The Video Head Impulse Test: Administering and Interpreting the Test

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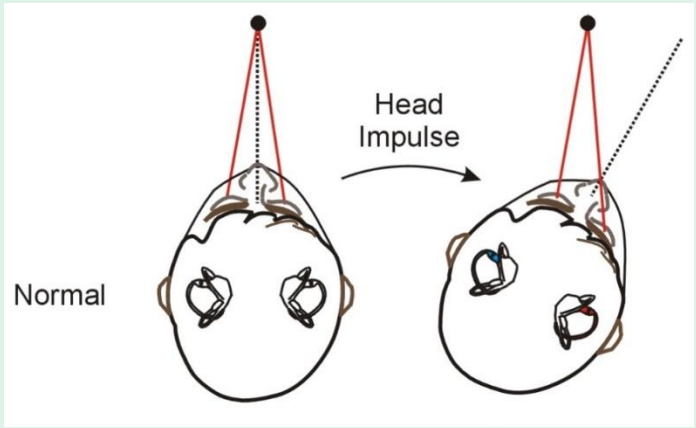
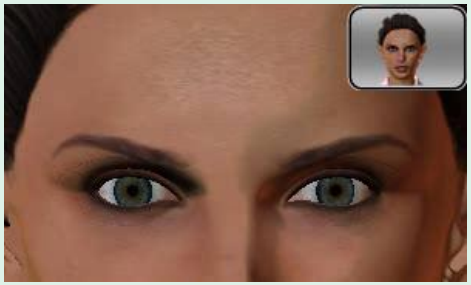
Overview

- Video head impulse test (vHIT) has become an important part of evaluation for patients with dizziness and other balance disorders
- The test is simple to perform and provides valuable information about all six semicircular canals
- Two main parameters, VOR gain and catch-up saccades, are used for interpretation of the test results but many questions remain:
  - What is the clinical significance of VOR gain?
  - What is the clinical significance of overt and covert catch-up saccades?
  - How to avoid artifacts and identify them when they occur

Bedside HIT – *Normal Responses*

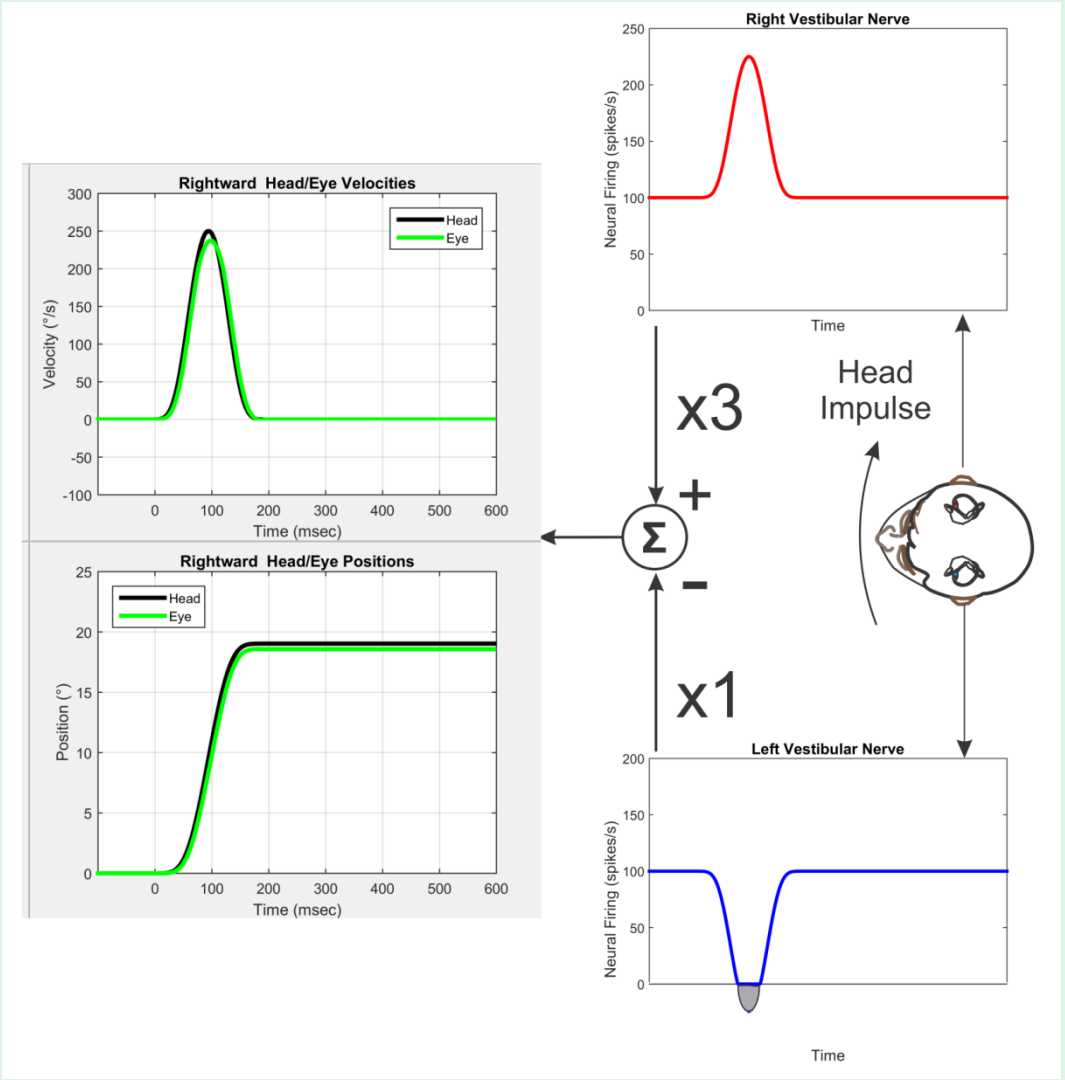
- HIT consists of moving the head using small-amplitude high-velocity high-acceleration unexpected head movements as the patient fixates on a stationary target straight ahead
  - In order to avoid contamination from the oculomotor pathways, head velocities should be above 100°/sec for lateral impulses and above 50°/sec for vertical impulses
- In normal subjects, VOR eye velocities match the head impulse velocities in the opposite direction allowing the eyes to remain on the target after an impulse





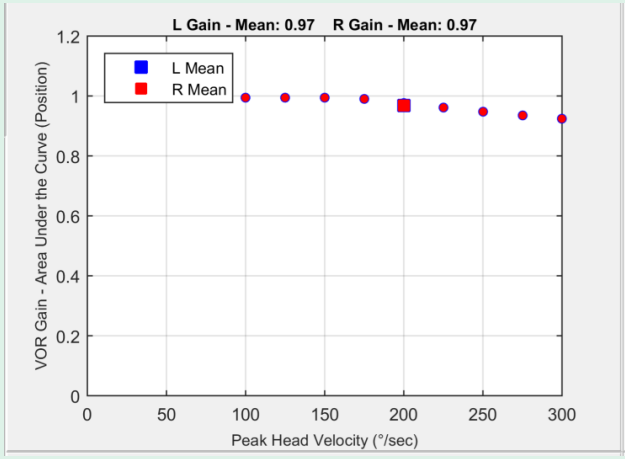
vHIT – *Normal Responses*

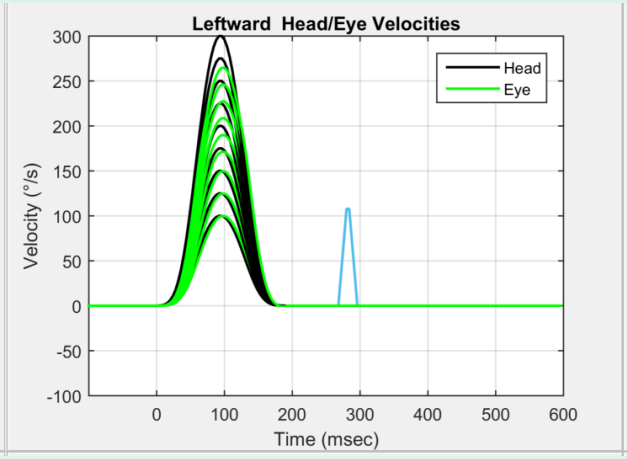
- Head impulses toward the canal cause excitation from that canal
  - Changes in the neural firing are proportional to the head velocity
- Head impulses away from the canal cause inhibition from that canal
  - Neural firing is clipped (saturates) at 0 spikes/sec and does not provide an accurate measure of head velocity
- <u>Both labyrinths</u> contribute to generating eye movements
  - The contribution of the ipsilateral labyrinth is larger (Ewald's second and third laws)

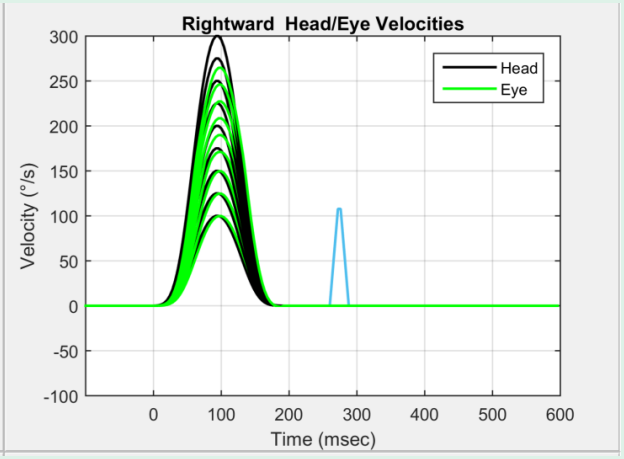


Interacoustics

vHIT – *Normal Responses*



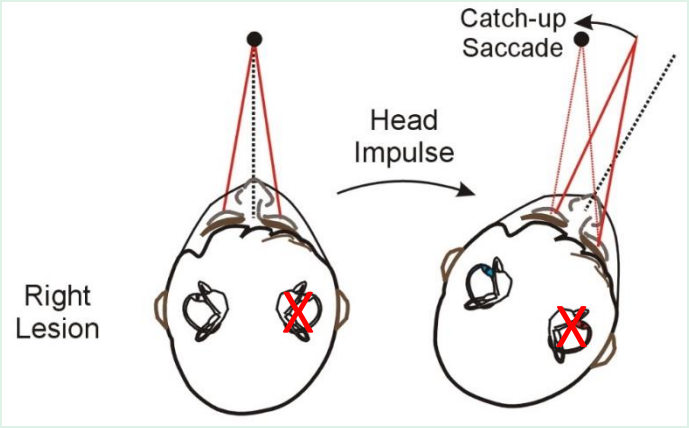


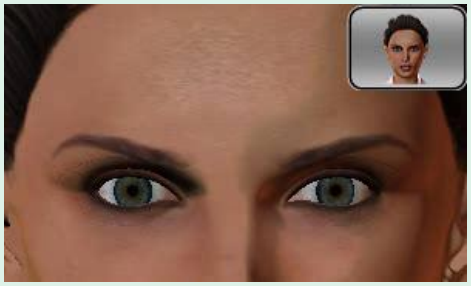


- In normal subjects, the VOR gain is around 1 at lower head velocities but begin to decline slightly at higher head velocities
- At higher head velocities (~300°/sec) even normal subjects may have catch-up saccades
  - Stay below 250°/sec for lateral head impulses and below 200°/sec for vertical head impulses

