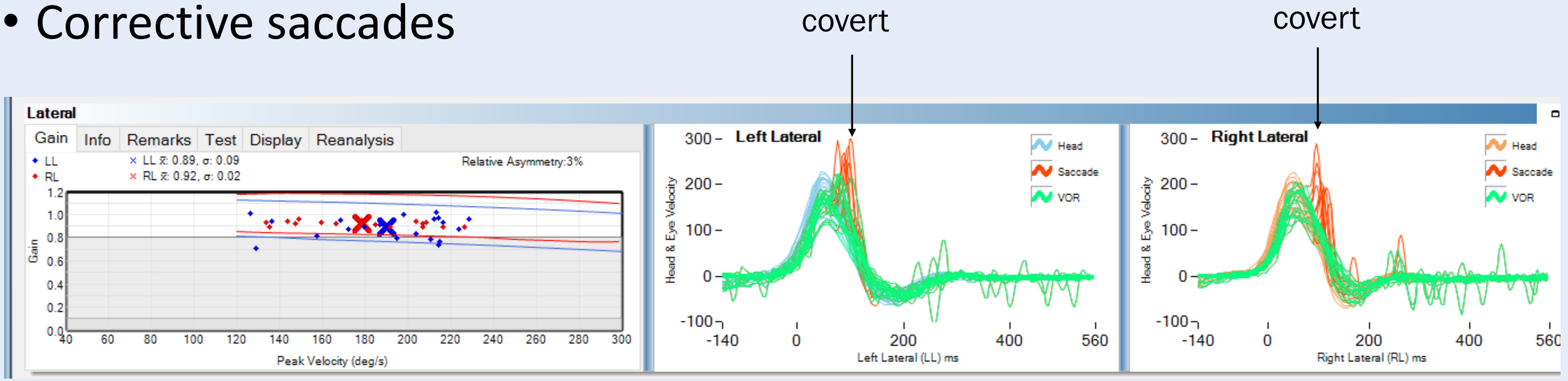
Gain

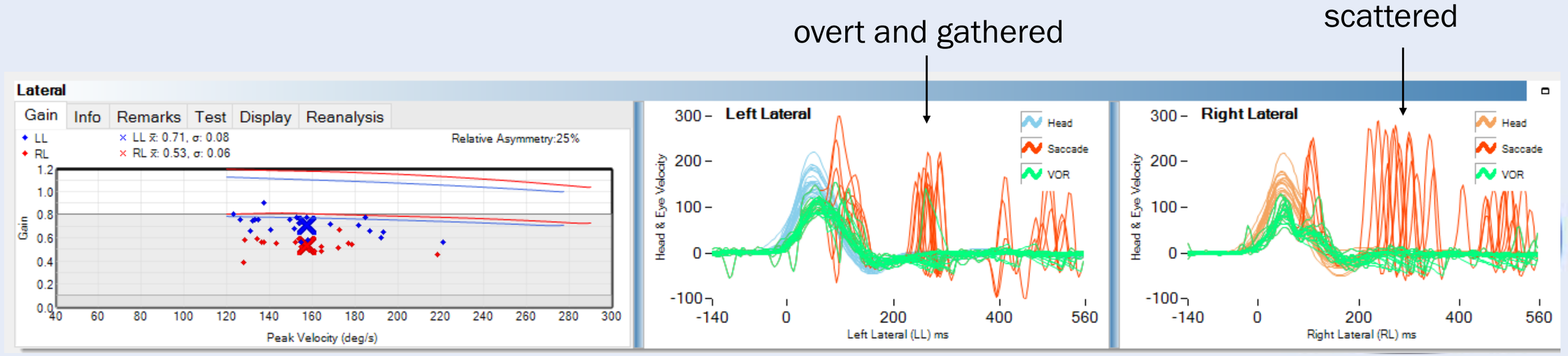




