Introduction To The Video Head Impulse Test

PRODUCT INSIGHTS

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This document provides a comprehensive overview of how to perform the video Head Impulse Test, starting from the physiological bases up to daily diagnostics. SYNAPSYS VHIT is a unique system that represents a fundamental step forward in the evaluation of the vestibular system. It does not require the patient to wear any goggles; all results are obtained from the analysis of the patient's head and eye movements, recorded by a remote camera.

ANATOMY AND PHYSIOLOGY OF THE VESTIBULAR RECEPTORS

The cupulo-endolymphatic system can be described through the physical model of the pendulum with critical damping, (i.e. the cupula after deflection quickly returns to the neutral position without overshooting) of which three constituent elements are represented by:

- **Mass (M)** of endolymph in the canal (M = 0.2 mg) which, in the event of angular acceleration of the head, determines the inertial force that deforms the cupula;
- **Viscosity (C)** of the endolymph, which prevents the system from oscillating, allowing the cupula to return to its equilibrium position in the shortest time possible;
- **Elasticity (K)** of the cupula, which determines its return to the position of equilibrium.

These three parameters that are intrinsic to the semicircular canals regulate the frequency response profile of the labyrinth and are connected to each other by a second order differential equation (Steinhausen model, 1933).

Elastic forces prevail at low frequencies, the cupular position will be in phase with the acceleration of the head. Viscous forces prevail at medium frequencies, the cupular position will be in phase with the velocity of the head. Inertial forces prevail at high frequencies, the cupular position will be in phase with the position of the head.

At low frequencies the labyrinth will send input to the vestibular nuclei in phase with the acceleration of the head, at which point the Nucleus Prepositus Hypoglossi (NPH) will perform an integration and transform the input into a velocity signal (but not a position signal). As a result, the stability of the retinal image will only be under visual control.

At medium frequencies the labyrinth will send input to the vestibular nuclei in phase with the velocity of the head. The NPH will perform an integration turning it into a position signal. As a result, the stability of the retinal image will be under both vestibular and visual control.

At high frequencies the labyrinth will send input to the vestibular nuclei in phase with the position of the head. No action will be required by the NPH; therefore, the stability of the retinal image will be exclusively under vestibular control.

Vestibular receptors, both at ampullary and macular level, are distinguished in phasic (type I) and tonic (type II) cells, the differences of which also concern anatomical and functional aspects.

Phasic cells are located on top of the crista ampullaris, are connected to large-caliber afferent fibers, and respond irregularly to the high-frequency movements of the head. Tonic ones occupy the most peripheral part of the crista ampullaris, are connected to smaller-caliber afferent fibers and have regular activity both when the head is still and in the presence of lower frequency movements.

Type I cells are involved in the perception of the movements of the head at high frequency, which are configured as unidirectional elements i.e. responsive only to one direction of movement. They are also under the control of only the semicircular canals, are not inhibited, do not encounter compensation phenomena and allow for short tests to be carried out in ambient light with excellent tolerability.

In the perception of low-frequency head movements, type II cells are involved; bidirectional receptors (responding therefore in both directions of movement) which are under the control of the brain stem are frequently subject to central inhibition. They encounter compensation phenomena and are investigated by prolonged tests performed in complete darkness and in conditions that are often poorly tolerated.

The description of this behavior is summarized in detail in the image in the appendix

CLINICAL HALMAGYI'S TEST (C-HIT)

In 1988 Gabor M. Halmagyi and Ian S. Curthoys (Halmagyi, 1988) described for the first time the head impulse test in which the patient, placed in front of the examiner, is invited to stare at the tip of the examiner's nose while the head is guided in a series of limited amplitude but high velocity movements which are unpredictable and without rebound.

The goal of the test is to examine the function of the canal at a high rotational velocity of the head.

In a healthy subject the gaze remains steady on the visual target at the end of the rotation of the head because, as a result of a valid vestibular-oculomotor reflex (VOR), the eye will have performed a counter-rotation of equal amplitude (remember that at high rotational velocity of the head the visual information is absolutely irrelevant to the stabilization of the gaze due to the limitations of visual tracking and optokinetic reflex).

In a pathological subject, in which the VOR is impaired, at the end of the rotation of the head towards the affected side, since there has been no expected counter-rotation of the eyeball, there will be a fast movement of the eye. This is called the refixation saccade, with which the patient will recover the primitive line of gaze: the test will therefore be defined positive. In people with a peripheral pathology, the c-HIT will yield a positive result by turning the head to the affected side. In patients affected by a central pathology, the test will be negative on both sides (except for some cases of stroke involving the inferior anterior cerebellar artery).

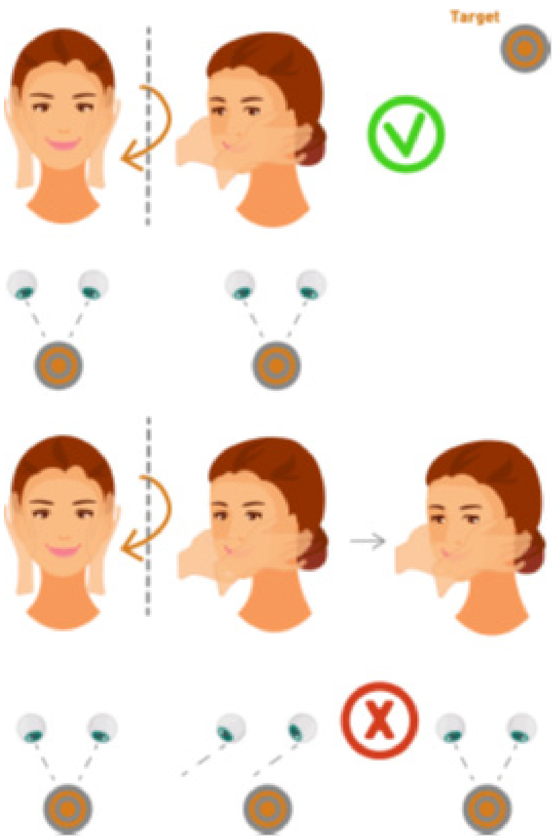


Figure 1 Inventis, 2021

VIDEO HALMAGYI'S TEST (V-HIT)

