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Alpha and beta changes in cortical oscillatory activity in a go/no go randomly-delayed-response choice reaction time paradigm

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Abstract

Objective: Predictable movements induce oscillatory changes over the contralateral motor cortex that begin before the movement, but their significance has not been fully established. We studied non-phase-locked changes in cortical oscillatory activity in a S1-centred double-stimulus go/no go paradigm with random interstimulus interval.

Methods: About 58 reference-free EEG channels were analyzed by means of Gabor transforms in a group of 10 healthy subjects. A 2000 Hz tone (S1go, 84% probability) indicated the subject to make a brisk wrist extension after a second 2000 Hz tone (S2go). The S1–S2 interval was either 1.5, 3 or 4.5 s. A 1000 Hz tone (S1 no go, 16% probability) indicated the subject not to move (and wait for another S1 tone).

Results: A frontal 15 Hz synchronization was observed after S1 in all conditions. No further significant changes were observed in the no go condition. A small pre-S2 alpha and beta desynchronization could be observed only in the 3 and 4.5 s-interval go conditions, being larger in the latter.

Conclusions: These results suggest that the predictability of the timing of a movement influences the appearance of the pre-movement oscillatory changes; not only motor planning (the ‘go’ decision) is necessary, but also an estimation of when to move.

Significance: Our findings provide new insight on the relationship between the decision-making process, movement, and cortical oscillatory activity.

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Keywords: Event-related desynchronization; Event-related synchronization; Go/no go; Predictability; Timing; Frontal

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1. Introduction

The possible role of cortical oscillatory activity as a substrate of the binding mechanisms involved in sensory, motor and cognitive processing has attracted much attention during the last decade (Singer, 1993). Voluntary movements are accompanied by changes in oscillatory activity, not only limited to cortical structures (Crone et al., 1998), but also occurring in the thalamus (Paradiso et al., 2004) and the basal ganglia (Cassidy et al., 2002). Some of these changes can be observed in normal subjects without the use of any further analysis, like the disappearance of the central mu rhythm (in the alpha range) during movement (Gastaut et al., 1954). With the help of different mathematical tools, a well-defined pattern of alpha (8–12 Hz) and beta (15–30 Hz) oscillatory changes during self-initiated movements has been characterized in the EEG. In the alpha band, a decrease in energy begins up to 2 s before the movement, and lasts till 2–3 s after its end (Derambure et al., 1993; Pfurtscheller and Aranibar, 1979). In the beta range, a fall in activity which begins more than 1 s before movement and lasts till the end of muscle contraction (beta event-related desynchronization, ERD), and a post-movement rebound over baseline level (beta event-related synchronization, ERS), have been thoroughly described (Alegre et al., 2003b; Derambure et al., 1999; Pfurtscheller, 1981;

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Pfurtscheller et al., 1996). The number of studies, however, is lower for stimulus-induced movements. Oscillatory changes in these paradigms begin after the stimulus, unless it is rhythmic and therefore predictable (Alegre et al., 2003a). In this latter case, changes begin before the stimulus, and are similar to those observed in self-initiated movements. Go/no go paradigms are series of stimulus-induced movements, in which the subject decides to move or not depending on the characteristics of the stimulus. These paradigms have been intensively used to study the processes linked to decision-making and response inhibition (Lai et al., 1997). An extended variation of this paradigm may include pairs of stimuli (S1 and S2); the decision (go or no go) is taken after S1, and motor preparation/inhibition occur afterwards, while S2 carries the information on the timing of the movement (but only in the go condition).

ERD/ERS changes in different go/no go paradigms have been addressed in several studies (Filipovic et al., 2001; Leocani et al., 2001). In a recent paper, our group described the different pattern of alpha and beta changes depending on whether the decision to move was taken after the first or the second stimulus (Alegre et al., 2004). Alpha and beta ERD only began after the decision to move had been taken, and lasted through the fixed interstimulus interval (1.5 s). However, as commented above, the predictability of the timing of the movement also affects pre-movement beta ERD (Alegre et al., 2003a). This activity could be related to motor planning or be due to the use of motor predictive strategies.

We studied alpha and beta changes in a S1-centred double stimuli go/no go reaction time paradigm with random interstimulus interval (1.5, 3 or 4.5 s), in order to separate the decision to move or not from the decision of when to move. Our analysis was therefore mainly focused on the differences in the pre-movement alpha and beta-ERD between the 3 go conditions.

2. Materials and methods

2.1. Signal recording

A total of 10 right-handed healthy volunteers (1 man, 9 women) with an age range between 27 and 31 years participated in the study. All of them gave their written consent after a detailed explanation of the procedure. The protocol was approved by the institutional ethics committee.

The subjects were comfortably sat in a dimly-lit sound-attenuated room with eyes opened looking at a fixed point. A standard electrode cap with 58 surface electrodes placed according to the 10–10 system was used for the recordings (ElectroCap Int.). All impedances were systematically kept below 8 kΩ. Both linked earlobes were used as initial reference. Current source density (reference-free) values were obtained for each electrode afterwards using BrainVision Analyser software. One electrooculogram (EOG) and one bipolar EMG channel (right extensor carpi) were simultaneously recorded. EEG channels were amplified ×20,000 and digitised at 500 Hz using BrainVision Recorder software, with low-pass and high pass filters set at 100 and 0.3 Hz, respectively. After downsampling data to 200 Hz to reduce computing time, all channels were stored for offline analysis.

2.2. Description of the stimulation paradigm

Sequences of 70 ms, 90 dB tone bursts were generated by means of the Neuroscan Stim module synchronized with the recording equipment, and delivered by means of bilateral intracanalicular earphones.

Fig. 1 shows the experimental paradigm. A minimum of 300 S1 stimuli was delivered to each subject. S1 was either a 1000 Hz (16% probability, $S1_{no\ go}$) or a 2000 Hz (84% probability, $S1_{go}$) tone. $S1_{no\ go}$ indicated the subject not to move, and wait for another S1 tone. $S1_{go}$ indicated the subject to make a wrist extension after $S2_{go}$, another 2000 Hz tone that always followed $S1_{go}$ with a random interstimulus interval of 1.5, 3 or 4.5 s (33% probability each). The interval between $S1_{no\ go}$ or $S2_{go}$, and the next S1 stimulus was randomized between 6 and 10 s.

2.3. Signal processing

An offline segmentation was performed on the continuously recorded data. S1 stimuli ($S1_{go}$ or $S1_{no\ go}$) were used as triggers, in 4 different conditions: no go, go with 1.5 s S1–S2 interval (go1.5), go with 3 s S1–S2 interval (go3), and go with 4.5 s S1–S2 interval (go4.5). For the no go and go1.5 conditions, 10-s sweeps were obtained, from 5 s before to 5 s after S1. For the go3 condition, 11.5 s sweeps were obtained, from 5 s before to 6.5 s after S1. Finally, for the go4.5 condition, 13 s sweeps were obtained, from 5 s

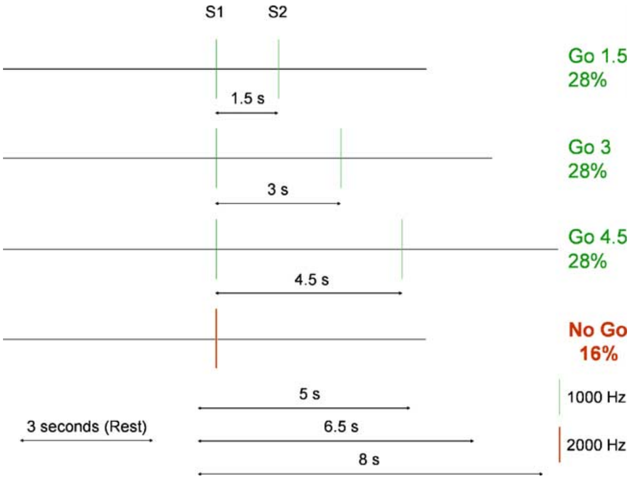

Fig. 1. Schematic representation of the 4 conditions of the paradigm studied. Vertical bars represent the 1000 or 2000 Hz tones. Horizontal arrows indicate the interstimulus interval and the two fragments obtained from each sweep for the offline statistical analysis.

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