The Integrated Optokinetic Nystagmus Inter-saccadic Interval Scales Statistical Different In a Group of Vertigo Patients Depended On The Stimulation Velocity, But Not For Healthy Subjects

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Research Article

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Abstract

Optokinetic nystagmus is rhythmic eye movements, back and forth, with a slow and fast phase, when the eyes are presented for full-field visual stimulus. OKN was recorded in 20 healthy subjects and 20 patients suffering from vertigo, for four conditions: stripes moving 30 ^{o}/s left and right and 60 ^{o}/s left and right.

Calculating the scaling, the spread over time, for the integrated optokinetic nystagmus inter-saccadic interval, the time intervals between the onsets of consecutive fast components, shows lower Hurst exponent for velocity stimulation of 30^{o}/s compared to 60^{o}/s for both patients and health subjects, but only reach statistical differences for the group of patients.

1 Introduction

In an earlier study it was shown that the pattern of the optokinetic nystagmus (OKN) amplitude sequence scales statistically different compared to random permutations of the same numbers [1]. The aim of the present study was to analyze if the OKN stimulation intensity, stripes moving with velocity of 30 and 60 ^{o}/s, influences the scaling properties of the integrated optokinetic nystagmus inter-saccadic intervals in a group of patients suffering from vertigo and a group of healthy subjects.

1.1 Optokinetic nystagmus

When presented with a moving image, the eyes respond with a movement in the same direction as the image, interrupted by quick/fast resetting phases [1–5]. Optokinetic nystagmus inter-saccadic interval (OKN-ISI) is the time intervals between the onsets of consecutive fast components.

1.2 Hurst exponent

The scaling coefficient *H*, the Hurst exponent, is a measure of memory of a time series with the three properties [6–11]. $H < 0.5$ corresponds to a process with negative autocorrelation. $H = 0.5$ corresponds to a time-integrated white noise time series with no memory. $H > 0.5$ corresponds to a process with positive autocorrelation.

2 Material And Methods

2.1 Subject

Ten patients suffering from vertigo and ten healthy subjects were included in the study. The patients included were consecutive patients examined at the Vestibular and Balance laboratory at the Department of Otorhinolaryngology and Head and Neck Surgery at Haukeland University Hospital, Norway. The healthy subjects were recruited among healthy hospital staff. All methods were carried out in accordance with and approved by the Regional Committee for Medical and Health Research Ethics (REK 2012-1075). Informed consent was obtained from all subjects.

2.2 Recording technique

Horizontal eye movements were recorded with two electrodes (Ag-AgCl skin electrodes), which were placed laterally to each eye, along with a reference electrode at the center of the forehead. The signal was amplified (10 s time constant and an upper cut-off frequency of 30 Hz) and digitized into a computer, using 12 bit A/D resolution and 100 Hz sampling frequency (sampling time $\tau s = 0.01$).

OKN was recorded for four conditions: stripes moving 30 º/s left and right and 60 º/s left and right. This gives a total of 40 recordings: 20 for 30 º/s -, and 20 for 60 º/s velocity.

2.3 Optokinetic stimulation and registration

OKN was obtained by stimulating the visual field with 3.75˚ width vertical light stripes separated by 11.25˚ width dark stripes. A slit projector presented the stripes on the inside of a hemispherical screen (100 cm in diameter). The subjects were sitting in front of a screen in a darkened room with the head restrained. The subjects were instructed to not follow the stripes with the eyes but to focus their vision on the screen, allowing the optokinetic reflex to control the eye movements. Recordings were performed with the movement of the stripes at a velocity of 30˚/s and at 60˚/s, which are below and above the normal threshold for smooth pursuit function [12, 13]. Each recording lasted for 1 min. Figure 1 shows a 1 s recording of OKN.

3 Methods And Analysis

Analyzing methods for distinguishing random behavior from long-term correlation/memory in time series have been described [14]. It has been shown that the mean square displacement exhibit scaling laws proportional to Δt^{2H} [15].

$$< \Delta x^2 > = <(x_i - x_{i-\Delta t})^2 > \sim \Delta t^{2H} \quad (1)$$

$< \Delta x^2 >$ is the mean square displacement, Δt is the time interval and H is the Hurst exponent. If data are independent, i.e. no memory, the displacement will increase with the square root of time and H = ½.

3.1 The algorithm

The algorithm was applied to the integrated - the cumulative sum - of the nystagmus intersaccadic-interval sequence series, T_i, adjusted for the mean.

$$\{x\}_{i=1}^{n} = \sum_{i=1}^{n} (T_I - meanT_i) \quad (2)$$

where

$$meanT_i = \sum_{i=1}^{n} \frac{T_i}{n} \quad (3)$$

The time series, x_i, represents the integrated OKN-ISI sequence. A 1 min recording gives approximately n = 160 nystagmus beats.

First, we calculated the mean square displacement in measure of number of nystagmus inter-saccadic intervals k_i.

$$< \Delta x_i^2 >_k = \left\{ \frac{\sum_{i=1}^{-k+n} (x_{i+k} - x_i)^2}{(-k+n)} \right\}_{k=1}^{n/2} \quad (4)$$

Then, from the scaling properties, we find the slope S_i.

$$s_i = \frac{1}{2} \frac{Log(< \Delta x_i^2 >_k)}{Log\ (k)} \quad (5)$$

The scaling was then calculated using the method of least square to fit straight lines for 1 to m (m = 4 to n/2) nystagmus inter-saccadic intervals (see Fig. 2).

Since the results of the Shapiro-Wilk test showed that the data was normally distributed ($P_{V30} = 0.949$ and $P_{V60} = 0.512$), paired Student t-test was used to compare the mean values of the Hurst exponent parameters for velocity stimulation of 30°/s and 60°/s for the group of healthy subjects and for the group of vertigo patients.

4 Results

Comparing the Hurst exponent for velocity stimulation of 30°/s and 60°/s for the group of patients for various scaling length shows highest significant differences for scaling of m = 36 nystagmus inter-saccadic intervals (p = 0.00319) (see Fig. 3). No significance was found for the group of healthy subjects.

Figure 4 shows the mean and standard error of the scaling for velocity stimulation of 30°/s and 60°/s for scaling length m = 36 for patients and healthy subjects. The mean Hurst exponent is lower for stimulation of 30°/s compared to 60°/s for both the patients and health subjects, but it only reaches statistical differences ($p < 0.005$) for the group of patients.

5 Discussion And Conclusion

The mechanism behind the regulation of the various nystagmus component, related to the dynamical behavior when responding to the environment, is still unexplored. In an earlier study surrogate data analysis shows that the pattern of the OKN amplitude sequence is statistically different compared to the random permutations of the same numbers [1]. The present study shows that there is difference in the scaling, the spread of the integrated optokinetic nystagmus inter-saccadic interval over time, when increasing the OKN stimulation from 30 to 60 °/s, implicating that the system switch to a different dynamical behavior. The result of discriminating finding between healthy and patients, based on statistical differences of the scaling between OKN stimulations of 30^o/s and 60^o/s velocity is a novel finding. This finding is a supplement for better understanding of the mechanism behind the regulation of the nystagmus sequence when reacting to the environment and can be helpful in diagnose vertigo patients.

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Figures

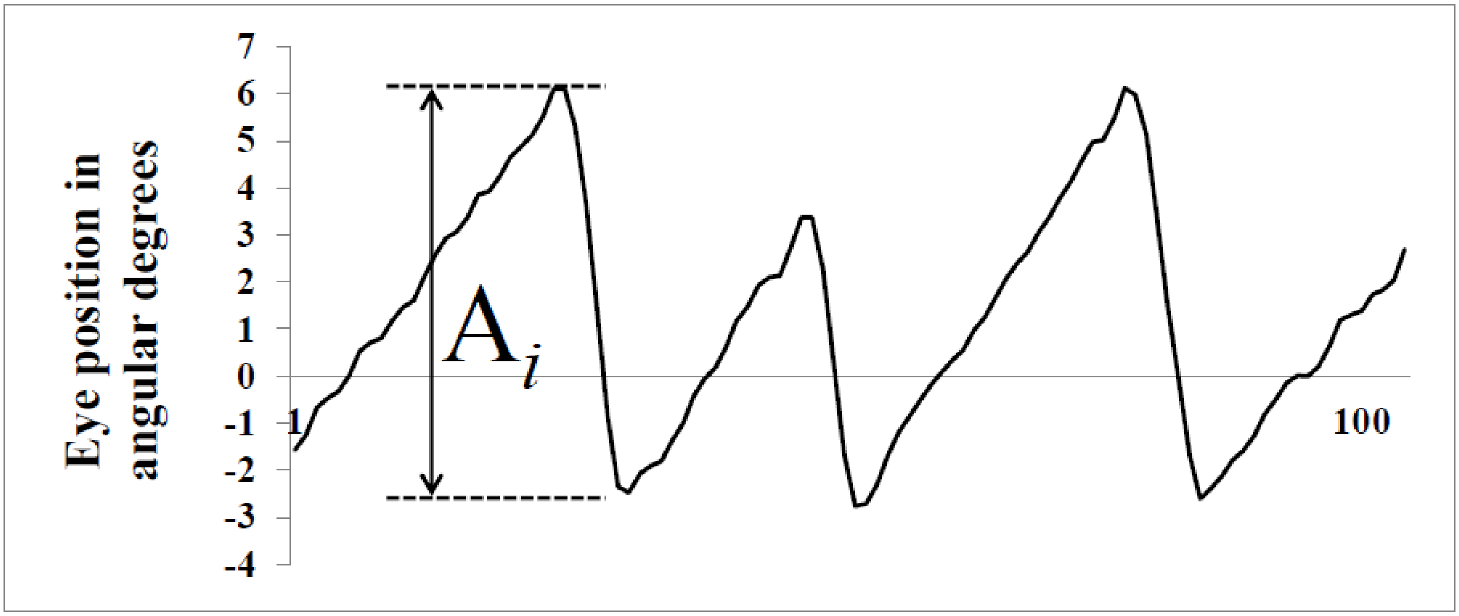

Figure 1

A 1 s registration of an optokinetic time series. Upward direction represents eye movement to the right and downward direction represents eye movement to the left.

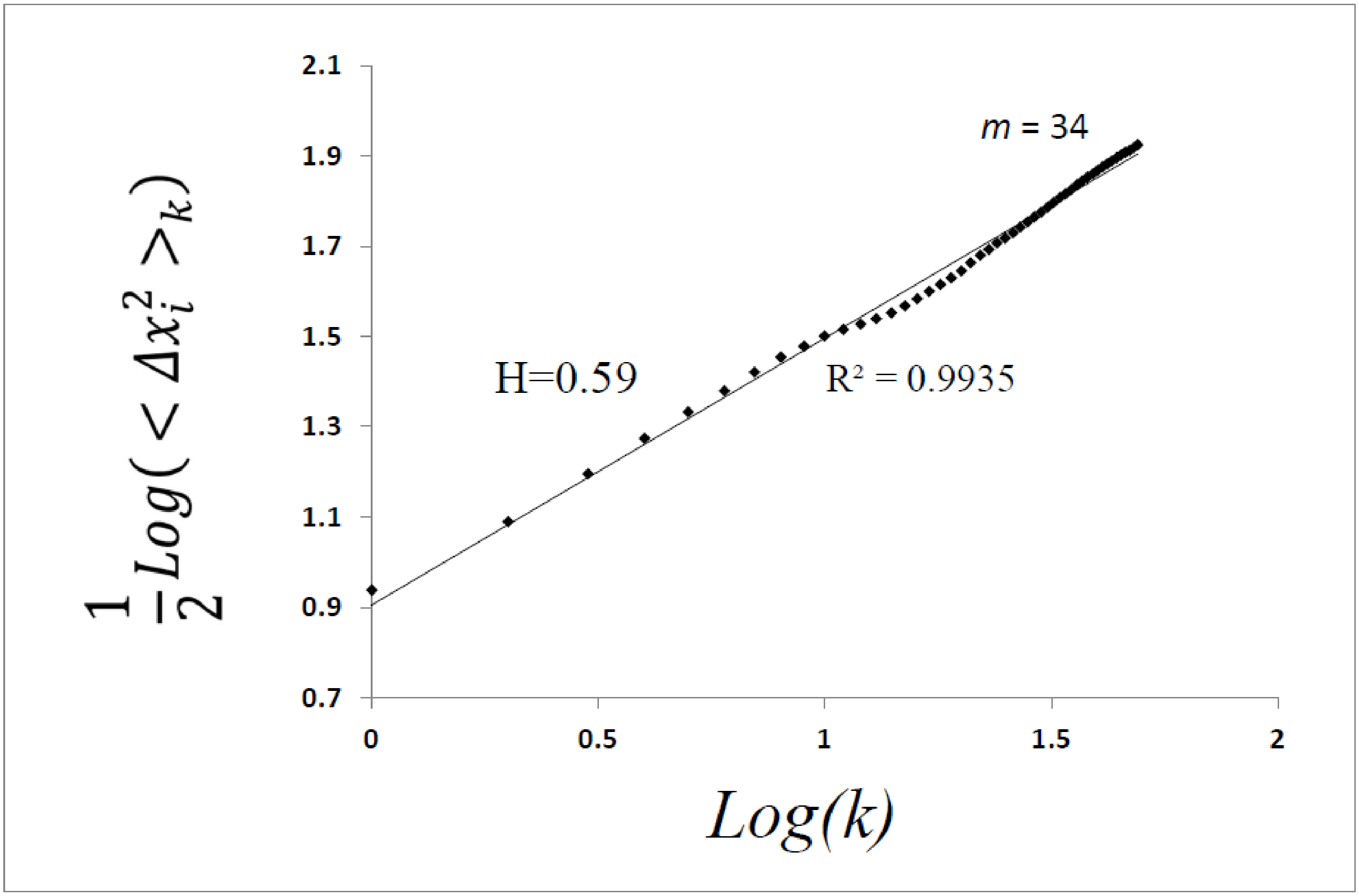

Figure 2

Plots of Log(k) versus $12Log(<\Delta x_i^2>k)$ for a sequence of integrated optokinetic nystagmus inter-saccadic interval for scaling length m = 36.

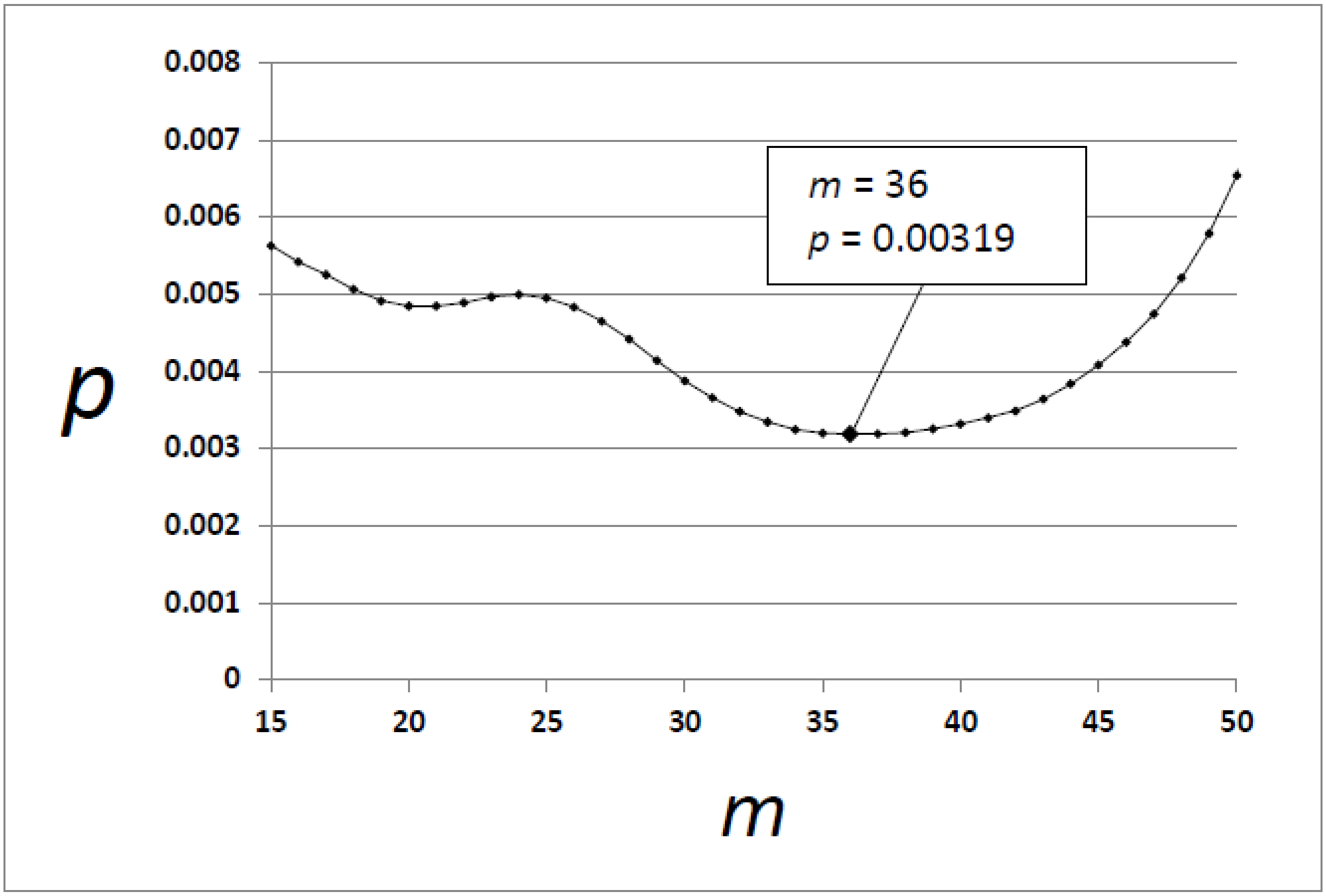

Figure 3

Plots of the significant level p for the difference between velocity stimulation of 30o/s and 60o/s for the group of patients for various scaling length m. Highest significant differences is found for scaling length of m = 36.

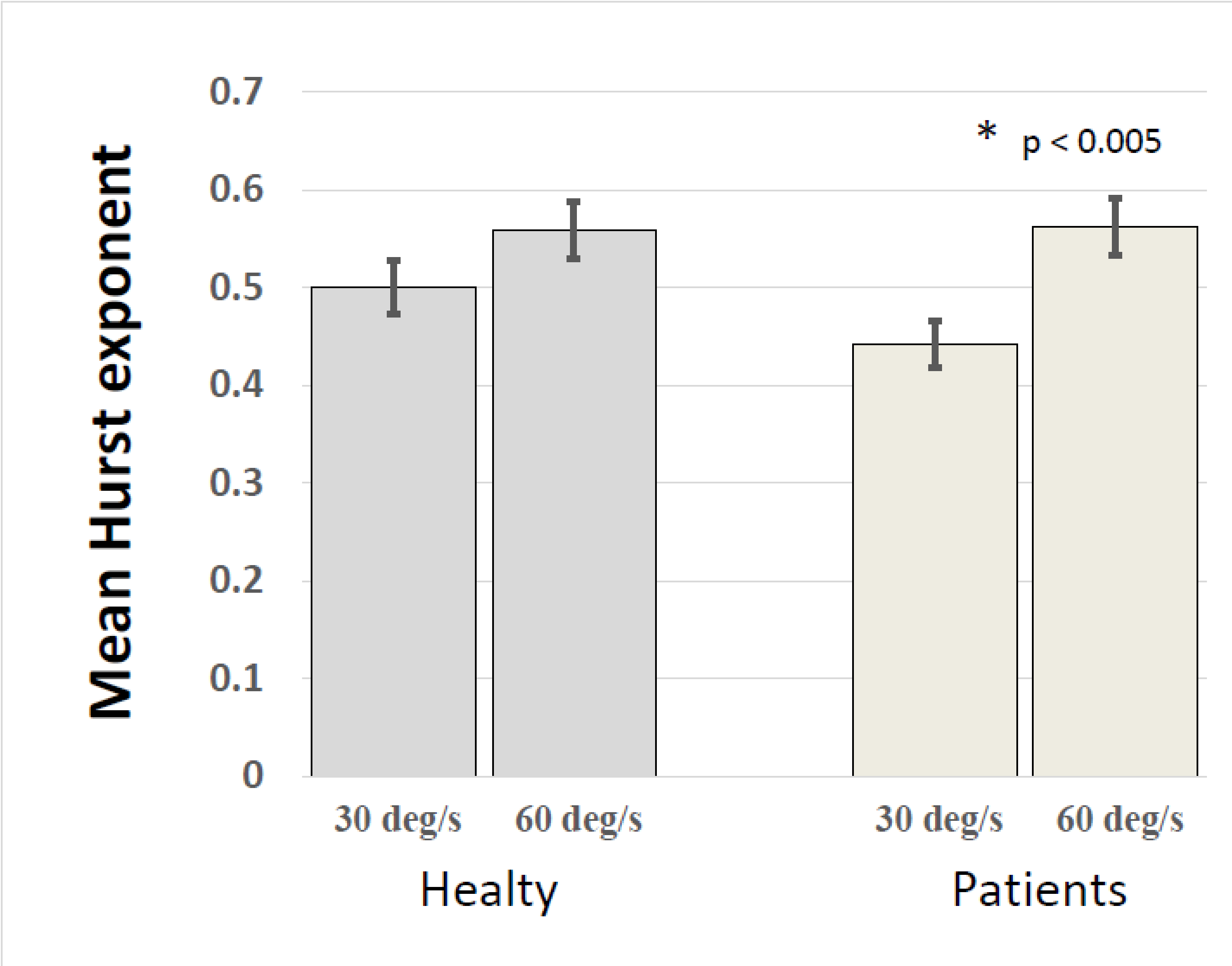

Figure 4

Mean and standard error of the Hurst exponent for OKN stimulation of 30o/s and 60o/s velocity for scaling length m = 36 for the groups of healthy subjects and vertigo patients. * p < 0.005