

Electrophysiological analysis of a sensorimotor integration task

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Received 23 July 2007; received in revised form 17 August 2007; accepted 24 August 2007

Abstract

The present experiment aimed at investigating electrophysiologic changes observed as beta band asymmetry, by Quantitative Electroencephalography (qEEG), when individuals performed a reaching motor task (catching a ball in free fall). The sample was composed of 23 healthy individuals, of both sexes, with ages varying between 25 and 40 years old. All the subjects were right handed. A two-way ANOVA was applied for the statistical analysis, to verify the interaction between task moment (i.e., 2 s before and 2 s after ball's fall) and electrode (i.e., frontal, central and temporal regions). The first analysis compared electrodes placed over the somatosensory cortex. Central sites (C3–C4) were compared with temporal regions (T3–T4). The results showed a main effect for moment and position. The second analysis was focused over the premotor cortex, which was represented by the electrodes placed on the frontal sites (F3–F4 versus F7–F8), and a main effect was observed for position. Taken together, these results show a pattern of asymmetry in the somatosensory cortex, associated with a preparatory mechanism when individuals have to catch an object during free fall. With respect to task moment, after the ball's fall, the asymmetry was reduced. Moreover, the difference in asymmetry between the observed regions were related to a supposed specialization of areas (i.e., temporal and central). The temporal region was associated with cognitive processes involved in the motor action (i.e., explicit knowledge). On the other hand, the central sites were related to the motor control mechanisms per se (i.e., implicit knowledge). The premotor cortex, represented by two frontal regions (i.e., F3–F4 versus F7–F8), showed a decrease on neural activity in the contralateral hemisphere (i.e., to the right hand). This result is in agreement with other experiments suggesting a participation of the frontal cortex in the planning of the apprehension task. This sensorimotor paradigm may contribute to the repertoire of tasks used to study clinical conditions such as depression, alzheimer and Parkinson diseases.

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Keywords: Motor control; Sensorimotor integration; Asymmetry; qEEG

The preparation of future actions in order to achieve a goal is a fundamental aspect of the performance and control of a motor task [26]. The performance of movements needs a motor planning in different levels and involves the choice of various actions [18,30]. Catching an object is a complex movement which involves not only programming but also effective motor coordination. Such behavior is related with the activation and recruitment of cortical regions which take part in the integra-

tion process that occurs between the information provided by the environment and the performed motor task [4]. Experiments that use electromyography have shown changes that occur in the muscular activity when individuals have to catch an object as a ball [13,14]. However, few studies have tried to clarify the changes that occur in the cortical electrical activity during the performance of movements related with catching objects [25]. QEEG is able to detect these changes related to the motor preparation, in particular as the predominance of contralateral activity (to the hand that moves) following the movement [1,6,22]. QEEG changes are associated with a neural re-organization that follows the acquisition and the motor ability control [32]. Previous results have demonstrated variations in the beta band, as

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synchronization and dessynchronization before and during the movement. Precisely, a decrease in beta activity starts 1 (one) second before the beginning of the action [1], and it is typically found in central areas during voluntary tasks which are performed manually [21,24,33]. Alterations in the beta band are also associated with movement control and sensorimotor integration processes [12,20], besides having been recently correlated to attention, but in this case having a complex, multifocal topographic distribution [3]. In this study, we analyzed the asymmetry measures in the moments prior to and following the objects' free fall. These measures allow one to verify the possible differences in activation in different brain regions along the right and left hemispheres [17], by an absolute comparison of amplitudes between homologous electrodes [16]. Specifically, we anticipated that somatosensory and the frontal areas would change power values few seconds before the ball's fall. Although some studies have examined this asymmetry measures in different experimental situations [5,16,17], few studies have tried to investigate such measure during reaching anticipation motor tasks.

Sample was composed of 23 students, of both sexes, right handed [19], with ages ranging from 25 to 40 years old. Inclusion criteria were: absence of mental or physical impairments (screened by a previous anamnesis) and the lack of use of psychoactive substances. Moreover, all individuals had no known neuromuscular disorders. All subjects signed a consent form and were aware of all experimental protocol. The experiment was approved by the Ethics Committee of Federal University of Rio de Janeiro (IPUB/UFRJ).