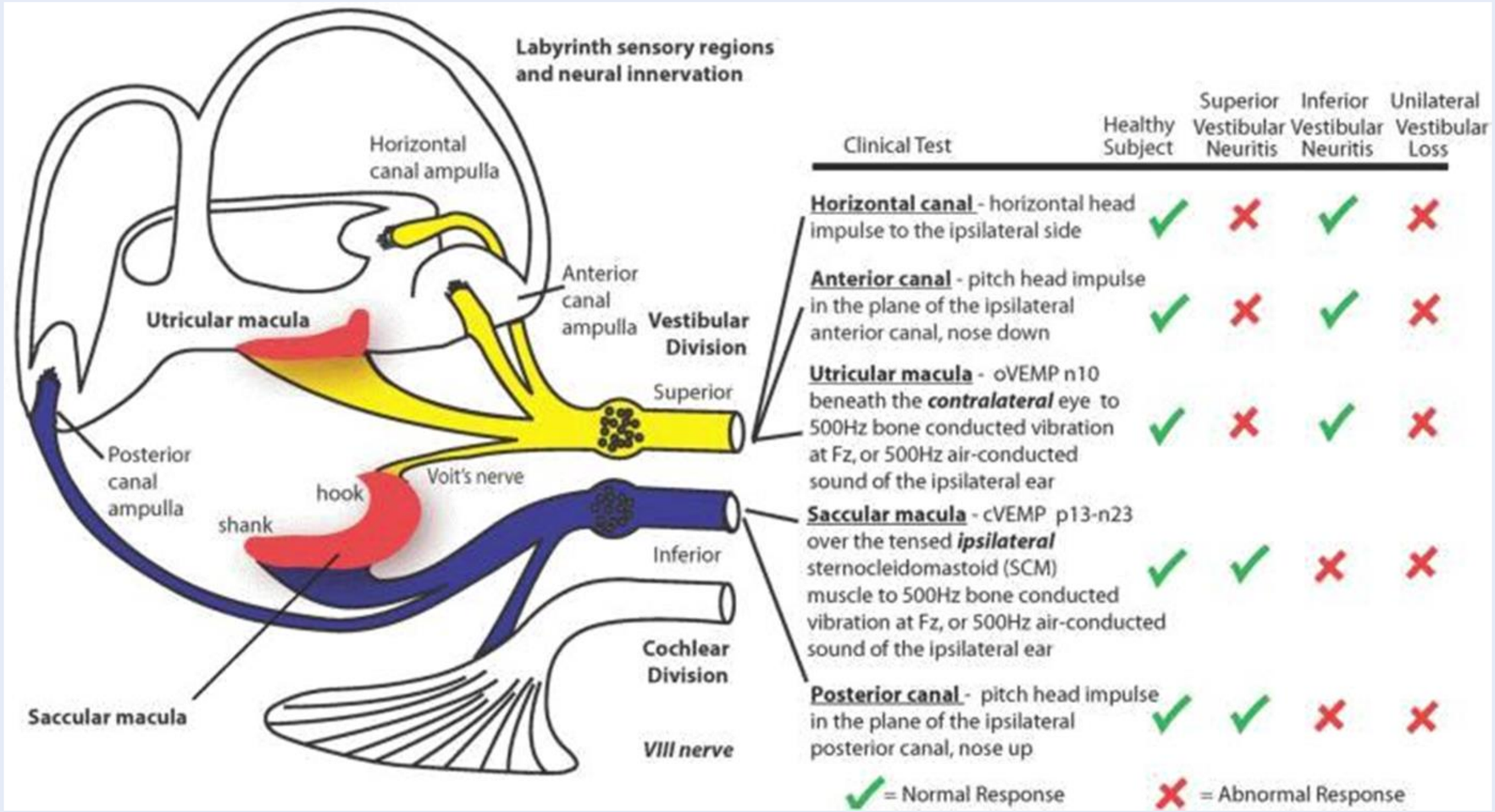
Interpretation