Halmagyi's clinical test is subject to certain limitations:

1. The answer obtained is of the "all or nothing" type: it is not possible to evaluate intermediate degrees of deficit;
2. In case of impaired VOR, the corrective saccadic that appears at the end of the movement of the head (OVERT saccades) is not the only compensatory response that the vestibulo-oculomotor system is able to provide: there are indeed saccadic movements invisible to the naked eye (COVERT saccades) that can be generated during the movement of the head and which, usually, contribute to the correct final position of the eye in the orbit.

These are the reasons that have led to the development of specific devices for performing the test (v-HIT device).

The c-HIT is unable to perceive refixation saccades during head rotation and can lead to false negative evaluations in patients with peripheral vestibulopathy. The v-HIT instead allows overt and covert saccades to be identified, providing information on the function of each semicircular canal quantifying the gain (i.e. quotient between the velocity of the eye and that of the head) of the VOR.

If the VOR in response to a high-velocity impulsive movement is not able to guarantee that the line of gaze is kept on the target, the difference between the position of the head and that of the eye will evoke the appearance of a corrective saccade.

In relation to the above, the saccades that are made after the head movement has finished (overt) will be visible to the naked eye during consultation by an examiner with a minimum of experience, without any instrumental aid.

If the difference in position between the head and the line of gaze can be predicted early, refixation saccades may manifest during the movement of the head (covert) and will be impossible to identify without a dedicated instrumental device (high sampling rate cameras).

We must also remember that when the head impulses have poor predictability, covert saccades have a limited ability to accurately position the line of gaze on the target. In these cases, a – probably overt - secondary saccade will be necessary to reach the target. Such secondary saccades will usually be characterized by an amplitude that is smaller (since they must fill a shorter distance gap), but with the same latency compared to primary covert saccades.

We will see in detail later how the constitutive elements of the oculomotor response after a impulsive head movement are represented by refixation saccades (covert and overt), VOR gain and the morphology of the VOR.

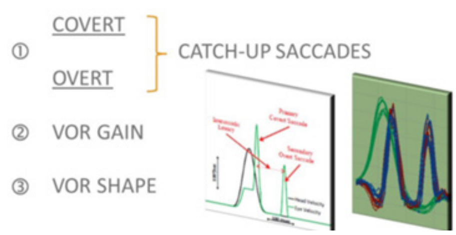


Figure 2 Analysis of constituent elements of the oculomotor response after impulsive head movement Armato E, 2016.

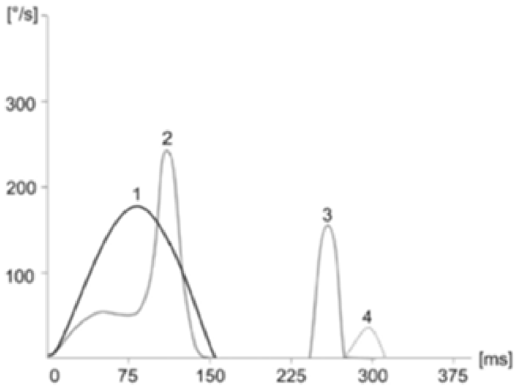
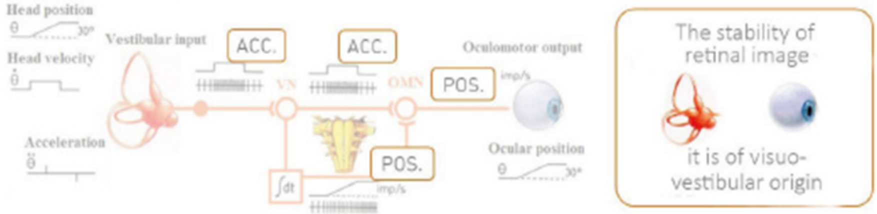


Figure 3 Schematic occurrence of refixation and physiological saccades. (1) eye velocity, (2) covert saccade, (3) overt saccade and (4) phisiological saccade. Blodow, 2013.

Low frequencies (non physiological)

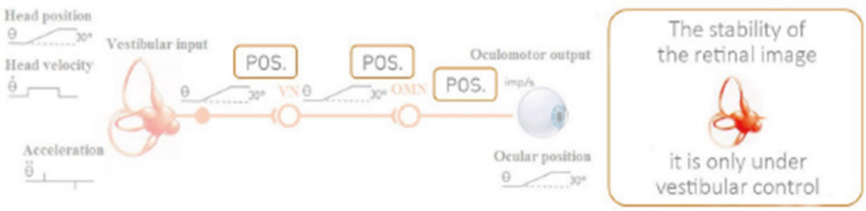
The signal is in phase with the **acceleration** of the head. The NPH performs an integration. A second integration (from a velocity signal to a position signal) is impossible.

Medium Frequencies



The signal is in phase with the **velocity** of the head. The NPH performs an integration.

High Frequencies



The signal is in phase with the **position** of the head. No additional integration required.

PI - Eye Detection_Rev01 • Date: 2024.01.29

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