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Principles and Methods of Ocular Recording in V-HIT

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.

LIMITATIONS OF THE CLINICAL HEAD IMPULSE TEST

The clinical Head Impulse Test allows the refixation saccades that occur after the movement of the head has finished, known as overt saccades, to be detected. The absence of an overt saccade, however, is not sufficient to guarantee the functionality of the VOR. From this the need arose that led to the development of sufficiently fast and highly accurate systems, capable of acquiring objective measurements of head and eye movements, as well as of detecting covert saccades.

SYSTEMS FOR EYE MOVEMENTS ANALYSIS

Videonystagmography (VNG): a camera takes an image of the patient's face and eyes, illuminated by an infrared source. Video sequences are recorded and then analyzed by the software through image processing algorithms. The advantages of this technique are its low cost, greater comfort for the patient, good precision (up to 0.1°) and a large range of measurement, and the fact that it is not subject to any electromagnetic noise. There are no substantial disadvantages, other than the need for the patient to keep his or her eyes open during the examination.

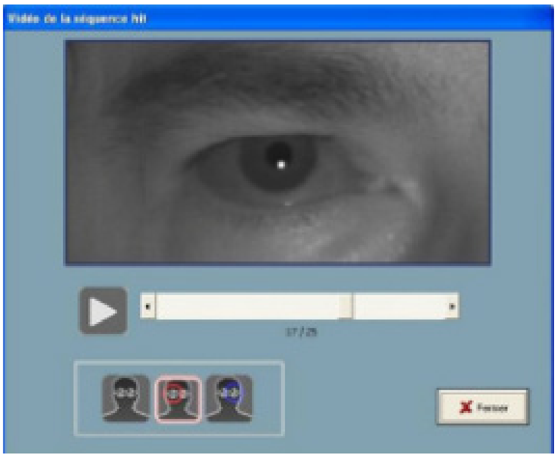

Figure 1 VNG video sequence.

THE V-HIT: TWO PRINCIPLES OF ACQUISITION

For numerical quantification of the VOR's functionality, it is necessary to calculate the ratio between the velocity of the eye movement and the velocity of the head following the maneuver imparted by the examiner, called the VOR gain. A subject with canal functionality will present a gain that is roughly unitary. The minimum requirements of a system designed for this purpose are therefore:

- Head velocity measurement
- Eye velocity measurements

There are essentially two video technologies that allow you to obtain what is needed:

- Remote camera-based systems
- Head mount-based systems with integrated accelerometric sensor and a camera.

REMOTE CAMERA-BASED SYSTEMS

A system of this type consists of a remote camera – usually an infrared one – that frames the patient's face during maneuvers. The software performs all processing and calculations related to the analysis of sequential images recorded by video, through Eye-Tracking and Head Pose Estimation algorithms. It is able to determine the position (and hence, the velocity) of the head and eyes.

The first vHIT ever made was in fact a remote camera-based system. Designed and developed in 2005 in Marseilles by Dr. Erik Ulmer, it is the only system on the market based on this technology (Ulmer, 2005).

Figure 2 Synapsys Ulmer v-HIT with remote camera

HEAD MOUNT-BASED SYSTEMS

These systems consist of a head mount, the velocity of which (supposedly perfectly integral to the head) is measured by an integrated accelerometric sensor, while an infrared camera mounted on the device captures the image of the eye reflected on a silver mirror, placed in front to the eye itself but so as not to impede vision.

The processing and calculations are carried out by a software combining the information coming from two different sources:

- from the camera, to calculate the velocity of the eye from the video images
- from the accelerometric sensor, to measure the velocity of the head.

The first vHIT based on this technology was developed by Engineer Hamish G. MacDougal in 2009, at the University of Sydney.

Figure 3 Natus ICS Impulse

Figure 4 Interacoustics EyeSeeCam

COMPARING TECHNOLOGIES

- **Design and development**

The head mount-based systems require that they are subject to as little slippage as possible due to the inertia that inevitably occurs during high velocity maneuvers. Such slippage generates fictitious eye movements relative to the camera and artifacts resulting from the head mount shifting position. It is therefore crucial to develop robust algorithms, which in addition to reconstructing the eye velocity from video sequences and syncing them to measure the head velocity, correct these artifacts so as not to affect the accuracy of the calculations.

Remote camera-based systems, on the other hand, do not present specific challenges in terms of hardware design, but must use accurate image-processing algorithms for the reconstruction of head and eye movements from video sequences. In these systems there are no artifacts from slippage and no need to adopt specific software features to correct them.

- **Set-up**

In head mount-based systems, the presence of a pair of goggles with a narrow band around the head is less comfortable for the patient compared to remote camera-based systems which do not have any accessories to wear. The mask also has elements that can enter in the patient's visual field. Systems with masks require an initial calibration with laser pointers for the subsequent correct measurement of eye movements.

Remote camera systems require the positioning of the patient at the correct distance so that the image is perfectly in focus. The mask does not lend itself well for use in children, both because of the excessive size and the obstruction it creates during the execution of the examination. A remote camera, on the other hand, can be used in pediatric patients of a few months old, as long as they manage to maintain their attention fixed on the lens. The examinations conducted by Dr. Sylvette Wiener-Vacher from the Robert Debré Hospital in Paris are impressive in this regard (Wiener-Vacher, 2017).

- **Operability**

In systems with masks, the practitioner must perform the maneuvers without touching the device so as not to introduce additional slippage between the camera and the head, resulting in artifacts; the freedom in maneuvering the patient's head is thus limited.

On the other hand, with a remote camera there is no limitation in this regard. Furthermore, due to the increased data interference due to artifacts and the acquisition technology that integrates the information coming from two different sources, systems with wearable masks require a greater number of acquisitions (15-20 versus 5 in devices with a remote camera) to obtain a reliable result. In addition, the remote camera-based systems allow the practitioner to review the replay of acquisitions in slow motion, with the opportunity to check with his or her own eyes for any reciprocal movements between the corneal reflection and the pupil. Finally, regarding portability, the devices with head mounts are certainly more comfortable to carry as they are less cumbersome.

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