Bedside HIT – *Responses in Unilateral Lesions*

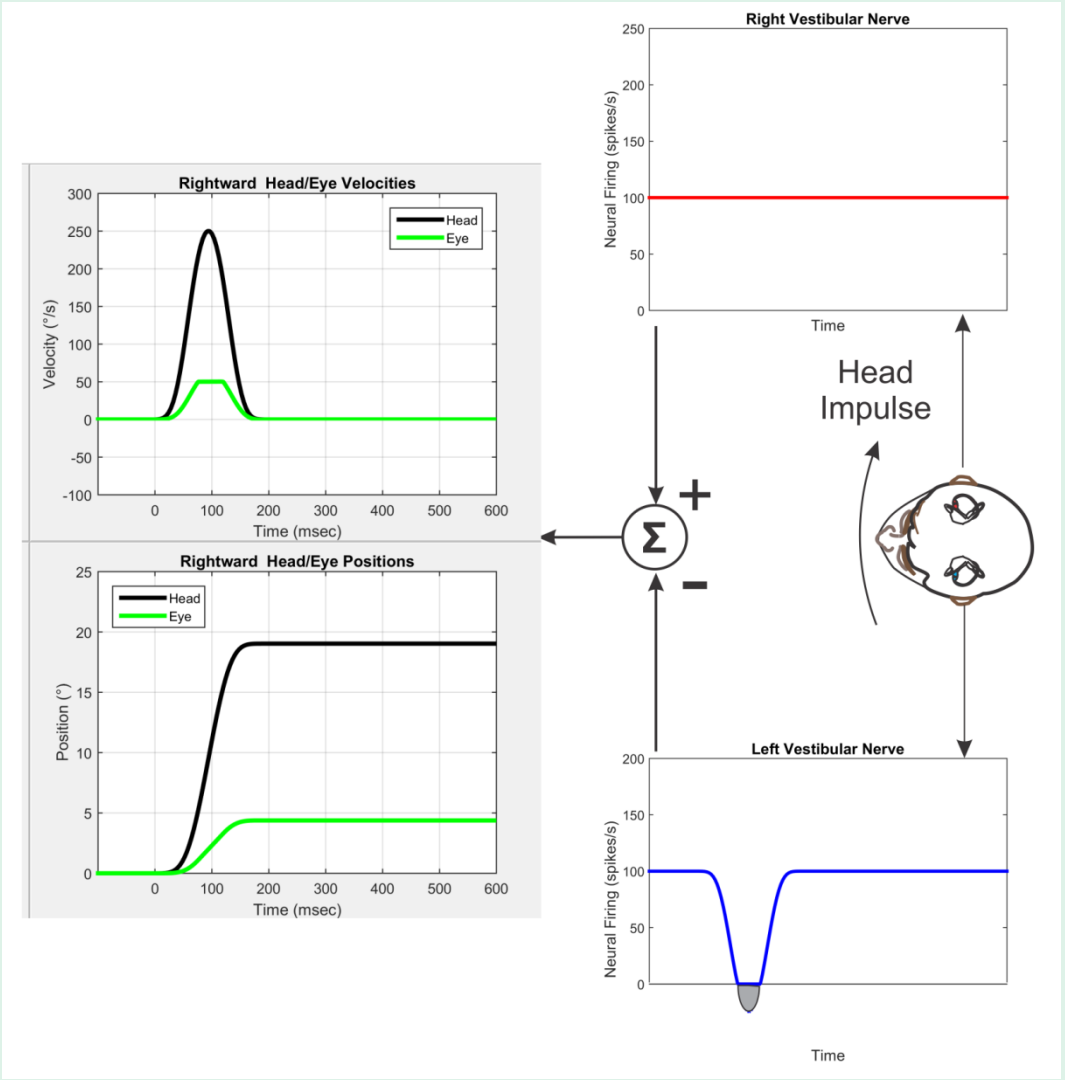
- In patients with vestibular lesions, the eyes fall short of the target for head impulses toward the damaged side
- After the head comes to a stop, a catch-up saccade is generated to reach the target
  - These saccades are called overt saccades because they are visible to the naked eye





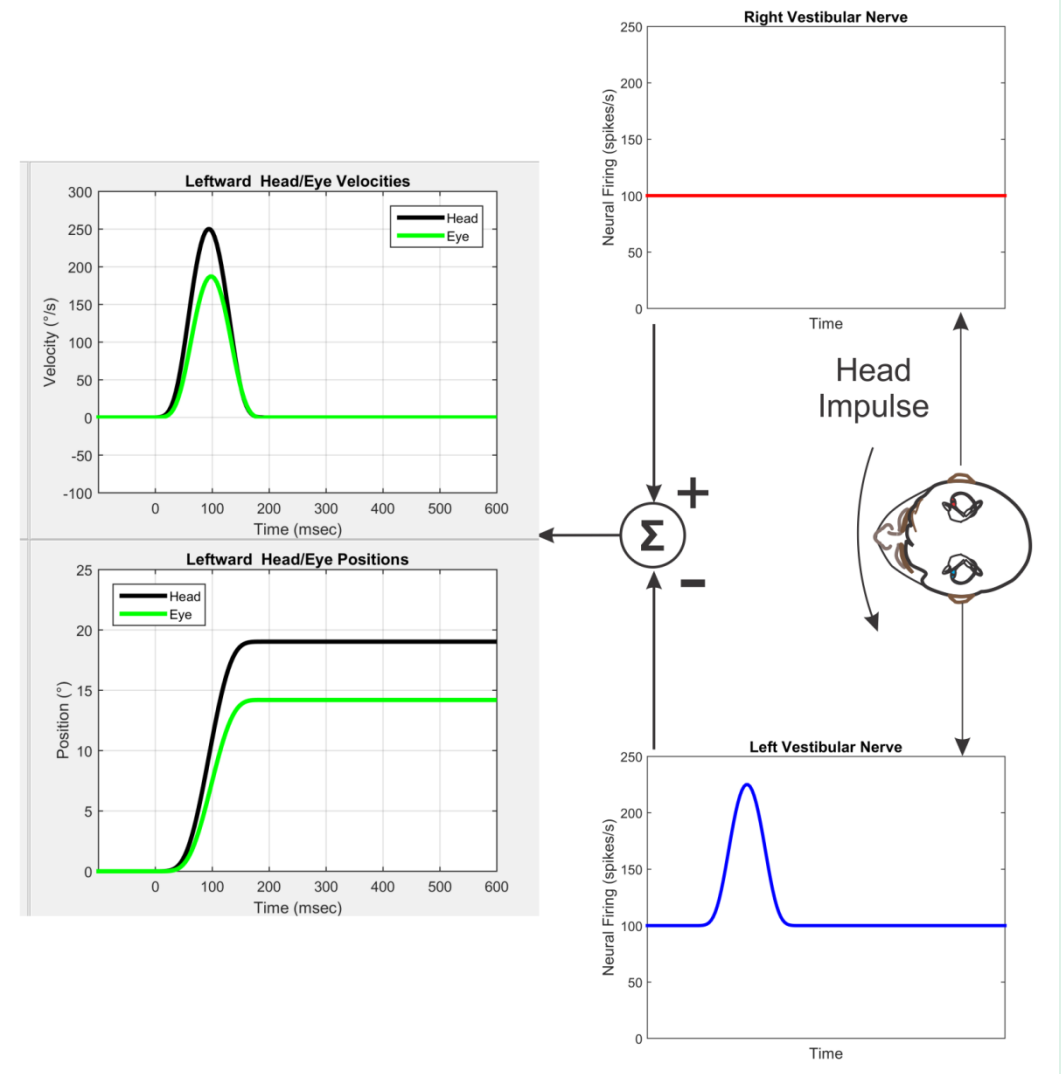
vHIT – *Responses in Unilateral Vestibular Lesions*

- For head impulses toward the side of lesion, the neural response from the damaged side is reduced or abolished
- The neural response from the intact side is saturated and no longer proportional to head velocity
- The resulting eye velocity does not match head velocity and the eyes fall short of target
- *VOR Gain = Eye Move./Head Move. << 1* (decreases rapidly with increasing head velocity)



