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# A Study on the Quantitative Functional Exploration of Vestivular Oculomotor System

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**=Abstract=**

This study describes the battery functional test in order to explore vestibular oculomotor system. These tests are the following : a) acceleration test by using a pseudorandom stimulus. b) caloric test by considering both the constant temperature variation in the semicircular canals for a short time and the only head movement, to the fore and the back, for the ear irrigation, which gave us two types of stimulus (cold and warm) according to the only head position. c) optokinetic test by continuous constant velocity displacement of a large image filling the entire subject's visual field. With relation to the clinical practices, some results of research programs which are at present in progress are presented.

## 1. INTRODUCTION

In general, vestibular oculomotor system subserves static and dynamic spatial orientation, and controls posture and locomotion. The vestibular and the visual system are the two primary inputs to this system. The vestibular system provides a compensatory mechanism to stabilize the environments during head movements. The visual system drives the oculomotor system to make compensatory eye movements when the visual field moves[1-2]. As shown in Fig. 1, the vestibular oculomotor system is mainly devided into four subsystems such as vestibulo-ocular reflex, saccade, pursuit and optokinetic system[3].

The vestibular oculomotor system can be considered as a multi-input and one-output system. Each input corresponds to a sensory channel providing the central nervous system with information that can be used to control eye movement. The output is eye movement in the orbit. With the input considered and the modality of stimulation, different input-output pathway are stimulated and different types of eye movement can be evoked. Then, an approach to the analysis of vestibular oculomotor system is to observe the system response to the appropriate stimulus of various sensory channels[4].

Fortunately, thanks to the recent progress in vestibular oculomotor research, most of pathway subserving the different vestibular oculomotor responses have been indentified and desc-

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ribed. Moreover many analytical porgram developed for the functional exploration of vestibular oculomotor system have been reported[5-6]. It has been also reported that important pathological situations induce significant modification in the vestibular oculomotor response. But it is worth asking what is the best way of exploring the vestibular oculomotor system in view of clinical practice. Thus the objective of the present work is to describe a battery test for functional exploration of the vestibular oculomotor system, which is more useful to solve a particular diagnostic problem than a single test from a clinical point of view. It is also to provide a comparison of the most important data with each other test and to enable the clinician to determine at a glance whether a pathology exists in the function of vestibular oculomotor system.

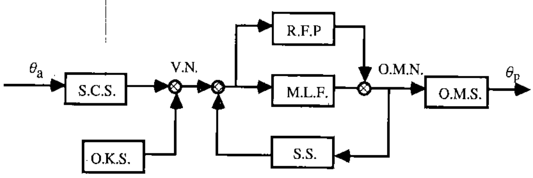


**Fig. 1** Block diagram of vestibular oculomotor system
S.C.S. : semicircular canal, V.N. : vestibular nucleus, M.L.F : medial longitudinal fasciculi, R.F.R. : reticular formation pontine, S.S : saccade system, O.M.S. : oculomotor system, O.K.S. : optok-inetic system, O.M.N. : oculomotor nucleus, $\theta a$ : Head Acceleration and $\theta p$ : eye Position.

## 2. BATTERY TEST

### 1) Pseudorandom acceleration test

Since the semicircular canal is a sensor of an angular head acceleration this test represents the specific stimulus for the semicircular canals of the vestibular system. The subject is seated in a chair mounted on the servocon-trolled motor that rotates about a vertical axis in the dark in order to exclude interactions with the visuo-motor system. The head of subject is inclined to 30 degrees forward for sermicircular canal to be just in the horizontal plan. The subject are rotated in a pseudorandom pattern, which consisted of a summation of seven sinusoidal frequencies (from 0.01 to 0.48 Hz). This psesudorandom stimulus permits to prevent habituation processes due to the repeated motion pattern, to minimize exploration time, and to obtain the frequency response in the multifrequency ranges in comparison with single frequency harmonic stimulus[7-9].

### 2) Caloric test

Classically, caloric test consists in an irrigation of one ear with either cold or warm water. In the inner ear a temperature gradient is so created which in turn produces a pressure gradient in the endolymph of the semicircular canal with the consequent stimulation of its receptors. The caloric test that we have proposed is to use only one temperature, which gives us two kinds of stimulus (cold and warm) according to only head position[10]. The ears of subject is irrigated with cold water (volume=50cm³, temperature=25℃, injection time=20sec). The head position is inclined forward with the angle of 30 degrees. Then the lateral semicircular canal is in the horizontal. As soon as the irrigation is over, the head is leaned backward with the angle of 90 degrees. This head position is maintained for 50 sec. The inverse stimulus is obtained by leaning the head forward with the angle of 180 degrees. This position is maintained for 50 sec. The new inverse stimulus is obtained by leaning the head backward with the angle of 180 degrees.

### 3) Optokinetic test

Optokinetic test is done by continuous constant velocity displacement of large image filling the entire subject's visual field. A subject is seated with head fixed in the chair which is surrounded by a cylinderical screen with a radius of 120 cm and a height of 180 cm. The inside of screen is colored with white. Above the head of subject on the chair there is an optokinetic drum which projects light slits onto the screen and rotates at a constant velocity by the servo−control. This rotation of optokinetic drum stimulates the subject's entire visual field. The light source of optokinetic drum is turn on during 40 sec for OKN. The light is turn off to measure OKAN in the dark during 40 sec. Six constant velocity of 5, 20, 35, 65, 80 deg/sec are used. Before each test, the subject is instructed to look forward but not to follow the moving projected images. During each test interval, the subject's eye is closed in order to avoid impressing the after−images of stationary stimulus pattern on the retina[11].

All of eye movements are recorded by electro−oculography (EOG) with silver−silver chloride electrodes placed at each outer canthus. The ground electrode is positioned in the forehead. EOG signals are amplified, low−pass filtered and digitized. Each calibration of eye movement is taken from the voluntary saccades by using a target with built in light emmiting diodes which are located 10 degree to the left or right of the primary fixed position in the center of target. The data analysis such as the detection of fast phase, the separation of two phases, the removal of fast phase, the reconstruction of slow phase, the calculation of slow phase velocity, and the calculation of frequency responses (gain and phase) are realized by real time processor (IN110). As shown in Fig. 2, the explorating system mainly consists of a rotating chair, a light panel for the calibration, optokinetic drum, cylinderical screen, and the personal computer which permits data acquisition and signal

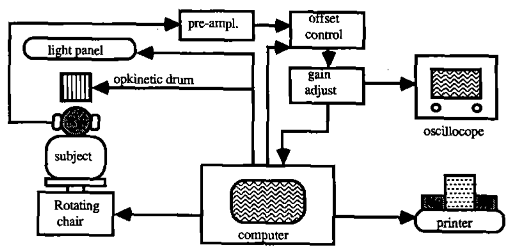


**Fig. 2** Block diagram of explorating system for vestibular oculomotor system

## 3. FUNCTIONAL EXPLORATION SYSTEM

The block diagram of the procedures explored is shown in Fig. 3. The exploration system consists of seven main procedures as like tree structure. The examination is started by the following.

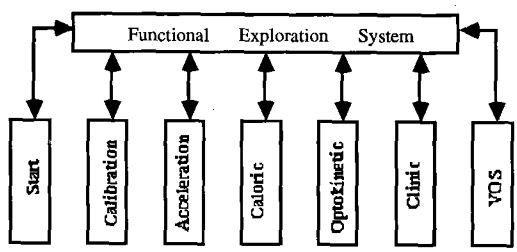


**Fig. 3** Block diagram of the exploration procedures for vestibular oculomotor system

### 1) Start

The number of examination is fixed.
The connection of devices is verified.

The subject is seated in the test chair and electrodes are placed on each outer canthus with the ground electrode in the center of the forehead.

The chart of patient is filled.

The adjustment of measurement system is carried out and then the operator chooses one of different tests.

### 2) Calibration

This is the test of conjugate ocular movement which is applied to all of the subject because it serves to calibrate the eye movement. This procedure is the following :

The creation of pseudorandom signal consisted of four periods. In the first period, the subject is instructed to fix their gaze at the central emmiting diode of the target. For next two periods, the subject is asked to make voluntary saccades by following the diode emmited randomly with the amplitudes of 20 degrees. During the last period, the subject is asked to fix their gaze at new central emmiting diode in order to verify if their behavior is not disturbed. The duration of each period is 25 sec. The light pennel is placed at the distance of 120 cm from the front of subject.

The acquisition of the eye movement and of the target movement.

The pretreatment is to correct slow drift by the least square method and to compensate the sudden jump of ocular signal depended on the subject.

The calibration is carried out automatically and the amplitude of saccade is determined by the histogram of the ocular signal. The mean delay is calculated on the base of the intercorrelation between the stimulus and the response. The eye velocity is calculated for both right and left saccade.

The graphical and numerical output are the target movement, the ocular movement, the calibration factor and the standard deviation of eye velocity.

### 3) Acceleration

-The creation of pseudorandom signal, which is used to control the chair rotation. This stimulus signal is composed of 10 periodes. The period is interpolated by cosine function and the duration is 100 sec. The first and the last period are modulated linearly in amplitude in order to assure the progressive start and stop of chair. For a good ratio of signal to noise, eight periods are explored.

-The acquisition of the eye movenemt and of the chair movement

-The signal treatement is the following :

Velocity and acceleration signals of eye movement are calculated.

Fast phase is detected by a threshehold.

Fast and slow phases are separated.

Fast phase is eliminated.

Slow phase estimator is multified by the velocity signal.

Linear interpolation is carried out between different slow phases.

Slow phase velocity is reconstructed.

Transfer function is calculated for both the slow phase eye velocity and chair velocity.

-Graphical ourput are the following :

Chair movement and eye movement.

Slow phase eye velocity and chair velocity (Fig. 4).

Cumulogram of eye movement and chair position (Fig. 5).

Frequency response (gain and phase)and coherence function (Fig. 6).

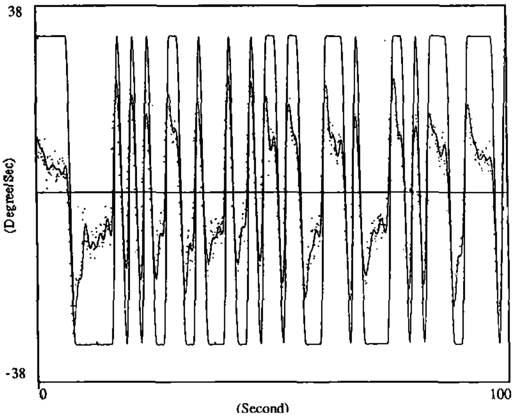


**Fig. 4** Chair velocity and alow phase eye velocity

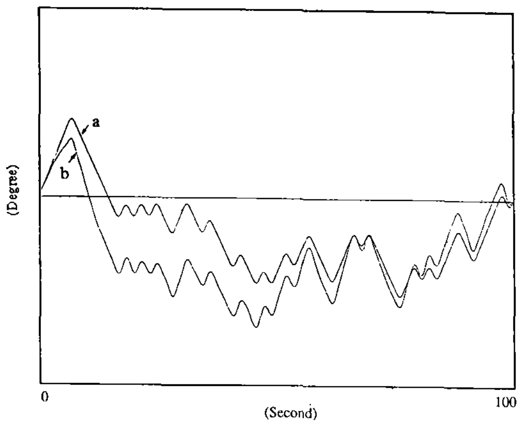


**Fig. 5** Cumulograms of chair and solw phase eye movement
a) Chair b) Eye

### 4) Caloric

—Stimulus is created by the injection of cold water and the head movement.

—Acquisition of the eye movement and of the head movement.

—Signal treatment is carried out by the same-method as like the accceleration.

—Histogram of time interval between the saccades is calculated.

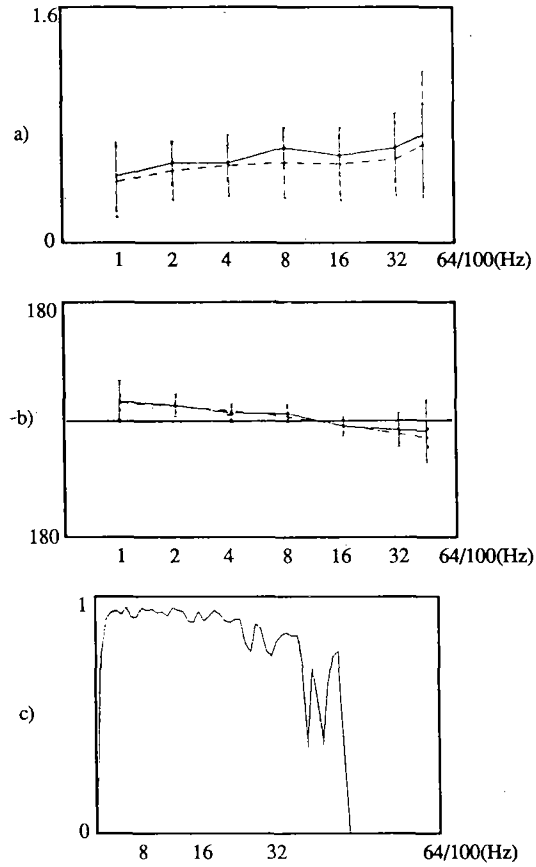


**Fig. 6** Frequency response and cohereance function
a) Gain b) Phase c) Coherence Function

—Graphical output are the following :

Cumulogram of solw phase eyemovement before and after inverse stimulus (Fig. 7).

Histogram of time interval between the saccades before and after inverse stimulus (Fig. 8).

### 5) Optokinetic

—Creation of stimulus is done by rotating the-optokinetic drum at a given constant velocity with the light turn on for OKN(optokinetic nystagmus)and with the light turn off for OKAN

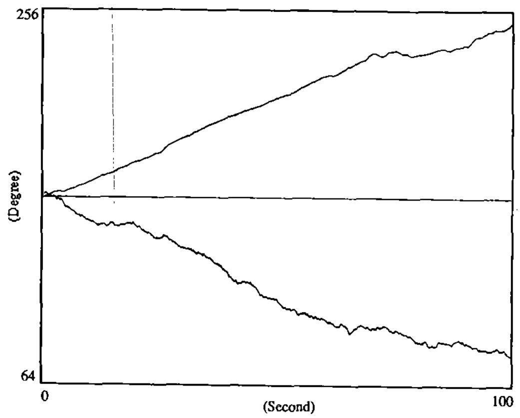


Fig. 7 Cumulograms of wlow· phase eye movement before and after inverse stimulus

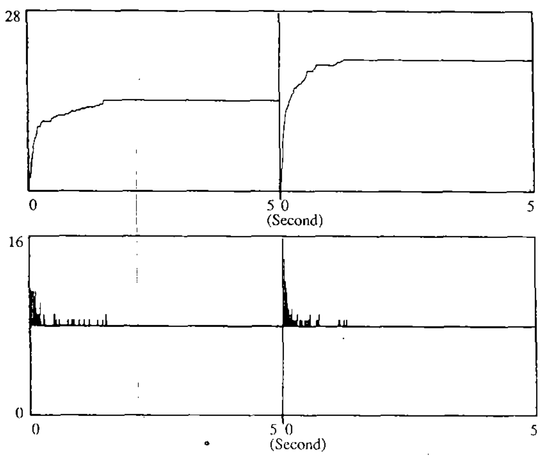


Fig. 8 Histogram of time interval between the saccades before after inverse stimulus

(optokinetic after nystagmus).

—Acquisition of eye movement and of the stimulus.

—Signal treatment is realized by the same method as like the acceleration.

—Slow phase velocity gain is calculated between the slow phase eye velocity and stimulus velocity.

—Graphical output are the following :

Solw phase velocity gain (Fig. 9).

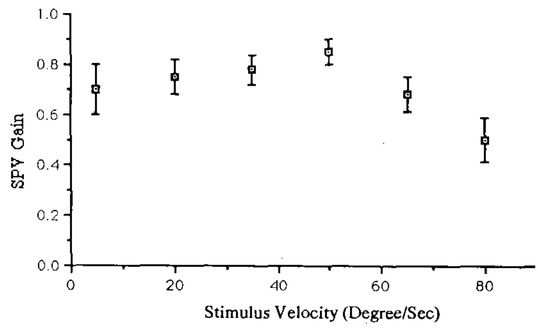


Fig. 9 Slow Phase Velocity Gain according to Stimulus Velocity

### 6) Clinic

—Four questions are given by the following.

Symptom.

Actual treatment.

Previous history.

Clinical examination.

—Examination report is printed.

### 7) Vos

—Several results are regrouped in this module.

—Report on the results regrouped is printed and is saved.

—Each test result can be called in case of need.

## 4. CONCLUSIONS

In this study, we have described the battery tests which is more useful to explore the vestibular oculomotor system than a single test from the clinical point of view. This study made it possible to systematize a large volume of clinical test data and to enable the clinician to come to a quick conclusion about whether a patient has a pathological response or not. This study also leaded us to the document of the complete set of clinical vestibular oculomotor investigation. But there are mang problems awaiting solution such as the realization of computer programs for eye movement processing easy to use but robust enough to stand the test of pathological response analysis and the definition of optimal exploration procedures for vestibular oculomotor system in relation to the suspected pathology.

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