Memory Load Reflected by 1-30 Hz Brain Oscillatory Responses

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Introduction

The aim of this study was to assess event-related electrophysiological responses in relation to memory load. The EEG (electroencephalogram) was gathered while subjects (n=36) were performing a visual sequential letter memory task with 4 memory load conditions.

EEG consists of several simultaneous oscillations of different frequencies. During cognitive processing, this brain oscillatory system shows integrative activation (Ward, 2003). Brain oscillatory activity of different frequencies has been proposed to reflect different aspects of cognitive processing (Krause, 2002). Memory processes have been associated with EEG responses of frequencies in theta band (4-7 Hz), alpha band (8-12 Hz) and beta band (~20 Hz). Besides frequency, oscillatory responses are also characterized by amplitude (i.e. power). The 1-30 Hz event-related brain oscillatory responses were assessed by examining relative power changes by the means of event-related desynchronization (ERD) and event-related synchronization (ERS) (e.g. Pfurtscheller & Lopes da Silva, 1999). ERD is defined as relative power decrease, whereas ERS denotes a relative power increase in amplitude of a frequency band.

Methods

Visual Memory Task

A visual sequential letter memory task (n-back task) with 4 memory load conditions was utilized. In the 0-back condition, subjects responded to a single pre-specified target letter ("X"). In the 1-back condition, the target was any letter identical to the immediately preceding one (i.e., one trial back). In the 2-back condition, the target was any letter that was presented two trials back and in the 3-back condition, any letter which was presented three trials back. Thus, working memory load was varied from 0 to 3. The visual stimulus lists were pseudorandom sequences of letters (randomly varying in case). Subjects' reaction times and incorrect answers to given task were measured.

EEG Data analysis

The EEG was gathered from 19 electrodes attached by 10/20 system. The data was recorded with a filter of 0.1 – 50 Hz and digitized with a sampling rate of 250 Hz. The digitalized EEG data were analyzed with wavelet transform method (Morlet, width 8). The relative difference in the power of EEG (ERD/ERS) between the reference period and the event period was calculated as a function of time and frequency. The ERD/ERS values were presented as percentage – negative values denoting a relative power decrease (ERD), whereas positive values denote a relative power increase (ERS). The data was presented as time-frequency representations (TFRs), which display the ERD/ERS values as a function of time and frequency.

Results

The behavioral results of the memory task showed an increasing reaction time and number of incorrect answers in relation to increasing memory load.

The four memory load conditions were found to elicit distinct ERD/ERS responses. Theta ERS was elicited in all conditions. In alpha (8-12 Hz) and beta (14-30 Hz) frequencies, ERD responses were observed which lengthened in time as a function of increasing memory load. In 0-back and 1-back conditions, a later ERS response was elicited in 14-20 Hz frequencies. This ERS response was found notably of lesser magnitude in 2- and 3-back conditions.

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