Arq Neuropsiquiatr 2007;65(3-A):623-627

CORTICAL ASYMMETRY

Catching an object in free fall

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ABSTRACT - The main goal of the present study was to analyze theta asymmetry through quantitative electroencephalography (qEEG) when individuals were exposed to a sequential motor task, i.e. catching a ball. The sample was composed of 23 healthy subjects, male and female, between 25 and 40 years of age. A two-way factor ANOVA was applied to compare pre and post moments related to the balls' drop and scalp regions (i.e., frontal and parieto-occipital cortices). The first analysis of the frontal region compared electrodes in the left, right and left/right hemispheres combined, with the frontal midline electrode (FZ) included in the analysis. The results showed moment and region main effects. The second analysis compared left versus right hemisphere without the FZ site. The findings demonstrated an interaction effect between moment and region. The first parieto-occipital analysis, comparing left, right and central regions, with PZ included in all regions, showed main effects of moment and region. The second analysis, comparing left, right (without Pz) and central regions strictly demonstrated a region main effect. Thus, we observed an asymmetric pattern in the frontal cortex (i.e., planning and response selection) when the subjects were waiting for the balls' drop. Moreover, the left hemisphere seems to engage differently from the other regions when the central nervous system needs to prepare for a motor action. On the other hand, the parieto-occipital cortex, which is related to attentive processes, demonstrated a more asymmetric activity towards the right region which implies a participation of this area in cognitive strategies in this particular task. Taken together, we concluded that the adopted experimental approach can be useful to explore several others directions combining sensorimotor integration tasks with different pathologies, such as depression, Alzheimer's and Parkinson's diseases.

KEY WORDS: motor control, sensory-motor integration, asymmetry, qEEG.

Assimetria cortical: apreensão de um objeto em queda livre

RESUMO - O objetivo do presente experimento foi avaliar medidas de assimetria na banda teta através da electroencefalografia quantitativa (EEGq) durante a realização da atividade motora de apreensão de uma bola em queda livre. A amostra constituiu-se de 23 sujeitos saudáveis de ambos os sexos, faixa etária entre 25 e 40 anos. ANOVA two-way foi utilizada para comparar os momentos pré e pós relacionados à queda da bola, e às regiões do escalpo (córtex frontal e parieto-occipital). A primeira análise da região frontal comparou eletrodos nos hemisférios esquerdo, direito e esquerdo/direito combinados, incluindo na análise o eletrodo frontal mediano (FZ). O resultado demonstrou um efeito principal para momento e região. A segunda análise comparou os hemisférios direito e esquerdo, sem o eletrodo FZ. Neste achado verificou-se um efeito principal para a interação entre os fatores momento e região. A primeira análise realizada na região parieto-occipital comparou as regiões esquerda, direita e central, com PZ incluídos em todas as áreas, demonstrou efeito principal para momento e região. A segunda análise comparou as regiões esquerda, direita (sem PZ) e central, e verificou-se um efeito principal para região. Tais achados indicaram um padrão de assimetria no córtex frontal (ex., planejamento e seleção de resposta) no momento em que os sujeitos esperavam a queda da bola. Além disso, o hemisfério esquerdo parece engajar-se diferentemente em relação às outras regiões quando o sistema nervoso central necessita se preparar para uma ação motora. Por outro lado, o córtex parieto-occipital, o qual está envolvido com processos de atenção, demonstrou uma maior assimetria no hemisfério direito, o que implica uma participação dessa área em estratégias cognitivas para uma tarefa particular. Então, podemos concluir que o procedimento experimental adotado pode ser utilizado para explorar diferentes direções combinando tarefas de integração sensório-motora com diferentes patologias, tais como depressão, doença de Alzheimer e mal de Parkinson.

PALAVRAS-CHAVE: controle motor, integração sensório-motora, assimetria, EEGq.

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Received 22 November 2006, received in final form 9 February 2007. Accepted 4 April 2007.

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Neuromuscular interactions involved in the production of a motor action and the role of practice in the control and regulation of motor behavior have been the target of many investigations in the last two decades, at least[1,2]. It is acknowledged the relevance of identifying, acquiring and processing sensory stimuli during the execution and control of a motor task. Such factors are the elementary components of the preparation and adjustment of a motor gesture, and they take part in the integration among different centers specialized in the final production of the movement[3]. The possibility of adjusting a certain action to the different environmental demands provides a variety of movements and skills essential to the improvement of the desired motor execution[4-6]. Among the brain regions related to the sensory-motor association, the frontal cortex is responsable for the motor gesture conception and for the process of sensory-motor integration[7]. Although it may be a little complicated to define the frontal functions, studies have been associating this cortex to, at least, three functional subdivisions: planning, preparing and directing all the actions[8]. Hence, the integration of sensory information and planning to motor execution might be facilitated by attentional processes. Studies show that the parieto-occipital region plays an important role in such processes[9-12].

Some experiments from the late 80's have examined antecipatory motor patterns employing as a central paradigm the act of catching objects during a free fall[1]. Through the implemantation of this paradigm, it has become possible to observe electromyographical changes originated by the muscles during the aprehension of balls when released from a certain height. Specifically, the present study employes the *ball fall* paradigm to try to elucidate preparatory principals in the cortex during the catching movement. Electrophysiological data acquired in the scalp (EEG) were synchronized to the balls' fall through an electronic optical device, which enables us to observe electrocortical alterations during the task. The EEG technique is able to detect the brain region activated during the execution of certain task and the level of neuronal activity in different brain areas[13-15]. Counting on a high temporal resolution, the EEG has been utilized to analyze diverse cognitive and motor processes[16]. Among the EEG variables, asymmetry detects the energy balance between the two hemispheres and cortical areas[8]. Asymmetry is defined by the difference on the EEG absolute power between homologous electrodes[3,8]. Asymmetry also seems to detect possible pathological characteristics or suboptimal neurological conditions. Researchers have investigated asymmetrical processes in the frontal cortex and their possible correlation with motor planning and preparing[17].

Therefore, the aim of the present study is to analyze electrophysiological changes when aprehending balls during a free fall. Our focus is in the variable asymmetry between the frequency ranges of 3.5 to 7 Hz (theta). The theta frequency band has been linked to the modulation of attention[15,18,19-22]. Such investigations compared the following scalp regions: frontal áreas associated with movement planning during the[5,6], and the parieto-occipital "junction", traditionally related to attentional processes[10,23].

METHOD

Sample – Sample was composed of 23 students, both genders, right handed (Edinburgh[19]) with ages varying from 25 to 40 years old. Inclusion criteria were: absence of mental or physical commmitments (screened by a previous anamnesis) and the non-use of psychotropic or psychoactive substances. All subjects signed a consent form and were aware of all experimental protocol. The experiment was approved by the Ethics Commitee of the Psychiatry, at the Federal University of Rio de Janeiro (IPUB/UFRJ).

Experimental procedure – At day and time previously scheduled, subjects arive at the Brain Mapping and Sensory Integration Laboratory and were informed once again of all experimental protocol. Each subject accomplished the experiment in only one time. During the task, all lights (and sound) remained turned off to minimize visual stimuli interferences. Individuals were placed comfortably in a large supported chair in order to minimize muscular artifacts, while EEG was collected from 20 monopolar derivations during the task. An electromagnetic system, composed of two solenoids, was placed right in front of the subject and released 8 cm-balls, one at each 11 seconds, at a 40 cm height, right in the hand of the subject. The right hand was placed in a way that the four medial metacarpus were in the fall line. Subject depended on the visual feedback of the ball in order to catch it. After its aprehention, the ball was immediatly discharged. Each released ball composed a trial and blocks were made of 15 trials. The total experiment had 6 blocks. Each block lasted two minutes and thirty seconds with an one-minute interval between them. Interval was essential to avoid muscular fatigue.

Data acquisition - International 10/20 System (22)[20] for electrode placement (referred to linked earlobes) was used with a 20-channel Braintech-3000 (EMSA-Medical Instruments, Brazil). The 19 monopolar electrodes were arranged in a nylon cap (ElectroCap Inc., Fairfax, VA, USA). Impedance for EEG and eye-movement (EOG) electrodes were under 5 kΩ and 20 kΩ, respectively. Visual inspection was employed for detection and elimination of artifacts. The data acquired had total amplitude of less than 100 μV. The signal was amplified with a gain of 22,000. The EEG signals were acquired between 0.01 and 50 Hz. Eye-movement artifact was monitored with a bipolar electrode montage using two 9-mm diameter electrodes attached above and on the external corner of the right eye. Moreover, independent component analysis (ICA) was applied to remove possible sources of artifacts. The EEG signal was analogically filtered between 0.01 Hz (high-pass) and 100 Hz (low-pass), and sampled at 240 Hz. The software *ERP Acquisition* (Delphi 5.0), developed at the Brain Mapping and Sensorimotor Integration Laboratory, was employed with the following digital filters: Notch (60 Hz), high-pass of 0.3 Hz and low-pass of 25 Hz.

Frequency band and spatial electrode localization – Theta band was chosen for its association to different mental tasks, especially attention processes[15,18,19,21,22]. Therefore, two cortical areas were pre-established: the frontal cortex and parieto-occipital junction. The frontal cortex is related to cognition mechanisms (planning) of voluntary movements[14,24]. The following electrodes were observed: F7, F3, FZ, F8, F4. On the other side, previous studies have correlated the parieto-occipital junction to modulation of attention[9,25]. The following electrodes were observed: O1, O2, OZ, P3, P4 e PZ.

Asymmetry parameter – The dependent variable asymmetry is defined: Pa-Pb/ Pa+Pb; where P=Absolute Power, a and b=electrode site for each specific scalp`s position.

Statistical analysis – Four statistical analyses were carried out. The first analysis was a two-way ANOVA, which compared the factors time and position. The first factor represents the pre and post ball release times (2 seconds before and two seconds after). The factors position was subdivided as: 1 (left frontal hemisphere: F7F3; F7FZ E F3FZ), 2 (right frontal hemisphere: F8F4; F8FZ e F4FZ) e 3 (inter-hemispheric: F7F8; F3F4; F7F4 e F8F3). A second two-way ANOVA was carried out analyzing the frontal cortex comparing time and position, but this time, electrode FZ was removed from the analysis. Therefore, only a interhemispheric analysis was carried out (F7F3 versus F8F4). The third two-way ANOVA analyzed the factors time and position in three great regions 1 (P3-O1 e PZ-O1), 2 (P3-OZ; P4-OZ; PZ-OZ) and 3 (P4-O2 e PZ-O2). Finnaly, the last two-way ANOVA (parieto-occipital junction) compared time and position among the three electrode pairs, which were subdivided as followed: 1 (P3-O1), 2 (PZ-OZ) e 3 (P4-O2).

RESULTS

In the first statistical analysis, which compared frontal regions before and after the ball release, results showed a main effect for the factors time (p= 0.003) and region (p=0.000). Factors did not show any interactions (p=0.532). Post Hoc analysis demonstrated that the three regions of the scalp are different among them (Fig 1). The second ANOVA (which removed the FZ electrode), demonstrated an interaction between factors time and region (p=0.000), and a main effect for factor moment (p=0.000). No differences were detected for region (p=0.881) (Fig 2). In the third statistical analysis (parieto-occipital regions), a main effect for factor region (p=0.000) and time (p=0.042) were observed. There was no interaction between the factors time and region (p=0.596) (Fig 3). At last, when different areas from the parieto-occipital cortex was analyzed (P3-O1 vs. PZ-OZ vs. P4-O2), a main effect for factor region was observed (p=0.000), but not between experimental times (p= 0.145), or any interactions between the factors (p= 0.638) (Fig 4).

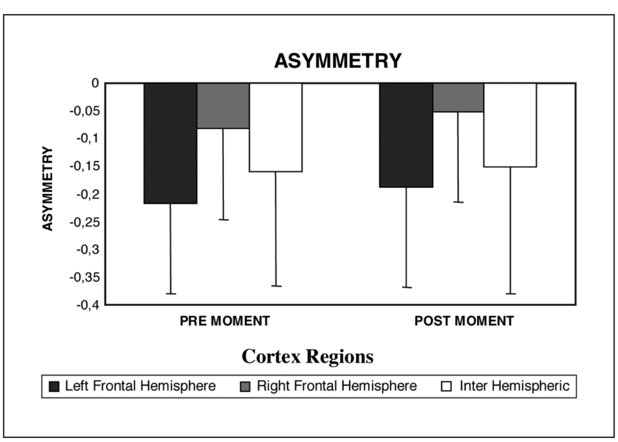

Fig 1. Theta band asymmetry between pre and post moments (balls' drop) in three different frontal cortex sites. Results showed a main effect for the factors time (p=0.003) and region (p=0.000). Post Hoc analysis demonstrated that the three regions of the scalp are different among them. Factors did not show any interactions (p=0.532).

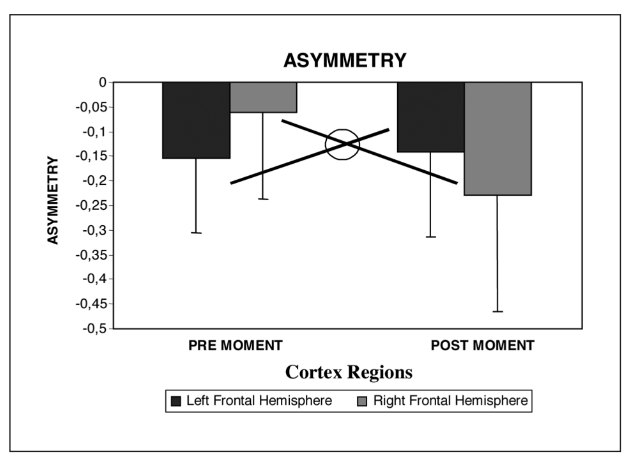

Fig 2. Theta band asymmetry between pre and post moments (balls' drop) in two different prefrontal cortex sites. Results demonstrated an interaction between factors time and region (p=0.000), and a main effect for factor moment (p=0.000). No differences were detected for region (p=0.881).

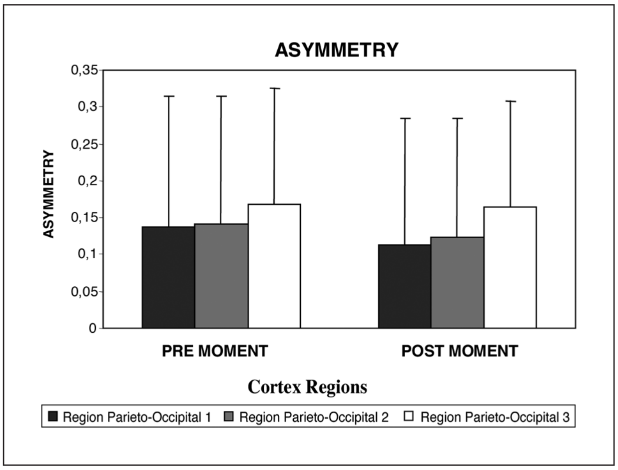

Fig 3. Theta band asymmetry between pre and post moments (balls' drop) in three different parieto-occipital cortex sites. Results demonstrated a main effect for factor region (p=0.000) and time (p=0.042). Post Hoc analysis demonstrated that the three regions of the scalp are different among them. There was no interaction between the factors time and region (p= 0.596) .

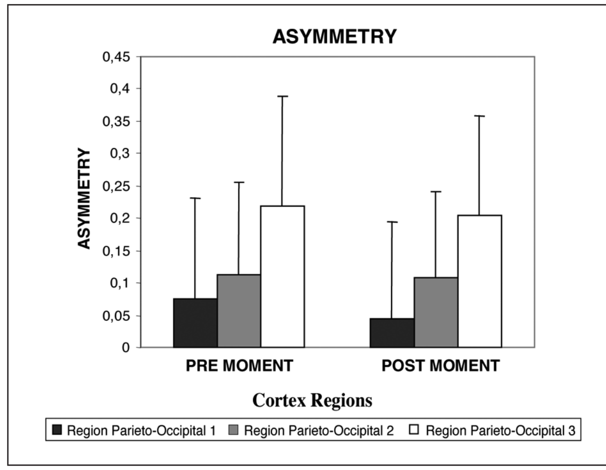

Fig 4. Theta band asymmetry between pre and post moments (balls' drop) in three different parieto-occipital cortex sites. Results demonstrated a main effect for region (p=0.000), but pre and post moment are the same (p=0.145). Post Hoc analysis demonstrated that the three regions of the scalp are different among them. There was no interaction between factors (p=0.638).

DISCUSSION

The present study observed electroencephalographic changes during the execution of a motor task, consisting of catching falling balls. The ball fall was synchronized to the EEG signal, through an electric pulse generated by a light beam placed in a bulkhead exactly in the ball exit. The experiment tried to answer whether or not asymmetry showed any variations at all before and after the ball fall at different cortical regions, specifically, frontal and parieto-occipital areas (theta frequency band). For each region, two statistical analysis were carried out. The first one compared electrodes from the left and right intra-hemisferic regions at frontal sites during distinct experimental times (before and after the ball fall). We observed a main effect for the factors time and region. Regarding the factor time, asymmetry results show a much simetrical cortex after the object release. Such outcomes might be interpreted as an unbalance in neural activity before the object fall. Tradicionally, the frontal is associated to different planning and behavioral processes, such as emotional answers like anxiety, worry or expectation, all involving cognition and goal-directed motor[26-30].

Our data suggest that the asymmetry increase in the pre fall time might occur due to a greater functional heterogeneity of frontal regions. Such period is related to a "temporal window" broadening a greater number of event-related planning and expectation processes. In this experimental time, the subject waits for the visual stimulus and since there is no visual contact, we can only assume that the subject is expecting the appearing of the object[26,31,32]. On the contrary, in the post-ball release time, just a brief "window time" is related to planning processes, which justifies an asymmetry reduction observed in the second experimental time, since the subjects are no longer cognitively involved in the execution of the motor action[33,34]. Another significant result was the difference found among frontal regions. Such differences demonstrate an increase in left frontal asymmetry, when compared to the inter-hemispherical region and to the right hemisphere, respectively. Such evidences suggest that left frontal areas are involved in the planning and execution of catching mechanisms. Previously published data have demonstrated that the left frontal cortex has a crucial role in the attention and visual-motor integration processes[18,22]. However, experiments have concluded that the "asymmetry effect" occurs during the motor response preparation, and not during the motor response itself[8]. This suggests that left frontal asymmetry is not only related to motor response, but, instead is a cognitive-emotional process which might produce such answers or not.

In the second frontal analysis, a significative interaction was found between the factors time and region. Observing carefully this interaction, we noticed a greater left frontal asymmentry, compared to the right hemisphere, in the pre fall experimental time. However, in the pre fall experimental time the contrary occurred[8,18,32]. Such outcomes might be explained by the involvement of the right hemisphere with task perceptive and spatial processes. Our findings are in agreement with previously observed results, which corroborate the hypothesis that the frontal area is engaged in cognitive processes (readiness and expectation) related to planning and execution[35]. Parieto-occipital results confirmed a main effect for the factor time. In the second experimental time, the brain became more simetrical, compared to the first experimental time. Components of the visual cortex are responsable for the attention processes, especially, object detection in dynamic environments, requiring sudden and constant changes in the readiness[9,36]. The parieto-occipital area is also involved with object localization, eye-hand coordination, integration and attention[9,23]. This is evidenciated by the asymmetry increase that occured during pre fall time. Statistical analysis also revealed a main effect for subregions of the parieto-occipital cortex. Neuroimage studies reveal the importance of selective and divided attention in the visual information processing, although data are still not conclusive when it comes to the involvement of the primary visual area (V1) in such processes[10,37]. Our findings demonstrate that the right parieto-occipital junction expressed an increased asymmetry, when compared to the other regions. This suggests the combination of the right primary occipital area with the right central and parietal regions might be associated to an increase in alert and attention originated by the antecipation of the task[25]. The role of asymmetry in such attention states is even more noticed when specific region of the parieto-occipital junction is compared (our last analysis). The right parieto-occipital region became even more asymmetrical, when compared to others. Therefore, our findings seem to corroborate with the hypothesis that the parieto-occipital cortex participates effectively in the attention processes, and that the left parieto-occipital cortex has very low influenced on the preparatory processes involved in the motor task.

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