The task was performed on dim illumination and silence, to minimize sensory interference. Individuals sat on a comfortable chair to minimize muscular artifacts, while electroencephalography (EEG) and electromyography (EMG) data were collected. An electromagnetic system, composed of two solenoids, was placed right in front of the subject and released 8 cm-balls, one at each 11 s, at 40 cm above the floor, straight onto the subject's hand. The right hand was placed in a way that the four medial metacarpi were in the fall line. After its catch, the ball was immediately discharged. Each released ball composed a trial and blocks were made of 15 trials. The total experiment had six blocks that lasted 2 min and 30 s, with 1-min intervals between them.

The International 10/20 System for electrodes was used with the 20-channel EEG system Braintech-3000 (EMSA-Medical Instruments, Brazil). The 20 electrodes were arranged in a nylon cap (ElectroCap Inc., Fairfax, VA, USA) yielding monopolar derivations referred to linked earlobes. In addition, two 9-mm diameter electrodes were attached above and on the external corner of the right eye, in a bipolar electrode montage, for eye-movement (EOG) artifacts monitoring. Impedance of EEG and EOG electrodes was kept under 5 k Ω and 20 k Ω , respectively. Visual inspection and independent component analysis (ICA) were applied to remove possible sources of artifacts produced by the task. The data acquired had total amplitude of less than 100 μ V. The EEG signal was amplified with a gain of 22,000, analogically filtered between 0.01 Hz (high-pass) and 35 Hz (low-pass), and sampled at 240 Hz. The software *Data*

Acquisition (Delphi 5.0), developed at the Brain Mapping and Sensorimotor Integration Lab, was employed with the following digital filters: *notch* (60 Hz), high-pass of 0.3 Hz and low-pass of 25 Hz.

Electromyographic (EMG) activity of the flexor carpi radialis (FCR), flexor carpi ulnaris (FCU), extensor carpi radialis (ECR) and extensor carpi ulnaris (ECU) was recorded by an EMG device (Lynx-EMG1000), to monitor and assess any voluntary movement during the task. Bipolar electrodes (2 mm recording diameter) were attached to the skin. The reference electrode was fixed on the skin overlying the lateral epicondyle near the wrist joint. The skin was cleaned with alcohol prior to electrode attachment. The EMG was amplified ($\times 1000$), filtered (10–3000 Hz), digitized (10,000 samples/s), and recorded synchronously to the EEG onto the computer's hard drive. In each trial, the EMG signal was rectified and averaged over the 500 ms starting from the trigger onset. EMG was used in order to detect and remove possible artifacts related to the object's fall that could affect the electroencephalographic signal.

A classic power spectral density (PSD) estimator was used (i.e., based on the squared absolute value of the Fourier Transform), for consecutive (non-overlapping) artifact-free, 4-s EEG epochs (spectral resolution: 0.25 Hz), with rectangular windowing. One relative power value (percentage of the total power) was estimated for each epoch based on numerical integration of PSD in each considered EEG band, resulting in a set of values for each moment. Asymmetry measure is defined as the functional difference between the left and right hemispheres; it measures the difference in absolute amplitude which exists between the homologous electrodes located on these hemispheres [16,17]. It was calculated from the equation: $P_a - P_b / P_a + P_b$, where P_a corresponds to the absolute power of the electrode located on the left hemisphere, and P_b corresponds to the absolute power located on the right hemisphere.

Beta band is associated with the state that most of the brain is in when humans have their eyes open and are listening and thinking during analytical problem solving, judgment, decision making, movement preparation and processing information about the world around them [6,24]. Therefore, three scalp areas were assessed: frontal, central and temporal. The central and temporal areas are influenced by the somatosensory cortex, which plays an important role in providing information for the production and performance of the voluntary movement. The following pairs of electrodes were observed: C3–C4 versus T3–T4. On the other hand, the frontal cortex is related to cognitive processes (planning) of voluntary movements and event anticipation [29], and it plays a primary role in voluntary motor tasks [8]. Two homologous pairs were also observed: F3–F4 versus F7–F8. Due to the laterality of the participants (right handedness), the right hemisphere was considered ipsilateral.

Two statistical analyses were performed: (a) the first was a two-way ANOVA, which compared task moment and scalp position factors, being that the former represents the pre and post ball release times (2 s before and 2 s after), and the later the scalp's electrode position: central (C3–C4) versus temporal (T3–T4); (b) a second two-way ANOVA was carried out analyzing the moment and position factors in the frontal cortex region. This

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