- Corrective saccades



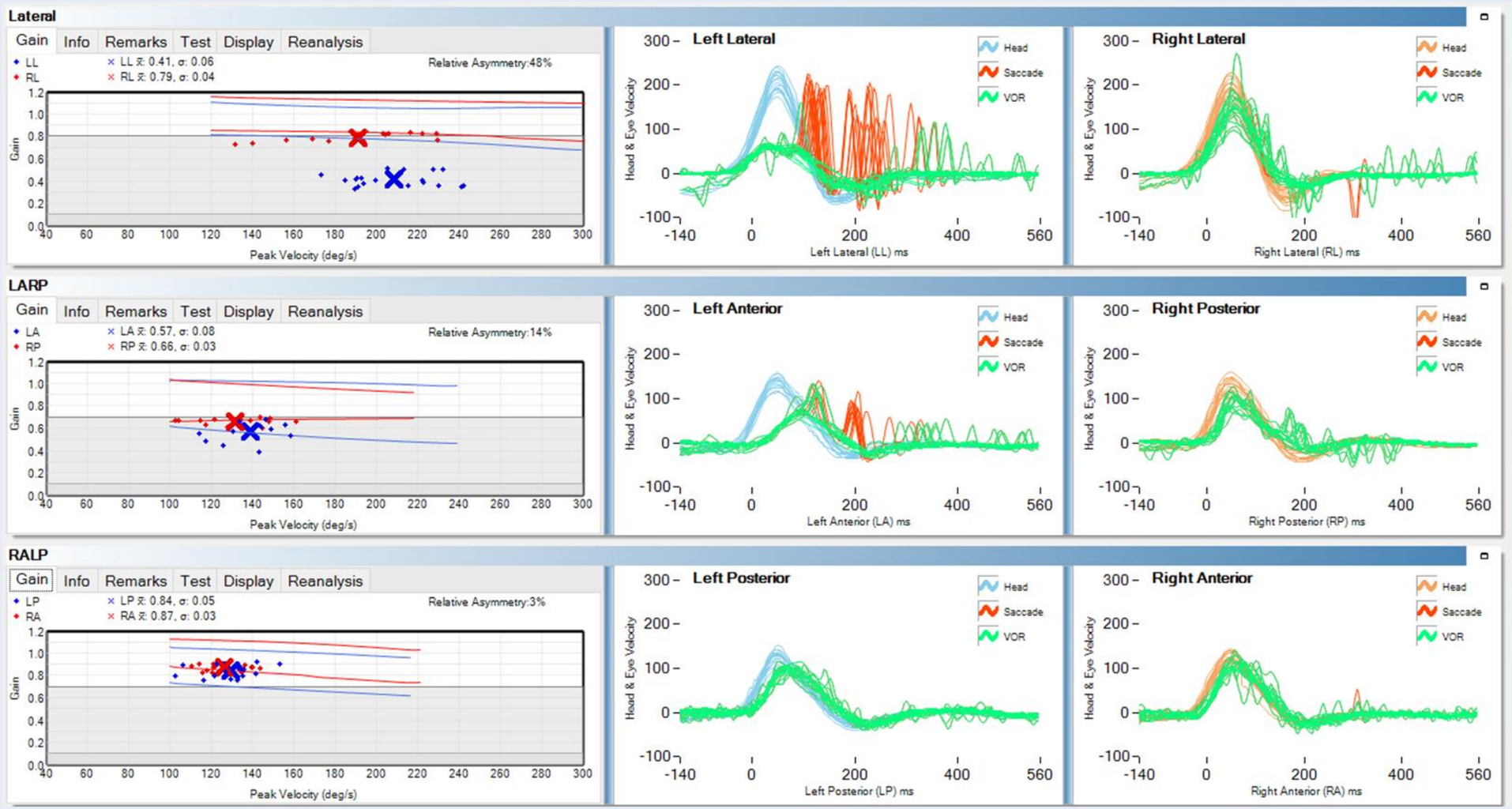


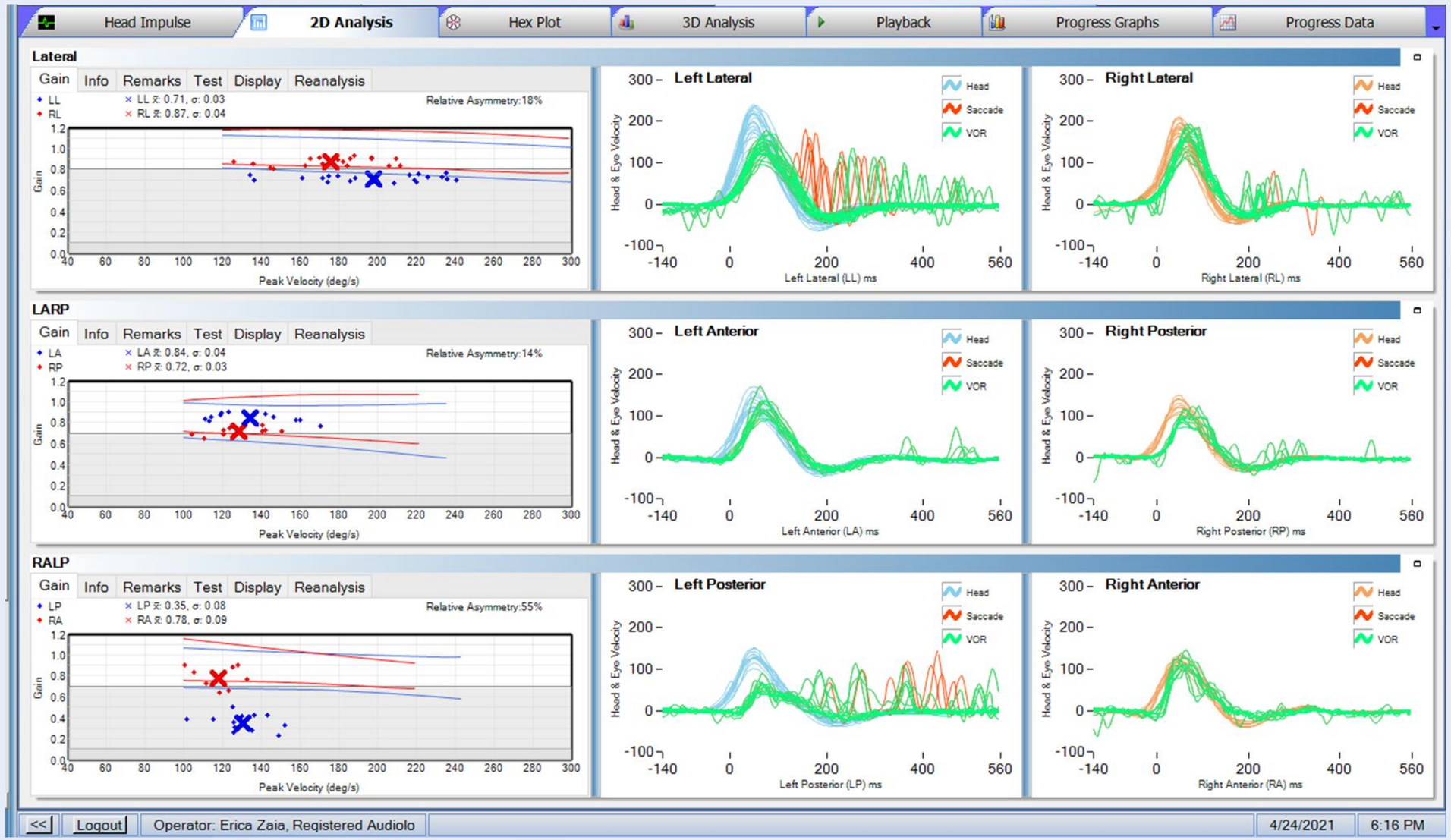
How does it help in the diagnostic puzzle?

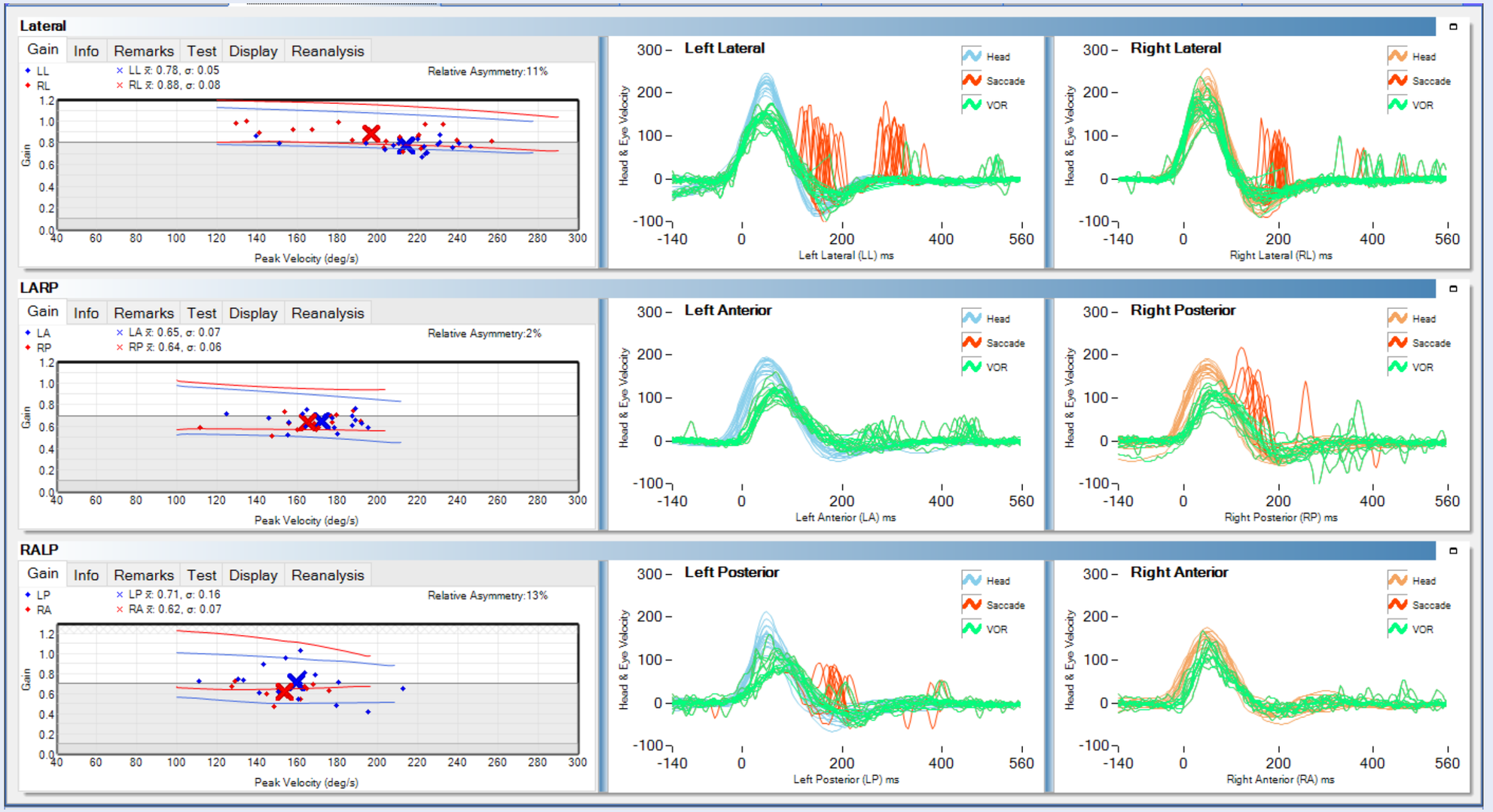


Clinical Test	Healthy Subject	Superior Vestibular Neuritis	Inferior Vestibular Neuritis	Unilateral Vestibular Loss
Horizontal canal - horizontal head impulse to the ipsilateral side	✓	✗	✓	✗
Anterior canal - pitch head impulse in the plane of the ipsilateral anterior canal, nose down	✓	✗	✓	✗
Utricular macula - oVEMP n10 beneath the ***contralateral*** eye to 500Hz bone conducted vibration at Fz, or 500Hz air-conducted sound of the ipsilateral ear	✓	✗	✓	✗
Saccular macula - cVEMP p13-n23 over the tensed ***ipsilateral*** sternocleidomastoid (SCM) muscle to 500Hz bone conducted vibration at Fz, or 500Hz air-conducted sound of the ipsilateral ear	✓	✓	✗	✗
Posterior canal - pitch head impulse in the plane of the ipsilateral posterior canal, nose up	✓	✓	✗	✗

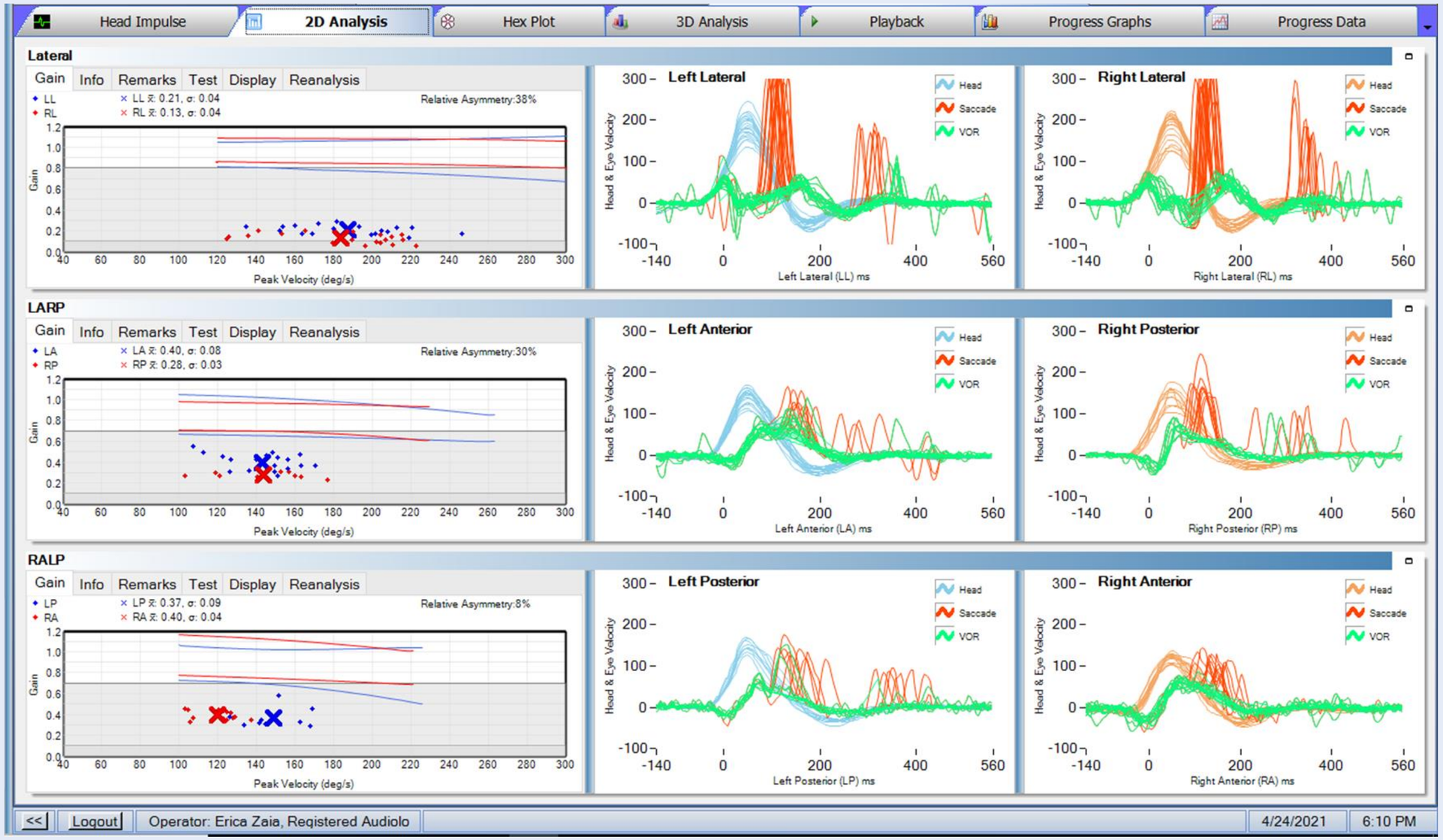
✓ = Normal Response ✗ = Abnormal Response


Lateral
Gain
Info
Remarks
Test
Display
Reanalysis
LL
RL
LL x̄: 0.41, σ: 0.06
RL x̄: 0.79, σ: 0.04
Relative Asymmetry:48%
Gain
Peak Velocity (deg/s)
Left Lateral
Right Lateral
Head
Saccade
VOR
Head & Eye Velocity
Left Lateral (LL) ms
Right Lateral (RL) ms
LARP
LA
RP
LA x̄: 0.57, σ: 0.08
RP x̄: 0.66, σ: 0.03
Relative Asymmetry:14%
Left Anterior
Right Posterior
Left Anterior (LA) ms
Right Posterior (RP) ms
RALP
LP
RA
LP x̄: 0.84, σ: 0.05
RA x̄: 0.87, σ: 0.03
Relative Asymmetry:3%
Left Posterior
Right Anterior
Left Posterior (LP) ms
Right Anterior (RA) ms


Head Impulse
2D Analysis
Hex Plot
3D Analysis
Playback
Progress Graphs
Progress Data
Lateral
Gain
Info
Remarks
Test
Display
Reanalysis
LL
RL
LL x̄: 0.71, σ: 0.03
RL x̄: 0.87, σ: 0.04
Relative Asymmetry:18%
Gain
Peak Velocity (deg/s)
Left Lateral
Right Lateral
Head
Saccade
VOR
Head & Eye Velocity
Left Lateral (LL) ms
Right Lateral (RL) ms
LARP
LA
RP
LA x̄: 0.84, σ: 0.04
RP x̄: 0.72, σ: 0.03
Relative Asymmetry:14%
Left Anterior
Right Posterior
Left Anterior (LA) ms
Right Posterior (RP) ms
RALP
LP
RA
LP x̄: 0.35, σ: 0.08
RA x̄: 0.78, σ: 0.09
Relative Asymmetry:55%
Left Posterior
Right Anterior
Left Posterior (LP) ms
Right Anterior (RA) ms
<<
Logout
Operator: Erica Zaia, Registered Audiolo
4/24/2021
6:16 PM



Chen L, Halmagyi GM. Central Lesions With Selective Semicircular Canal Involvement Mimicking Bilateral Vestibulopathy. Front Neurol. 2018 Apr 24;9:264.)


Head Impulse
2D Analysis
Hex Plot
3D Analysis
Playback
Progress Graphs
Progress Data
Lateral
Gain
Info
Remarks
Test
Display
Reanalysis
LL
RL
LL x̄: 0.21, σ: 0.04
RL x̄: 0.13, σ: 0.04
Relative Asymmetry:38%
Gain
Peak Velocity (deg/s)
Left Lateral
Right Lateral
Head
Saccade
VOR
Head & Eye Velocity
Left Lateral (LL) ms
Right Lateral (RL) ms
LARP
LA
RP
LA x̄: 0.40, σ: 0.08
RP x̄: 0.28, σ: 0.03
Relative Asymmetry:30%
Left Anterior
Right Posterior
Left Anterior (LA) ms
Right Posterior (RP) ms
RALP
LP
RA
LP x̄: 0.37, σ: 0.09
RA x̄: 0.40, σ: 0.04
Relative Asymmetry:8%
Left Posterior
Right Anterior
Left Posterior (LP) ms
Right Anterior (RA) ms
<<
Logout
Operator: Erica Zaia, Registered Audiolo
4/24/2021
6:10 PM

It is time to practice!

erica@vestibular.ca