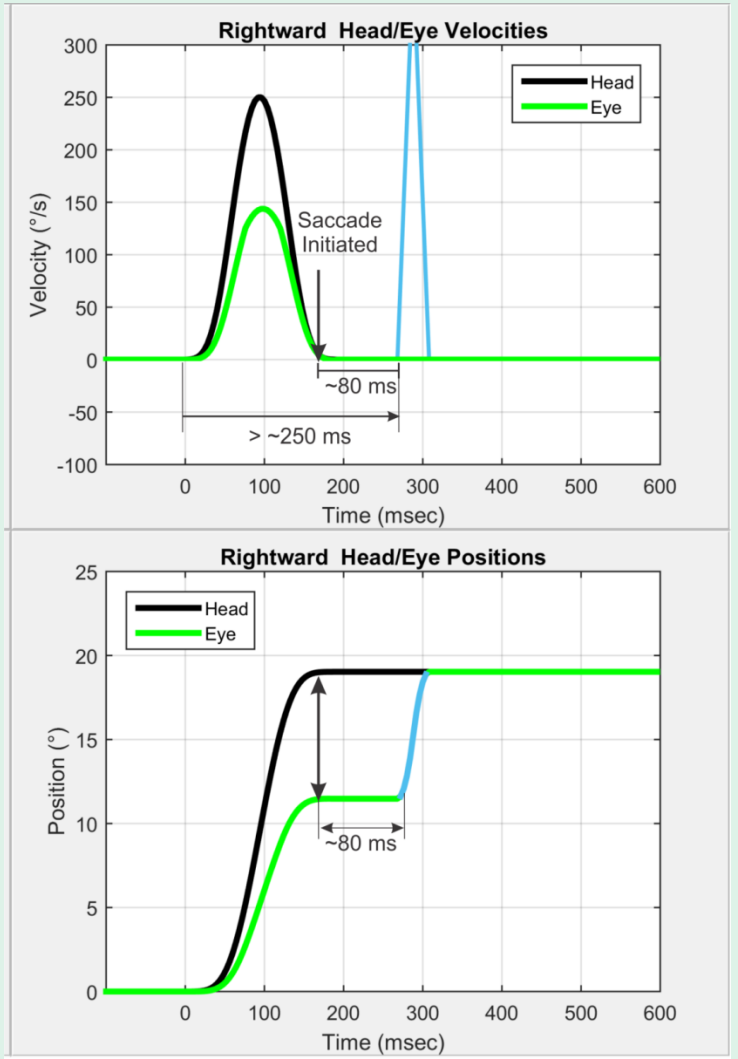
vHIT – *Responses in Unilateral Vestibular Lesions*

- For head impulses away from the side of lesion, the neural response from the intact side is proportional to head velocity
- The neural response from the damaged side is again reduced or abolished
- The resulting eye velocity is closer but still does not match head velocity and the eyes fall somewhat short of target
- VOR Gain = Eye Move./Head Move. < 1 (decreases with increasing head velocity but not as rapidly as the VOR gain for head impulses toward the side of lesion)



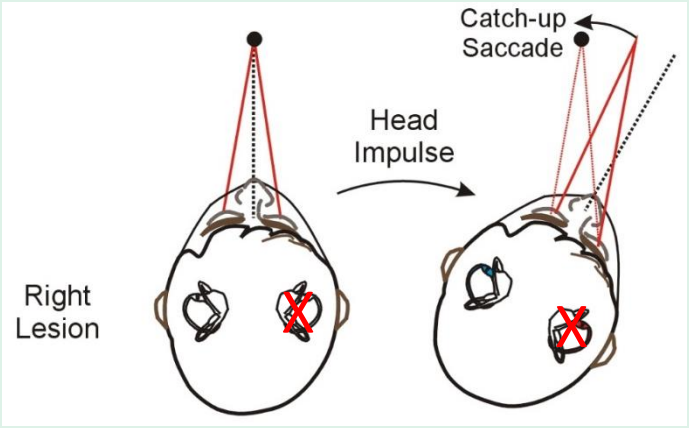
vHIT – *Catch-Up Saccades*

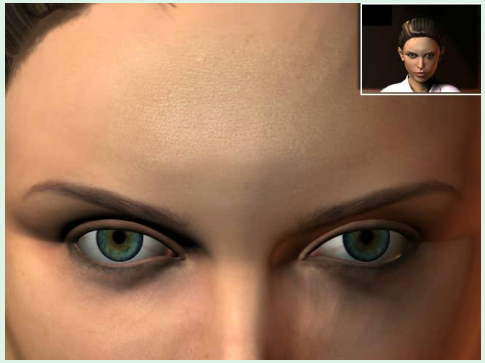
- The mechanism for triggering catch-up saccades is intuitively understood to be the difference between the gaze and target positions at the end of a head impulse
- After the position difference is detected and the saccade is initiated, it takes about 80-100 ms for the eyes to begin to move
- These saccades have long latencies (>~250 ms)
  - They are called <u>overt</u> saccades because they occur after the head movement and are visible to the naked eye



Bedside HIT – *Responses in Unilateral Lesions*

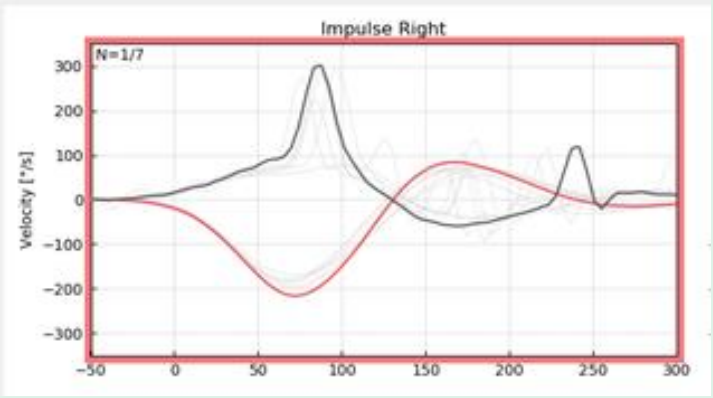
- Some patients are able to initiate saccades during head movements
  - The saccades are called <u>covert</u> saccades because they often (but not always!) occur during head movements and are not visible to the naked eye during the bedside HIT
- These saccades have short latencies (<~200 ms)

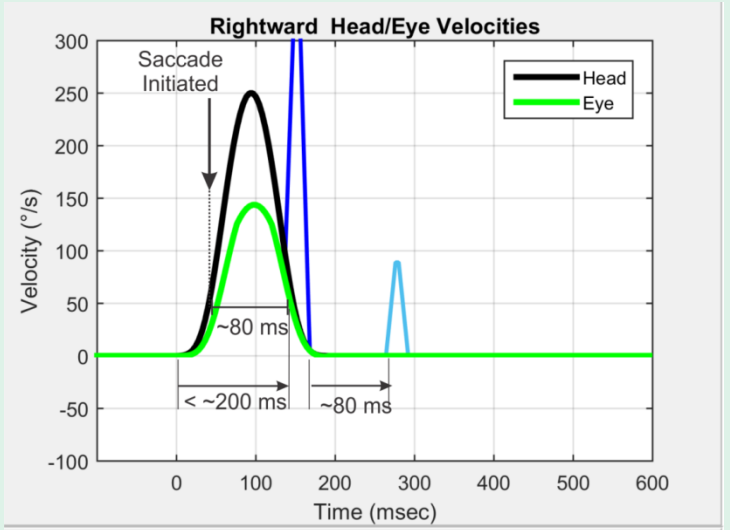


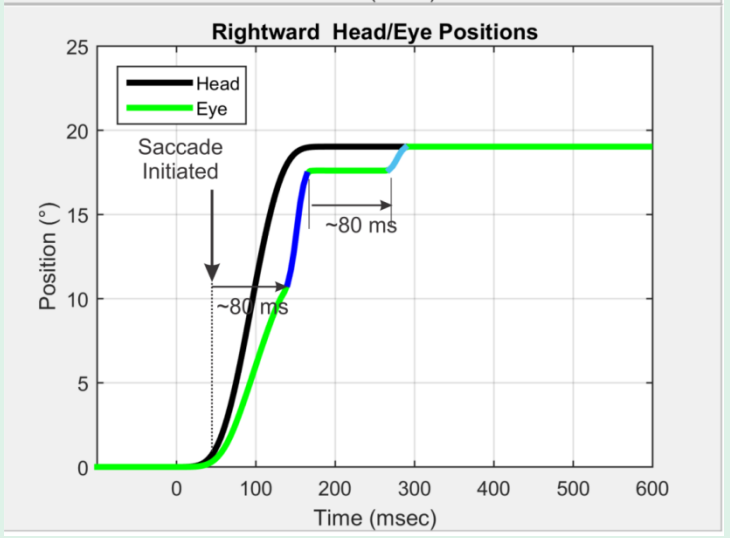


vHIT – *Covert Saccades*

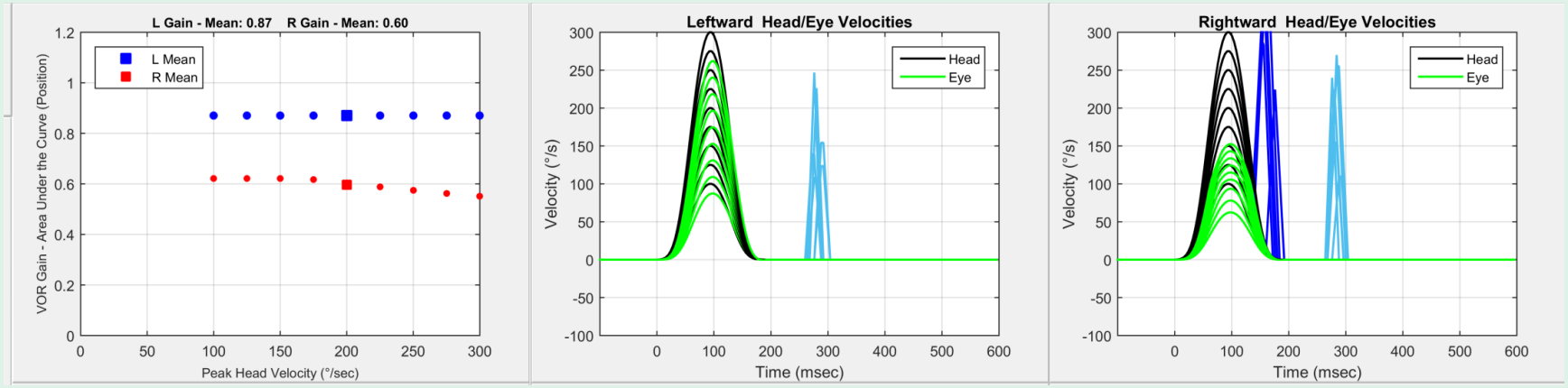
- Coverts saccades require some form of learning and prediction
- Coverts saccades usually are followed by a small overt saccade
- In preliminary reports, covert saccades have been associated with compensation
  - Better dynamic visual acuity, improved balance, and reduced symptoms





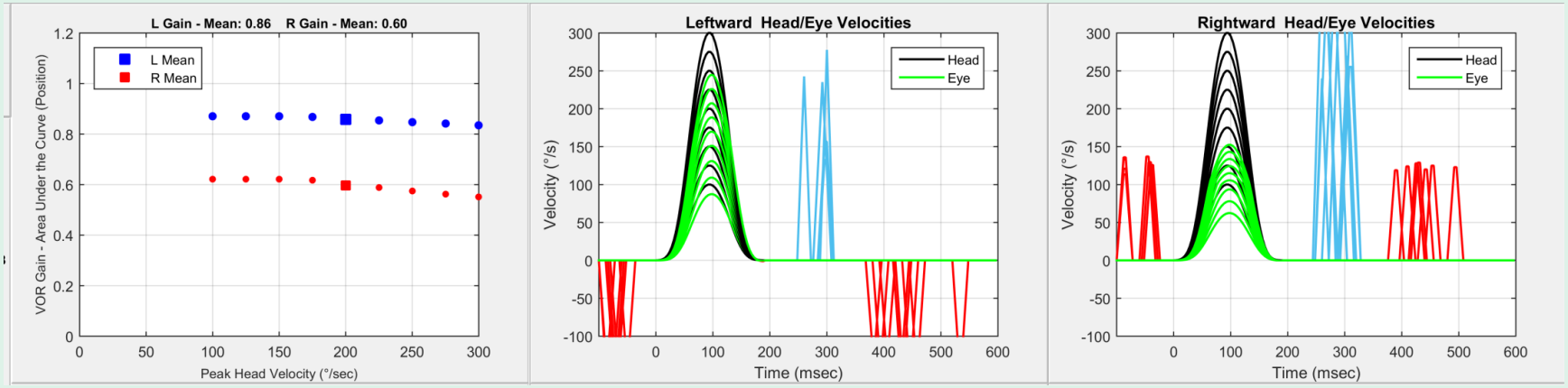


vHIT Summary – *Unilateral Lesions*



- VOR gain is << 1 for head impulses toward the side of lesion and declines with increasing head velocity
- VOR gain is < 1 for head impulses away from the side of lesion but does not decline as much with declining head velocity
- Significant catch-up saccades are present for impulses toward the side of lesion
- Catch-up saccades can be present for impulses away from the side of lesion also but they are not as large and start at higher head velocities
- Initially, most of the catch-up saccades are the long-latency type (overt)
- Over time, with learning and prediction, short-latency (covert) saccades may develop

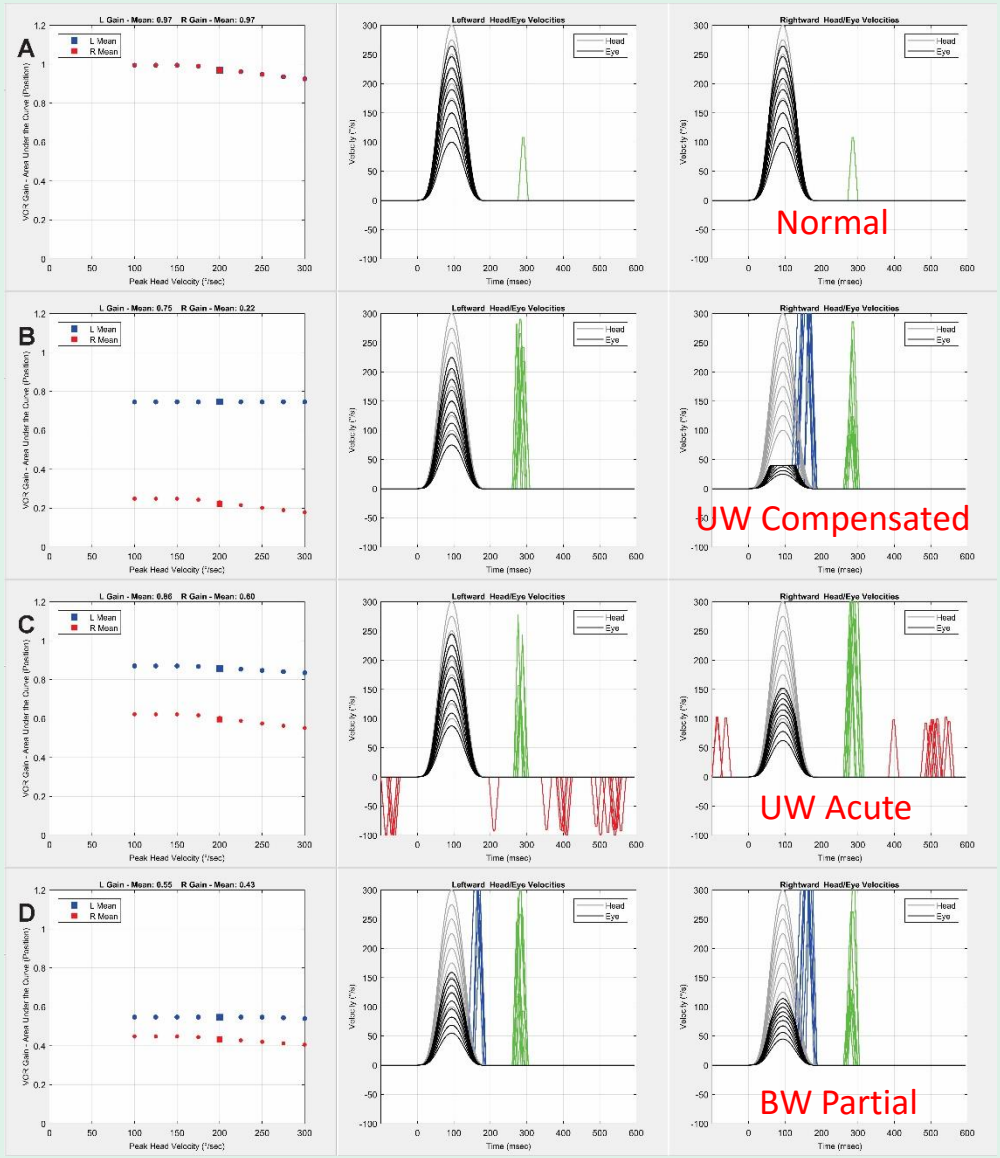
vHIT Summary – *Unilateral Lesions*



- In acute lesions, fast phases of spontaneous nystagmus will be intermixed with catch-up saccades for impulses toward the side of lesion and in the opposite direction of typical catch-up saccades for impulses away from the side of lesion
- Spikes for spontaneous nystagmus can occur before or after head impulses

Interpretation of vHIT

Different Patterns of Valid vHIT Results

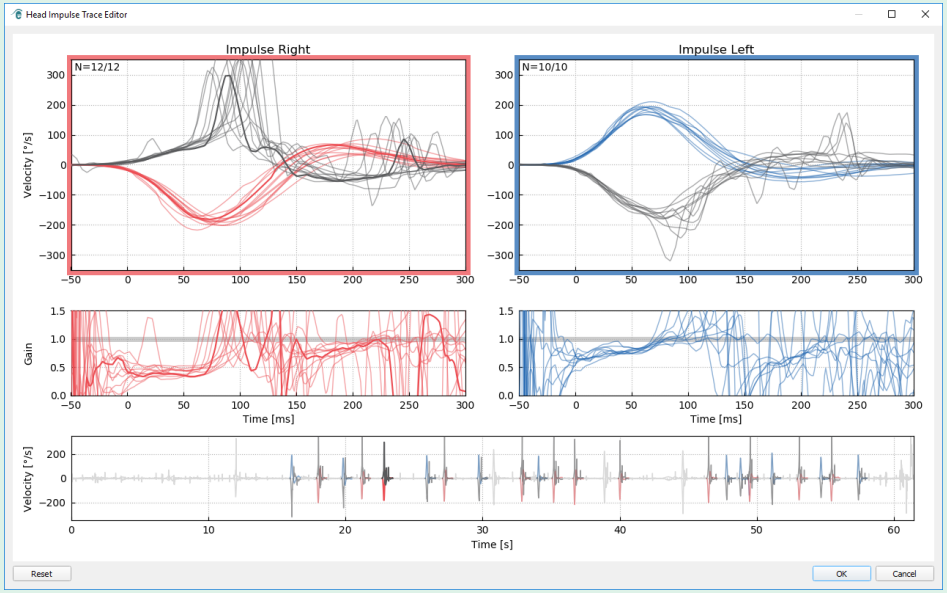


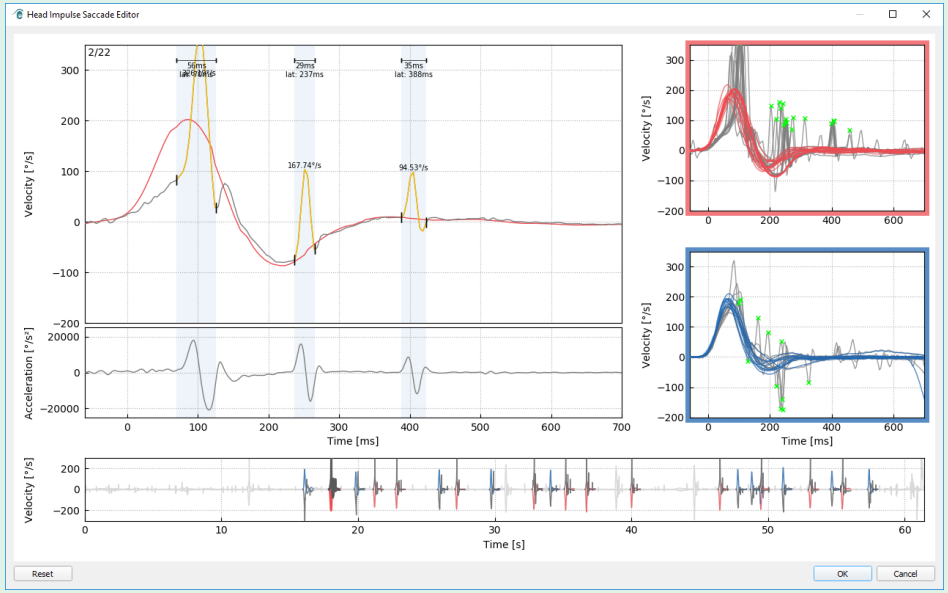
vHIT Interpretation – *Step-by-Step Guide*

- Different types of eye movements in vHIT
  - Slow VOR eye movements
    - VOR eye velocities are either shaped like the head velocities or in case of severe loss, they will appear as the clipped version of the head velocities
  - Fast eye movements
    - Long-latency catch-up saccades (overt)
    - Short-latency catch-up saccades (covert)
    - Fast phases of spontaneous nystagmus
  - All others (artifacts)

vHIT Interpretation – *Step-by-Step Guide*

- Step 1 – Identify the artifacts and determine if the test is interpretable
  - Delete impulses with artifacts as you need only a few impulses for interpretation
- When trying to identify saccade types, look at the individual impulse tracings



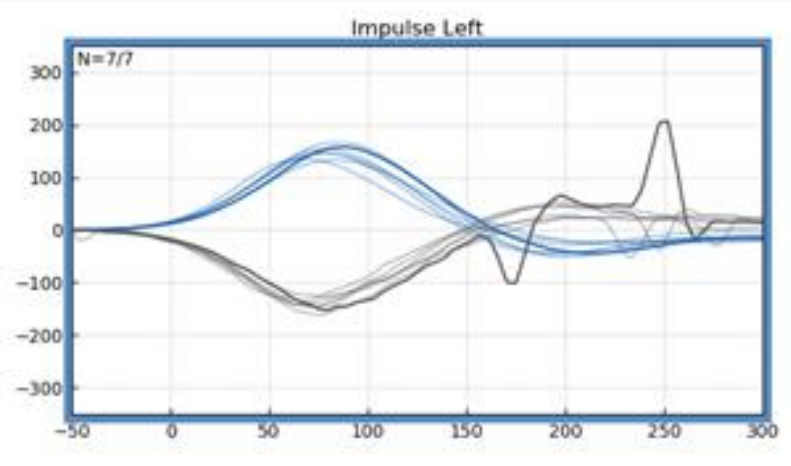


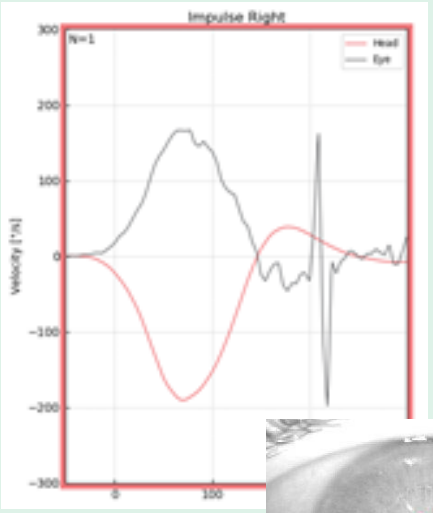
Saccades

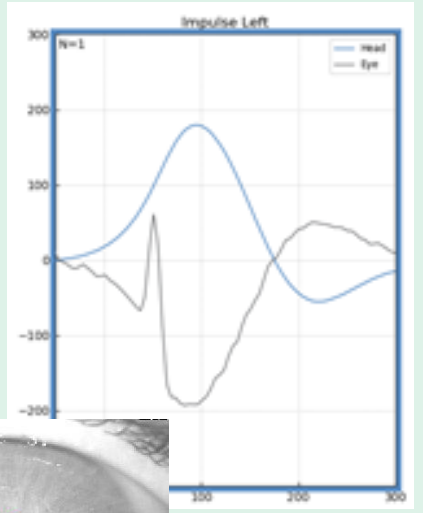
	Right			Left		
	1st Saccade	2nd Saccade	3rd Saccade	1st Saccade	2nd Saccade	3rd Saccade
Amplitude [°]	4.92 ± 003.34	1.45 ± 000.51	1.09 ± 000.06	0.27 ± 001.58	-0.57 ± 001.05	-
Peak Velocity [°/s]	235.75 ± 109.30	135.97 ± 036.42	88.85 ± 005.67	4.86 ± 105.22	-65.00 ± 091.91	-
Duration [ms]	66.50 ± 006.96	56.38 ± 010.69	42.50 ± 007.50	55.71 ± 013.42	58.25 ± 003.90	-
Latency [ms]	132.92 ± 074.12	253.62 ± 072.03	407.50 ± 019.50	134.00 ± 053.72	236.00 ± 040.40	-
Total	12	8	2	7	4	0

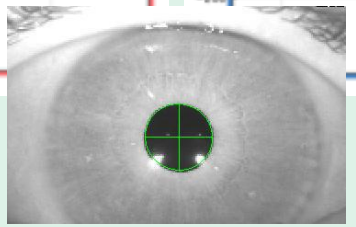
vHIT – Artifacts and Saccade Look-Alikes

- Two consecutive saccades going in opposite directions at about 80-100 ms apart
  - The patient is looking around
  - Reinstruct the patient
- Biphasic or uniphasic artifacts due to eye blinks, eyelids obstructing part of the pupil, or LED light intruding on the pupil
  - Shine a light to shrink the pupil
  - Pay attention to the display while performing the test
  - Delete affected impulses
  - Recording the video of eye movements can help with identifying these artifacts



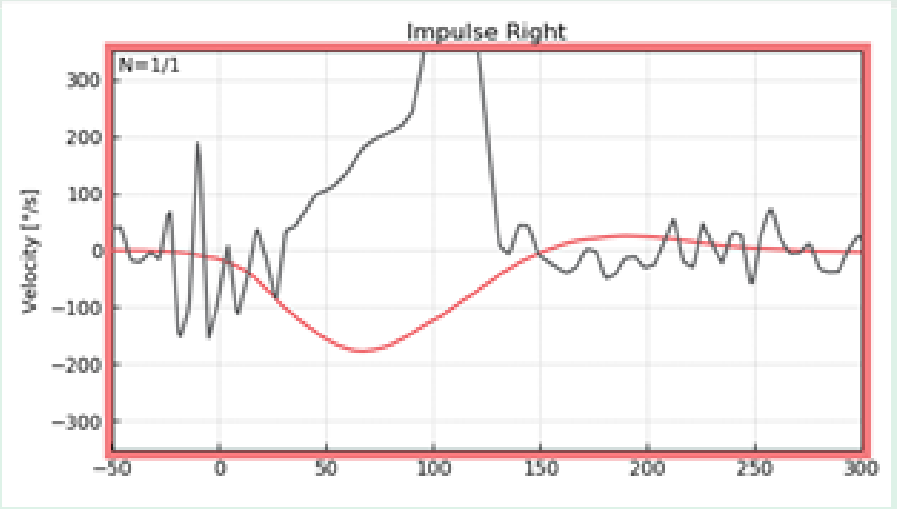


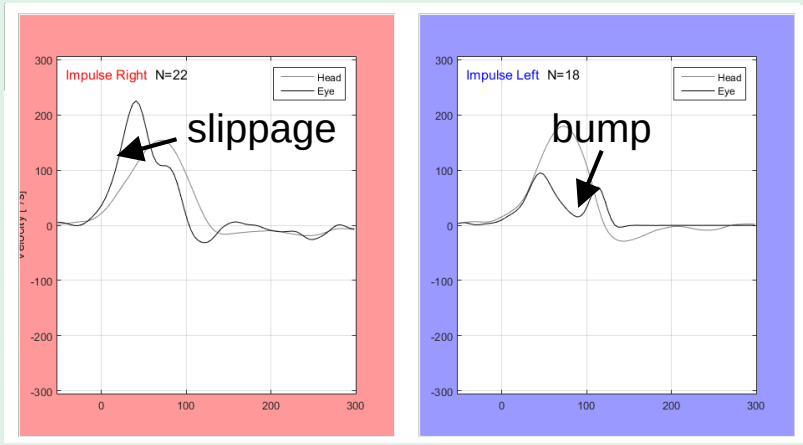


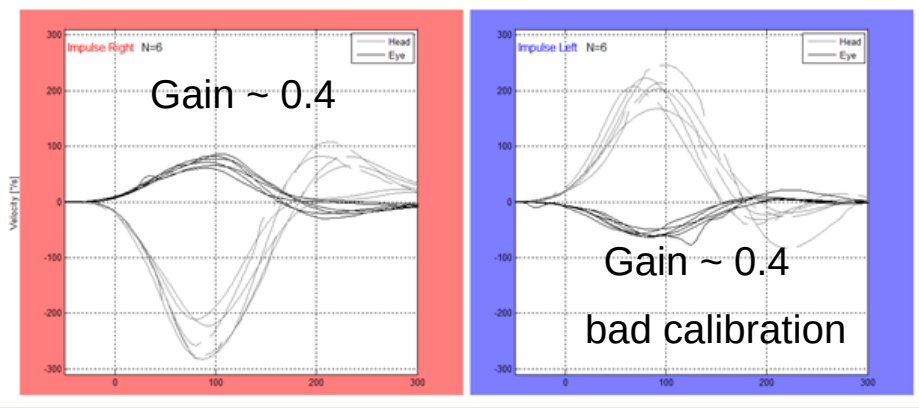


vHIT – Artifacts and Saccade Look-Alikes

- High-frequency oscillations due to pupil detection issues
  - Adjust the cameras, the focus, and the threshold (in some systems)

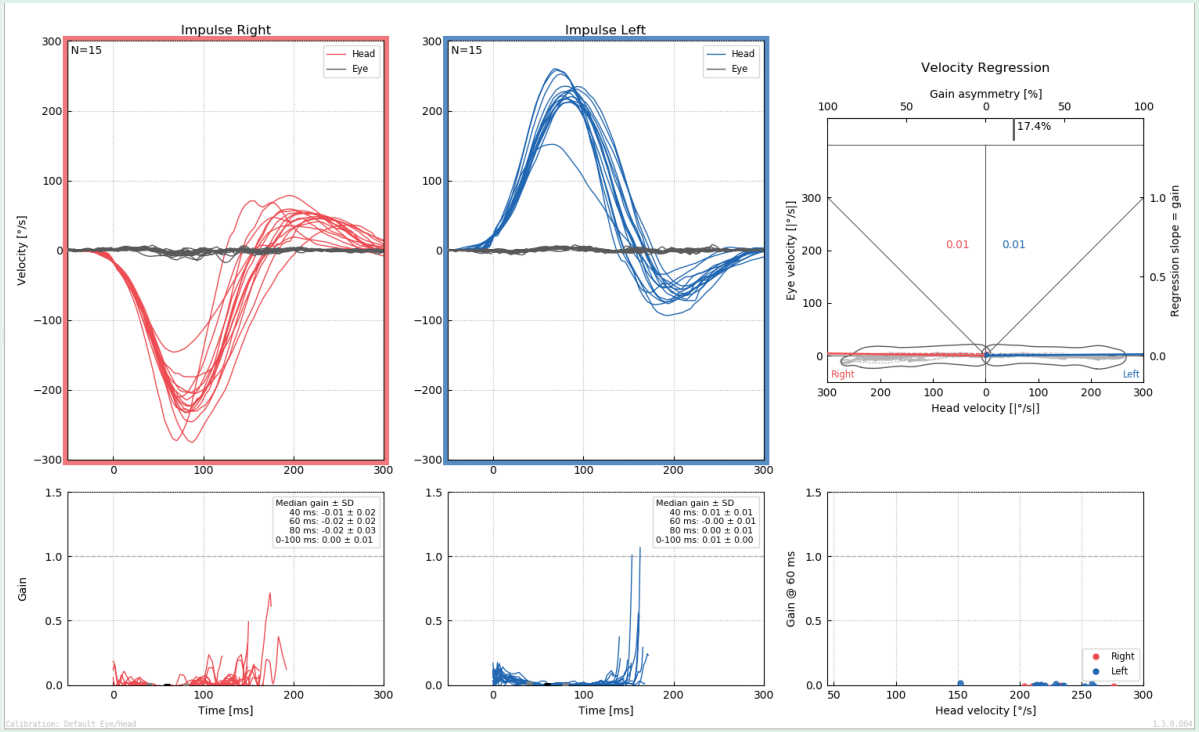






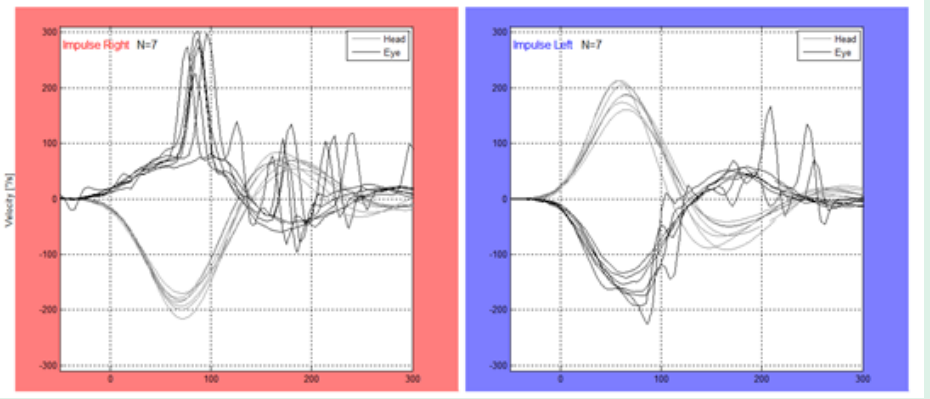
Abnormally high or low VOR gain in the absence of catch-up saccades usually indicates an artifact (do a quick saccade test to rule out saccadic palsy)

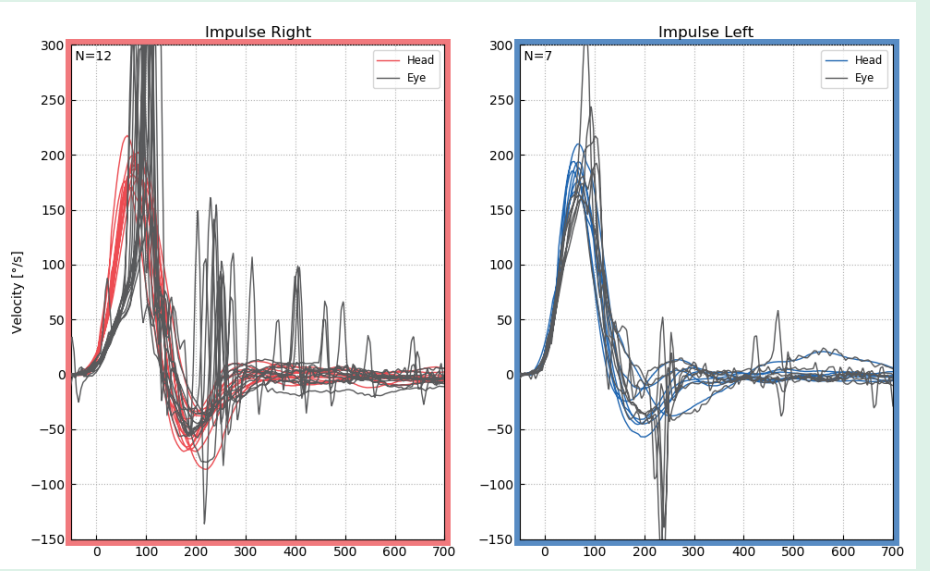
vHIT – Other Artifacts



vHIT – Spontaneous Nystagmus

- Step 2 – Account for spontaneous nystagmus
  - Fast phases of spontaneous nystagmus appear as spikes in eye velocity tracings
  - Spontaneous nystagmus fast phases can occur before or after head impulses
  - For typical spontaneous nystagmus that beats away from the side of lesion, spikes appear in the opposite direction of VOR eye movements following head impulses toward the *intact* side
  - Fast phases of spontaneous nystagmus are intermixed with the catch-up saccades during head impulses to the lesion side



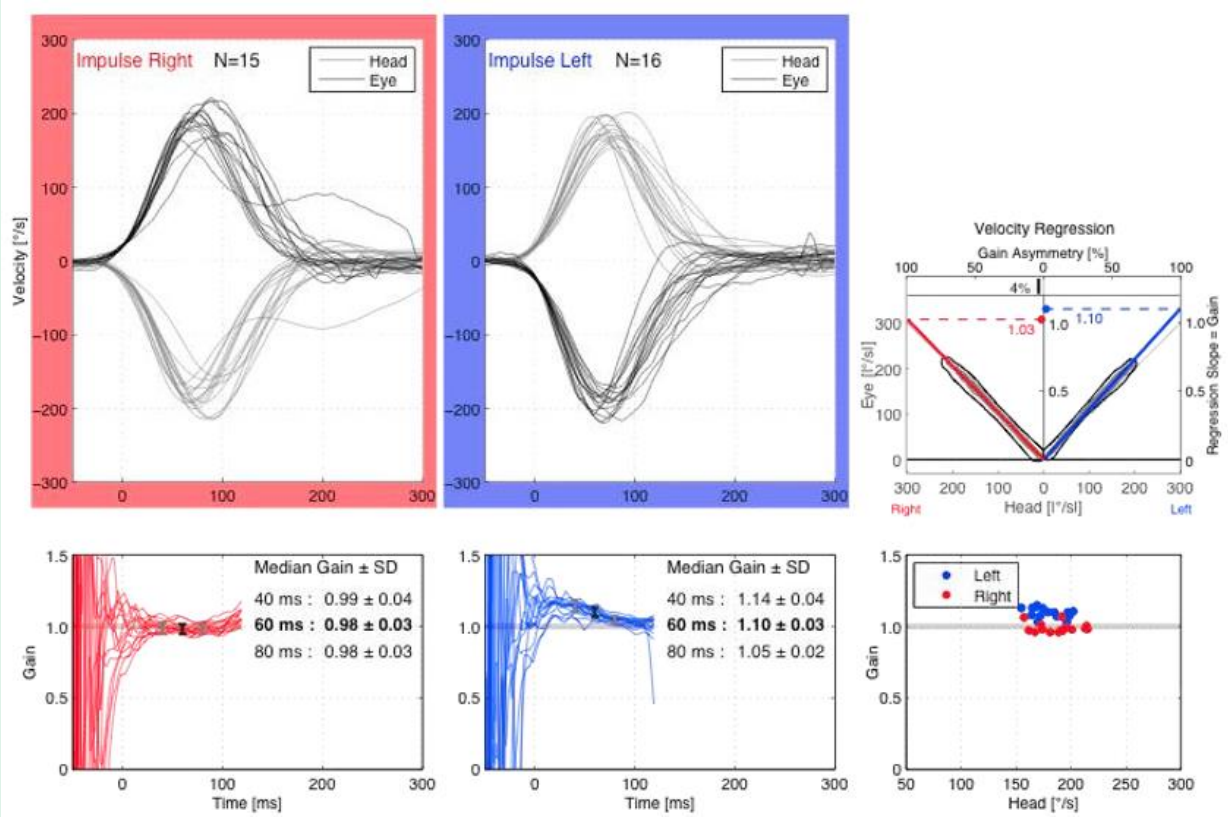


Modifying the display parameter can help with identifying nystagmus fast phases

vHIT Interpretation – *Step-by-Step Guide*

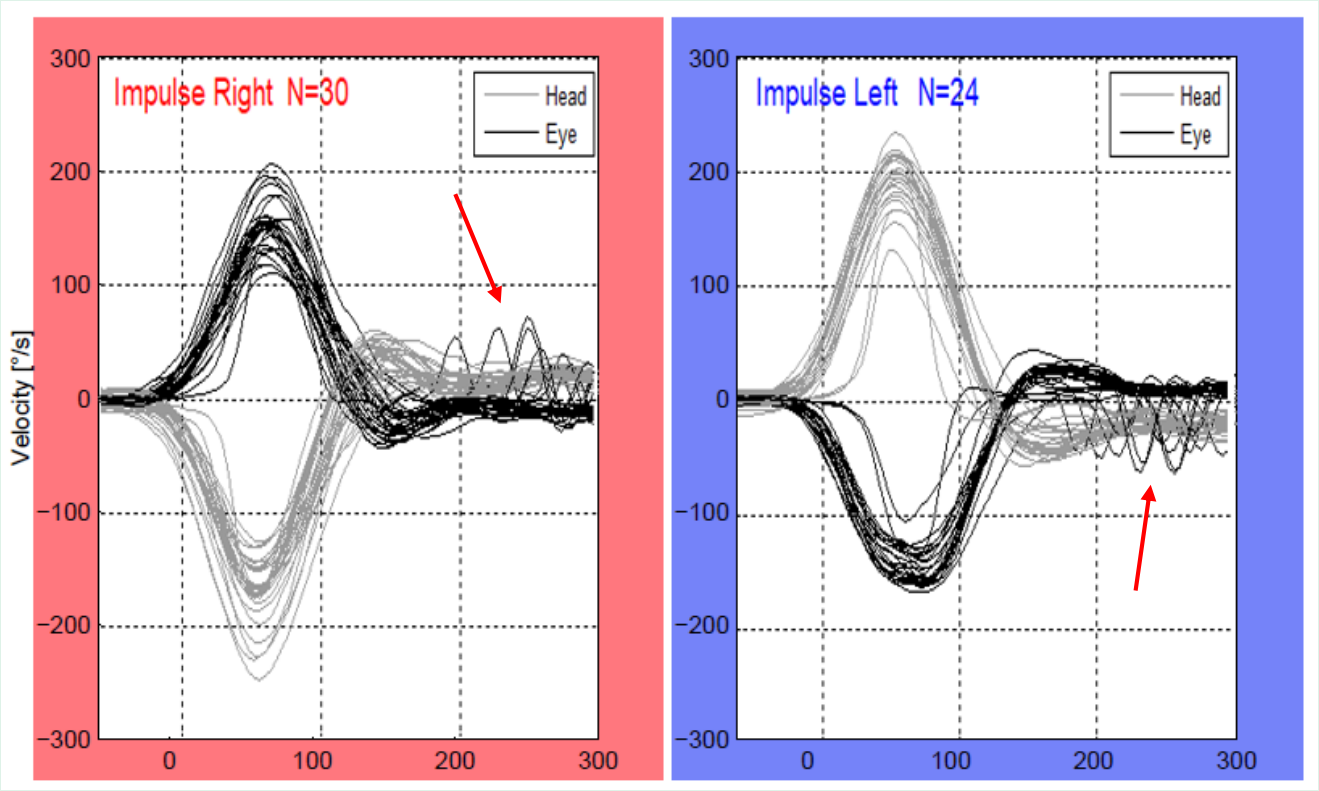
- Step 3 – Determine if abnormal catch-up saccades are present
  - Identify true catch-up saccades using the latency of first saccade
    - Short latency ~80-225 ms, long latency ~225-350 ms
  - Determine significant saccades using the saccade peak velocity
    - Use peak saccade velocity > 100º/sec or > half of the peak head velocity
    - Velocity may be too variable but there is no other established criteria
- When there are no significant catch-up saccades, check the VOR gains and if they are within normal limits (close to 1), vHIT should be considered within normal limits
- If VOR gains are not within normal limits in the absence of abnormal catch-up saccades, consider presence of an artifact

vHIT Interpretation – *Normal Results*



- No clearly-identifiable catch-up saccades
- VOR gains are close to 1 bilaterally
  - Head velocities are approximately equal for right-left impulses and within the optimal range
  - No other sign of artifacts

vHIT Interpretation – *Normal Results*

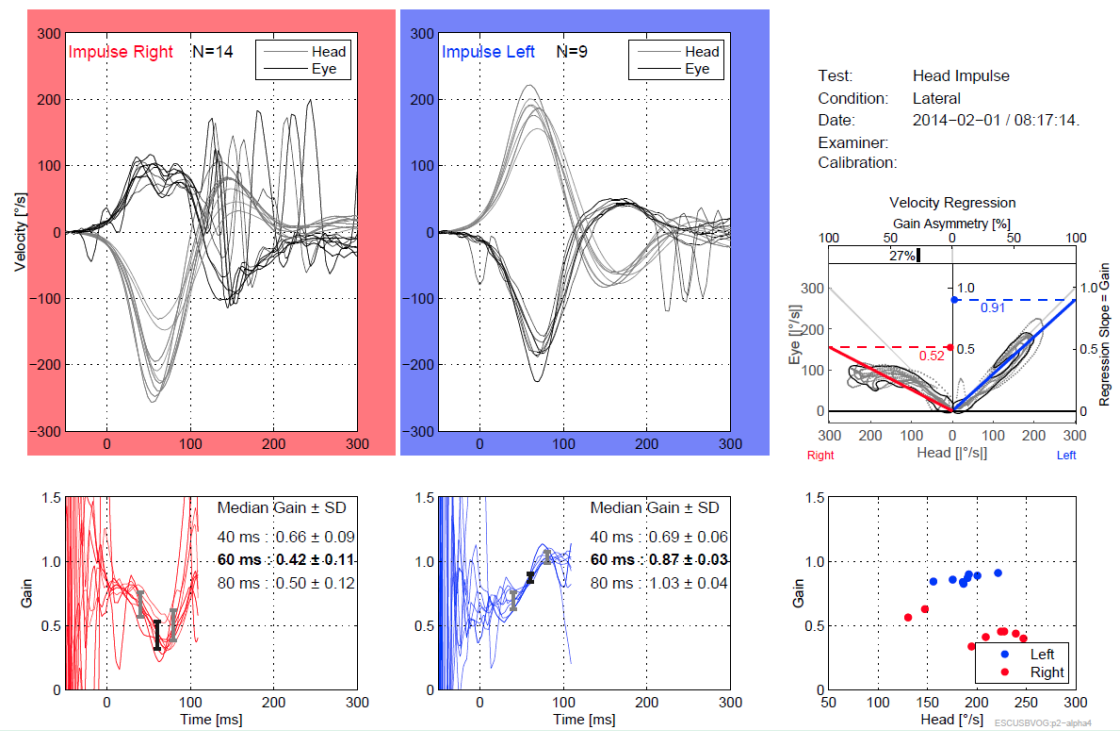


- There are few catch-up saccades bilaterally for higher head velocities
  - Saccade velocities are considerably smaller than the corresponding head velocities

vHIT Interpretation – *Step-by-Step Guide (continued)*

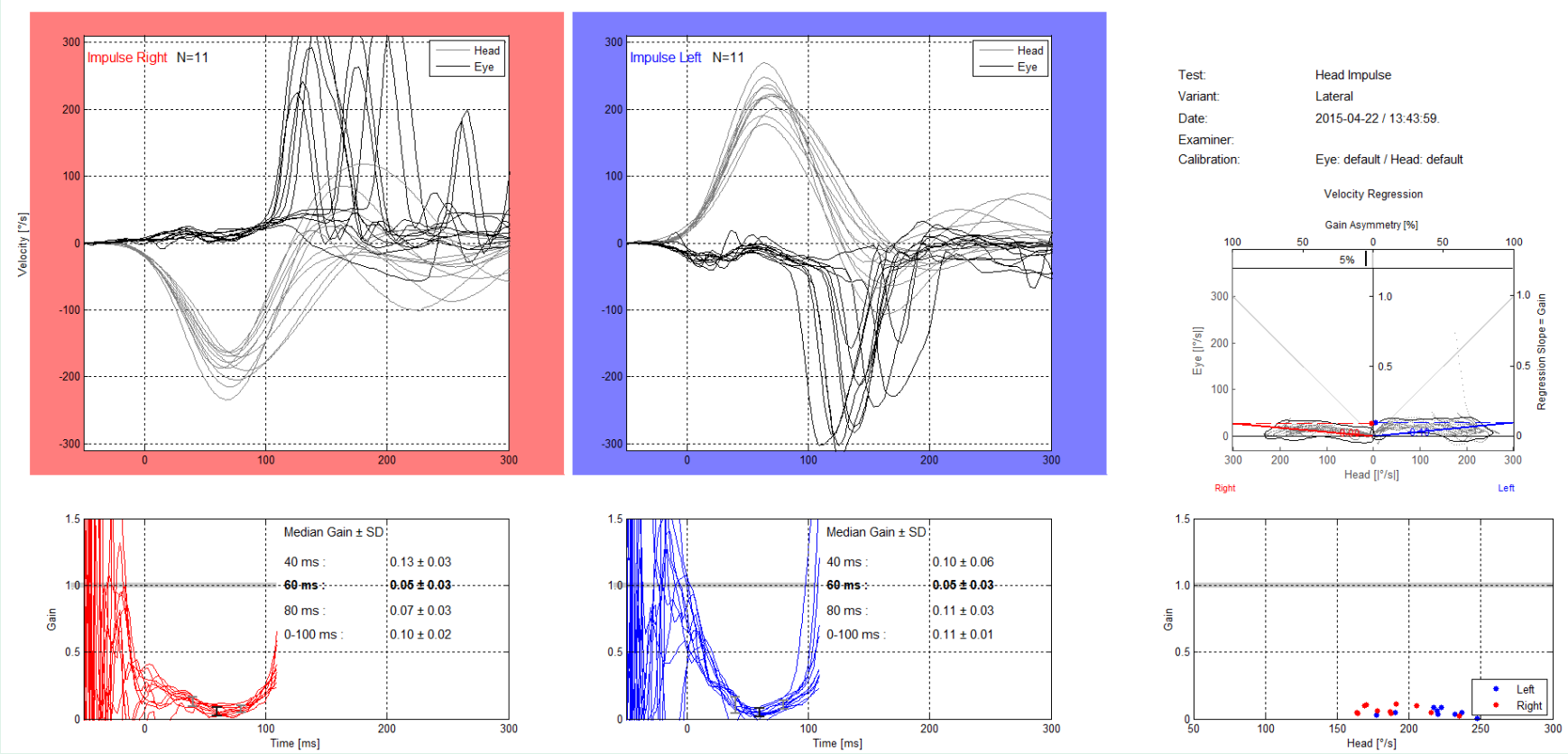
- Step 4 – If abnormal catch-up saccades are present in one direction only and the VOR gain is abnormal for the same side, consider vHIT consistent with a unilateral lesion
  - If the VOR gain is normal in the presence of abnormal saccade, still consider the vHIT abnormal (may signify mild lesions)
  - The VOR gain to the opposite direction is usually normal but it does not contribute to the interpretation even if it is abnormal
- If abnormal catch-up saccades are present to both directions, there is no easy way to distinguish between purely unilateral and partial bilateral lesions
  - Assume unilateral unless proven otherwise
  - For unilateral lesions, catch-up saccades are more frequent to the side of lesion and start at lower head velocities
  - For unilateral lesions, VOR eye velocities are clipped/saturated for one direction but proportional to head velocities in the opposite direction
  - For bilateral lesions, the sum of right and left VOR gains is less than one

vHIT Interpretation – *Unilateral Vestibular Deficit*



- Abnormal catch-up saccades to both directions but more significant for rightward head impulses
  - Saturated VOR eye velocities for rightward head impulses and proportional VOR velocities for leftward head impulses denote a right unilateral vestibular deficit
  - VOR gain for leftward head impulses may be abnormal but interpretation is the same

vHIT Interpretation – *Bilateral Vestibular Deficit*



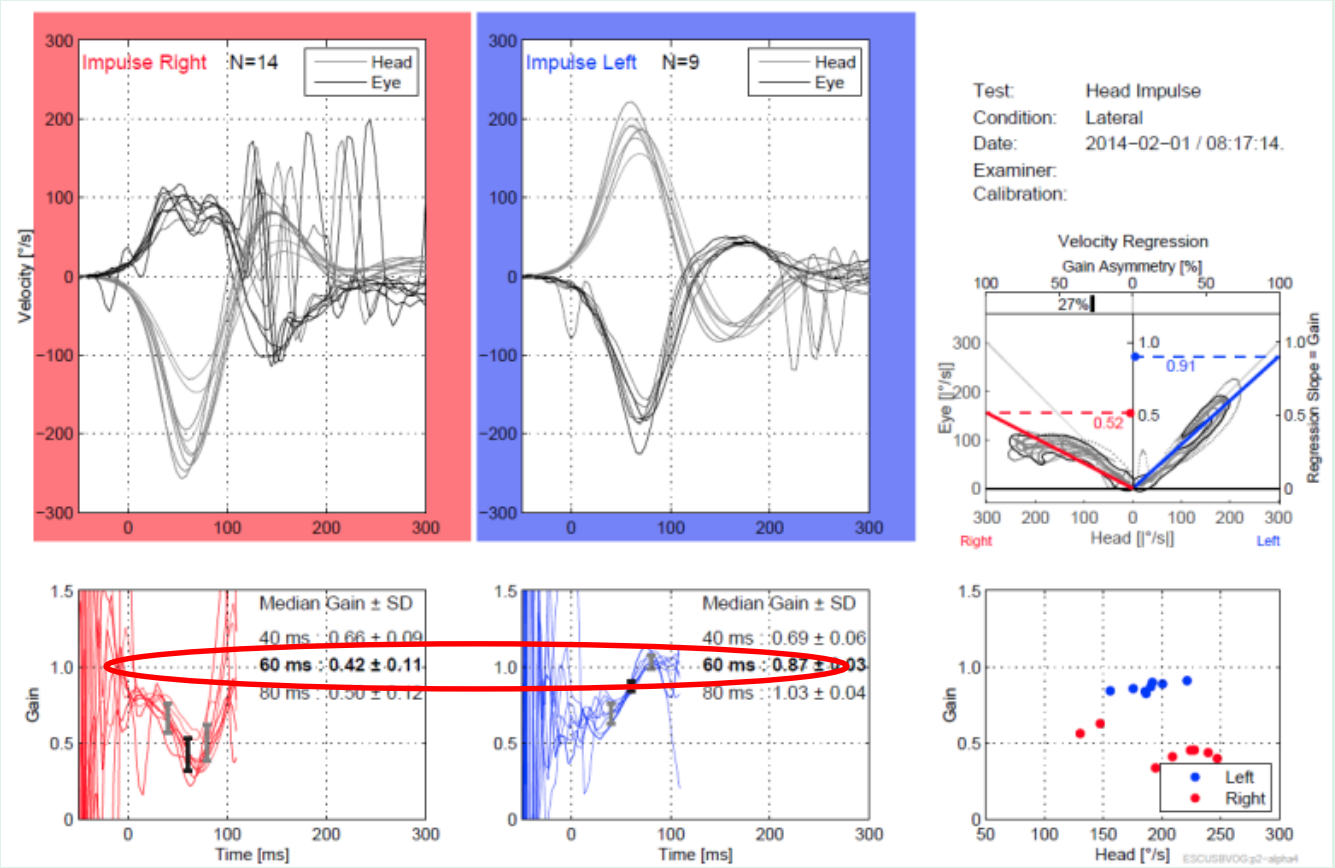
- Complete bilateral loss – Abnormal catch-up saccades and near 0 VOR gain for both directions

Summary

- Head velocities must be within a specific range and right-left velocity profiles must be approximately the same for valid interpretation of vHIT
- Catch-up saccades can be helpful in identifying abnormal vHIT
  - Abnormal catch-up saccades are more frequent and start occurring at lower head velocities
  - Presence of short-latency catch-up saccades has been associated with improved dynamic visual acuity, better balance, and reduced symptoms but more work is needed
- In the presence of abnormal catch-up saccades, vHIT should be considered abnormal regardless of whether the VOR gain is abnormal or not
  - Presence of consistent catch-up saccades with normal VOR gains is likely to represent a mild lesion
- Conversely, abnormal VOR gain in the absence of catch-up saccades should be investigated further for possible artifacts

Let's Do a Test!

R Gain = 0.42
L Gain = 0.87
Total R-L Gain = 1.29
Mean R-L Gain = 0.645



- Can we estimate the loss of canal function in this vHIT?
- Is the loss confined to the right canal?

VOR Gain and the Level of Vestibular Loss

R Gain = 0.42

L Gain = 0.87

Total R-L Gain = 1.29

Total Loss% =

(2 – 2 x Total R-L VOR Gain)*100 =

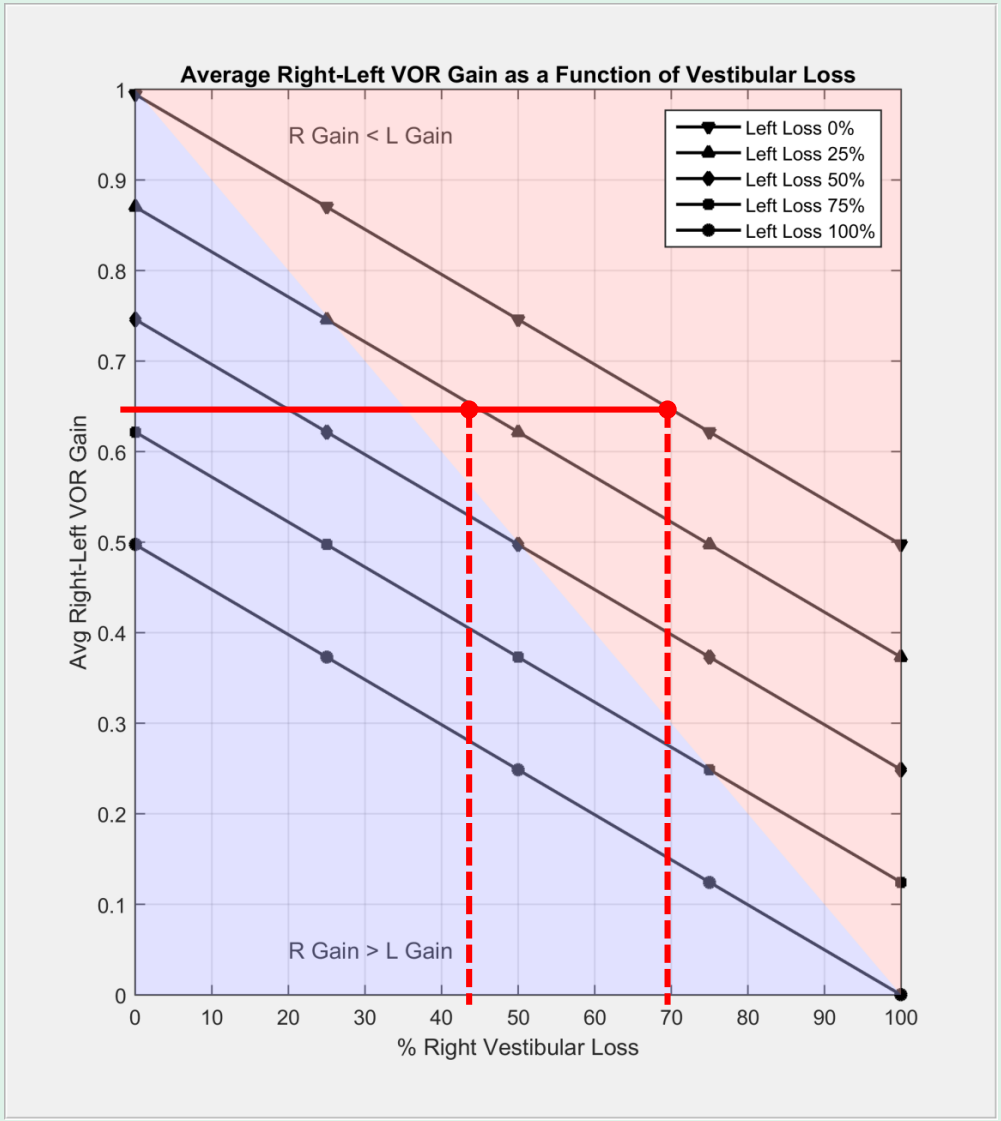
(2 – 1.29)*100 = 71%

DO NOT DO THIS!

(Different frequency ranges)

$$|UW\%| = \frac{1 - \text{Mean VOR Gain}}{\text{Mean VOR Gain}}\%$$

= 55%



vHIT – *Clinical Applications*

- For the first time, isolated abnormalities in vertical canals and their afferent pathways can be identified
  - In vestibular nerve abnormalities, vHIT can determine which branches of vestibular nerve are involved and can determine when and if function returns to the vestibular nerve
- In the case of acute vertigo, can differentiate between cerebellar strokes and peripheral vestibular lesions (Newman-Toker et al, 2013)
- Can be used for serial testing (e.g., monitoring Gentamycin therapy for Meniere's or monitoring vestibulotoxicity of different agents)
- Can be used in place of rotation testing in patients with bilateral caloric weakness
- Can be modified for testing children (e.g., before cochlear implant)
- Cost-effective because it reduces the need for unnecessary tests