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MOTOR LEARNING PROCESSES

An electrophysiologic perspective

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ABSTRACT - The goal of the present study was to investigate electrophysiologic, qEEG, changes when individuals were exposed to a motor task. Subjects' brain electrical activity was analyzed before and after the typewriting training task. For the neurophysiological variable asymmetry, a paired t-test was performed to compare each moment, pre and post-task, in the beta bands. The findings showed a change for the qEEG variable in each scalp site, F3/F4; C3/C4 and P3/P4. These results suggest an adaptation of pre-frontal, sensory-motor and parietal cortex, as a consequence of the typewriting training.

KEY WORDS: sensory-motor integration, procedural learning, qEEG.

Processos de aprendizagem motora: uma perspectiva eletrofisiológica

RESUMO - O objetivo do presente estudo foi investigar mudanças eletrofisiológicas através do EEGq quando indivíduos são expostos a uma tarefa motora. A atividade elétrica no córtex dos sujeitos foi analisada antes e após o treinamento da tarefa motora. Para a variável neurofisiológica assimetria, um teste t foi implementado para comparar cada momento, pré e pós-tarefa, na banda beta. Os achados demonstraram mudança em assimetria para as seguintes regiões no escalpo: F3/F4, C3/C4 e P3/P4. Estes resultados sugerem uma adaptação das regiões pré-frontal, somatosensorial e parietal como conseqüência do treinamento de datilografia.

PALAVRAS-CHAVE: integração sensório-motora, memória de procedimento, EEGq.

To maintain stability at a highly dynamic environment, the central nervous system (CNS) is in constant activity. It continuously receives external sensory stimuli, many specifically required to maintain motor performance[1-3]. Many studies have demonstrated that precision during the motor gesture is increased as consequence of motor learning[4,5]. Motor learning promotes a gradual minimization of task errors, an increase in coordination, agility and movement execution[6].

Different mechanisms take part in the complexity of motor learning which involves various levels of cortical structures, such as: pre frontal areas related to decision making, contralateral primary motor cortex[7], ipsilateral primary motor cortex, supplementary motor area, pre motor area, primary sensory areas[8], and the parietal region responsible for information integration processes. The different functional components and the plastic reorganization of the CNS have lead to investigations objecting the examination of neurofunctional phenomena involving motor learning[9].

Hence, this study aimed at investigating how participative is the learning of a motor task in the cortex organizational mapping. For that, we used quantitative electroencephalography (qEEG) to detect neural changes during the motor learning process[10]. Beta activity was specifically investigated, since it is responsive to movements and electro-stimulation of limbs[11,12].

METHOD

The methodology was presented before by our group

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in several other studies[13-15]. Thus, the methods will be summarized below.

The sample was composed for 29 healthy individuals, both sexes, with ages varying between 20 to 40 years, absence of mental and physical illness (previous anamnese), right handed (Edinburgh)[16], and do not making use of any psychoactive or psychotropic substance during the whole time of the study. The experiment consisted of a task of a typewriting method of progressive learning, in which training was performed on a single day. The exercise was made up of four blocks, each block represented by twelve lines. Each line had five sequences of letters for each hand.

Spatial electrode localization and frequency bands – Three areas of interest were investigated: pre frontal, central and parietal. Pre frontal area is related to motivation, planning and decision making. Central area is associated with sensory reports of motor gesture and execution of voluntary movements, corresponding to the somatosensory and primary motor cortex. The parietal region, including the posterior-parietal cortex relates to sensory and attention integration processes. The beta band (13–25 Hz) was than selected due to its relation to somatomotor processes.

Statistical analysis – As electrodes have different scalp (spatial) positions, we have chosen an independent statistical analysis. A t-test was employed for each electrode at beta (F3-F4/C3-C4/P3-P4).

RESULTS

Neurophysiological variables – Figure1 describes the variation in asymmetry between pre and post training times at F3/F4. Statistical analysis has dem-

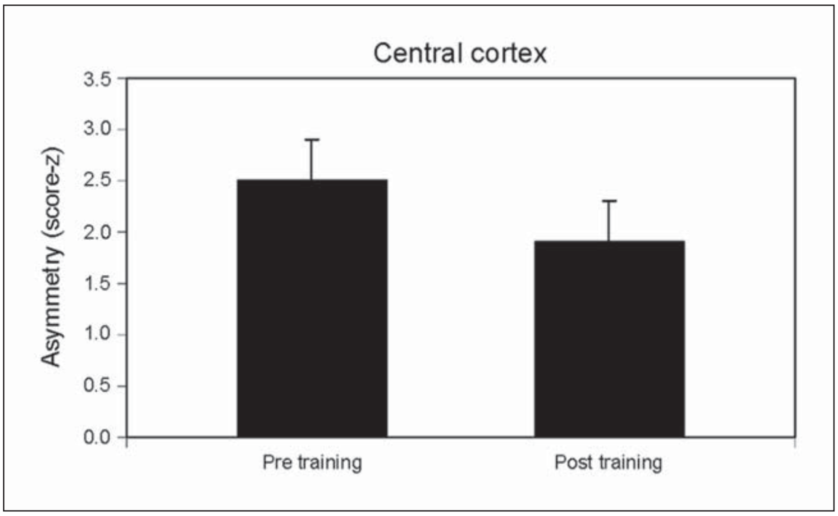

Fig 1. Asymmetry differences in beta between the pre and post training times (central cortex).

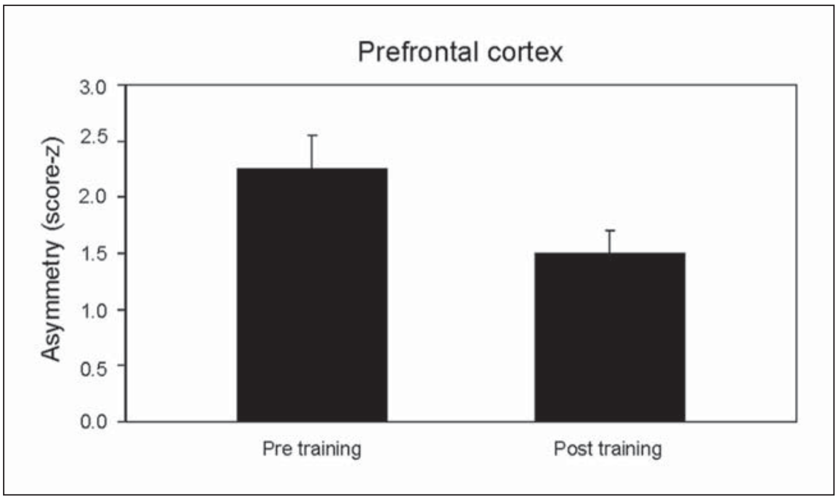

Fig 2. Asymmetry differences in beta between the pre and post training times (prefrontal cortex).

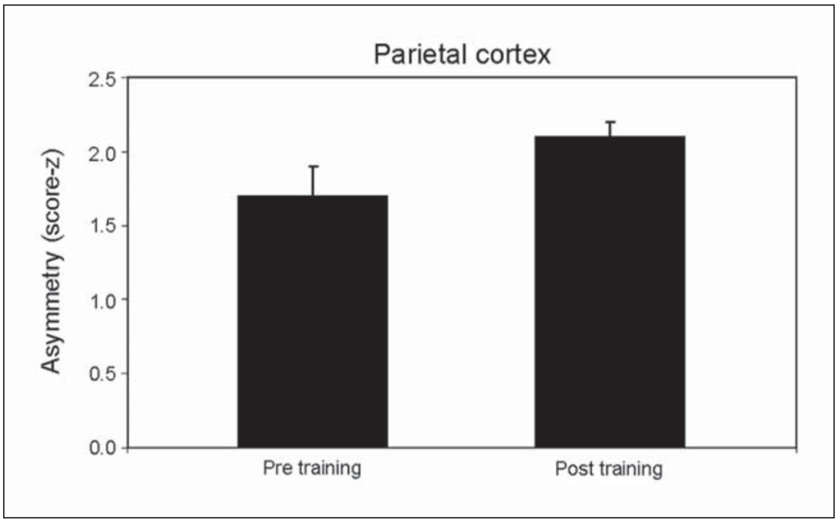

Fig 3. Asymmetry differences in beta between the pre and post training times (parietal cortex).

onstrated a significant difference between two experimental times (p=0.003).

Figure 2 displays the variation in asymmetry between the pre and post training times at C3/C4, with a significant difference of (p=0.019).

Figure 3 represents the oscillation in asymmetry between pre and post training times P3/P4. Statistical difference was also significant (p=0.025).

DISCUSSION

This investigation aimed at examining electrophysiological alterations produced by a learning task through quantitative electroencephalography. The discussion will be presented following the results appearance. Hence, the first section elaborates on the participation of the prefrontal cortex in planning and decision making processes. The second section conjectures over the possible plastic alterations occurring in the somatosensory cortex as a consequence of the motor task. The third section focus on the electroencephalographic outcomes regarding changes in the parietal cortex.

Prefrontal cortex: memory and planning – The prefrontal cortex is responsible for anticipation of consequences, planning and organizing strategies[17,18]. Our results show an increased hemispheric asymmetry at prefrontal regions following the two-hour typewriting task. Since all individuals had a prior experience with typewriting, it was assumed that they were all at the so-called "controlled stage" of learning[19]. This stage is associated to initial periods of learning where subjects divide the attention focus with differentiated elements of the task and the environment[2], leading to reduced motor coordination, increased number of mistakes and execution time. As observed in the results, such increase in symmetry suggests changes in the representation of neuronal activity at the prefrontal cortex, as noticed by other investigations[18,20]. The prefrontal cortex integrates with the limbic associative cortex, connecting directly to limbic structures as the amigdala and the cingulate cortex. Therefore, the results imply changes in structures associated with procedural memory, in particular the way information is registered[21,22].

Somatosensory cortex: plastic alterations as a consequence of the task – Results demonstrate that the two-hour typewriting training produced asymmetry changes at C3/C4, suggesting a reorganization of neuronal activity at the somatosensory cortex. Previous studies have observed such alterations as a consequence of sequential repeated finger movements[23,24]. It is important to remind that these investigations used animals and that they trained for months. Experimental proportions must be considered since training mode in primates (monkeys) is different from humans and gesture specificity between species is a key factor in cortical representation[25]. The reason between cortical areas, as expressed in asymmetry (C3/C4), detects changes in the relation between the two hemispheres after the typewriting task. This allegedly means that increased symmetry between regions suggests a reorganization of the supposed interaction between the two hemispheres[13]. It is essential, however, to replicate these findings employing other neuroimaging techniques since the spatial resolution of EEG does not allow a precise cortical identification of hands and fingers.

Posterior parietal cortex: attention and sensory integration processes – Our results show reduced asymmetry at P3/P4. Beta activity is related to stimulation processes and voluntary movements[26,27]. Posterior parietal cortex (Brodmann areas 5 and 7) is located next to the somatosensory primary area (S-1) and possesses neurons with great receptive fields, which allows this region to specialize in differentiated and complex activities. The parietal cortex has a convergence site of simple and segregated sensory stimuli, functioning as a multiple integration organization[28,29]. Therefore, the parietal region is associated to visual and motor information, also waking and attention mechanisms as well[30]. The reduced asymmetry values suggest possible changes in somatosensory and visual integration processes. Particularly, neurons in the area 5 collect information from different articulations or arm muscle groups; and neurons in the area 7 integrate tactile and visual stimuli, and participate actively in the eye-hand coordination[31]. The posterior parietal cortex also receives visual communication regarding the representation of the visual world and movement planning. Consequently, such variation in asymmetry might represent a task automaticity process[32].

REFERENCES

1. Teasdale N, Simoneau M. Attentional demands for postural control: the effects of aging and sensory reintegration. Gait Posture 2001;4:203-210.
2. Schmidt R, Wrisberg C. Aprendizagem e performance motora: uma abordagem da aprendizagem baseada no problema. 2.Ed. Porto Alegre: Artmed Editora, 2001.
3. Ladewing I. A importância da atenção na aprendizagem de habilidades motoras. Rev Paul Educ Fis 2000;2(Supl):S62-S71.
4. Jenkins I, Passingham R, Brooks D. The effect of movement frequency on cerebral activation: positron emission tomography. J Neurol Sci 1997;151:195-205.
5. Jones E. Cortical and subcortical contributions to activity-dependent plasticity in primate somatosensory cortex. Annu Rev Neurosci 2000;23:1-17.
6. Karni A, Meyer G, Jezzard P, Adams MM, Turner R, Ungerleider LG. Functional MRI evidence for adult motor cortex plasticity during motor skill learning. