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Clinical Neurophysiology 118 (2007) 551–557

www.elsevier.com/locate/clinph

EEG correlates of subcortical optokinetic nystagmus

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Accepted 29 October 2006
Available online 14 December 2006

Abstract

Objective: Our aim was to reveal the changes of concomitant scalp EEG activity during subcortical (stare-) optokinetic nystagmus (OKN).
Methods: Stare-OKN of 10 subjects was evoked and recorded simultaneously with the EEG. Frequency distribution of OKN-beats was determined in each subject. Power changes of alpha and beta frequency bands of the EEG during OKN stimulation were statistically analysed.
Results: During continuous subcortical OKN–the EEG alpha power decreased significantly while beta power increase was not significant. A significant transient alpha power enhancement around the onset of subcortical OKN-clusters was detected.
Conclusions: We found significant changes in the parieto-occipital alpha EEG activity during subcortical OKN. The transient alpha synchronisation at the beginning of each OKN-cluster is a paradox phenomenon which might indicate increased visual attention.
Significance: The present study is the first report investigating EEG changes related to subcortical OKN. Our findings suggest the involvement of cortical mechanisms in the generation of stare-OKN. The results might help in the elucidation of cortico-genicular mechanisms of ocular movements under physiological and pathological conditions.

Keywords: Stare-nystagmus; Optokinetic nystagmus; EEG; Alpha synchronisation; Attention

1. Introduction

The neurogenic mechanism behind human OKN has not been clarified yet. Clinical and electrophysiological observations suggest that there are two different types of OKN.

"Look"-OKN is the cortical type, which is elicited by voluntary pursuit mechanism during foveal stimulation in attentive subjects (Ilg, 1997; Ilg and Hoffmann, 1993; Honrubia et al., 1968; Magnusson et al., 1985). To evoke cortical OKN, subjects are instructed to look at and follow attentively a moving object. In this type of nystagmus the angular velocity of gaze is high while the nystagmus frequency is low (Magnusson et al., 1988; Ter Braak, 1936; Valmaggia et al., 2005).

"Stare"-OKN is the subcortical type, which appears if the peripheral retina is stimulated in inattentive subjects. It is induced if the subject stares at the centre of the stimulation field without paying attention to the moving pattern (Holm-Jensen, 1984). In this case the gaze velocity is low but the nystagmus frequency of OKN is high (Holm-Jensen, 1984; Magnusson et al., 1985, 1988; Ter Braak, 1936). Cortical and subcortical OKN often alternate during the stimulation (Konen et al., 2005).

Stimuli that modify the level of arousal and/or visual attention influence both the cortical and subcortical OKN (Campenhausen and Kirschfeld, 1999; Holm-Jensen, 1984; Jung, 1972). Sound or vibration increases the mean velocity of the slow phase of OKN, and reduction of slow phase velocity occurs when occipital alpha rhythm reappears in the EEG (Magnusson et al., 1985).

The main objective of our study was to co-register subcortical OKN and EEG in order to reveal EEG changes related to the process of subcortical OKN generation.

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1388-2457/$32.00
doi:10.1016/j.clinph.2006.10.020

2. Methods

2.1. Subjects

Ten healthy volunteers (4 females, mean age: 27.06 ± 4.39 years) were examined, all of them were right-handed (Edinburgh Handedness Inventory score: 35 or 36 points). None of the subjects had any history of neurological, ophthalmological or vestibular disease. No drugs or alcoholic beverages were allowed for at least two days before the experiment. Every subject had regular occipital alpha activity of 9–11 Hz at rest, with open eyes. The protocol was approved by the Local Ethical Committee, subjects signed informed consent.

2.2. OKN stimulation

Recordings were carried out in a darkened room. Subjects were seated 1.3 m from the middle of a white screen (1.5 m by 1 m), which was seen from 60°. OKN was elicited by projecting 10 cm (4°) wide black and white stripes onto the screen, which were moving horizontally with a velocity of 30°/s. Subjects were instructed to "stare at the middle of the screen without following the stripes", in order to evoke dominantly subcortical OKN. The direction of the first stimulation (right or left) was randomly selected. Subjects were allowed 10 min of rest before changing the direction of stimulation. Stimulation epochs in one direction lasted for 120 s, and were repeated twice.

2.3. Electrophysiological recording

Eye movements were recorded using standard electro-oculographic technique (EOG). Eight, Ag/AgCl electrodes were placed around the eyes. AC amplification with a time constant of 1 s, and 30 Hz upper cut off frequency was used (Brain Star EEG-Recording 3.55 ©Hienert-Brandl Software, Berlin, Germany).

The EEG signal was recorded simultaneously with the EOG. Six EEG electrodes (O2, P4, T6, O1, P3 and T5) were placed on the scalp according to the international 10–20 system. The temporal electrodes were not included in the analysis because the preliminary statistical results were not different from that of the parietal leads, and in the present study we did not intend to perform topographic analysis. Electrode impedance was kept below 5 kΩ, the time constant was 0.3 s, the upper cut off frequency was 70 Hz.

Cz electrode was used as reference. We are aware that position of the reference electrode is a frequently discussed problem. In studies related to ocular movements and visual attention different electrode localisations were used (left ear, bilateral ear, mastoid, Cz, etc. (Csibra et al., 2000, 2001; Hagemann and Naumann, 2001; Janelle et al., 2000; McDowell et al., 2005; Teyler et al., 2005)). We have performed preliminary recordings using left ear, right ear, vertebra prominens and Cz electrodes. Since the nystagmus related alpha power changes were similar regardless of the reference point, and also because relevant experiments have been performed earlier using the same method (Ille et al., 2002; Magnusson et al., 1985) we have decided to use Cz reference.

Analogue EEG signals were digitized at a sample rate of 256 Hz. Data were stored for offline analysis. Records were analysed using the ocular correction panel of the Brain Vision Analyzer software (Version 1.04.0002 Brain Products GmbH 1998–2003). Spectral EEG analysis was carried out by a home-made software using Fast Fourier Transformation (FFT) with Hahn window. Records with blink artefacts 1.5 s before or after the start of OKN were automatically rejected from the analysis by the computer screening software prior to visual checking by one of the authors.

2.4. Data analysis

2.4.1. Frequency distribution of OKN-beats

Frequency distribution analysis of OKN was performed within 60 s stimulation periods of each subject. We measured the duration of every single OKN-wave as shown in Fig. 1, and calculated their frequency (1/duration). Using these data the frequency distribution diagram of OKN of every subject was generated.

2.4.2. EEG power

To assess the alterations of alpha (8–13 Hz) and beta (14–20 Hz) activity occurring during OKN stimulation we analysed the EEG recorded during consecutive 60 s long control and 60 s long OKN periods, using 4 s analysis intervals with 1 s steps for running average. Offline visual analysis of the EEG records suggested that within a time window of 0.5 s around the first wave of a regular OKN-cluster (minimum of 4 beats) there was an increase of alpha

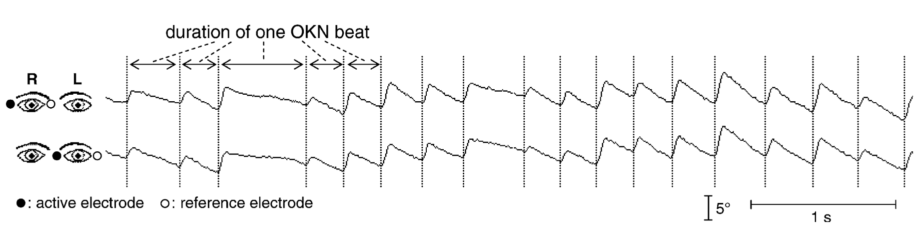

Fig. 1. Calculation of the duration of one OKN-beat.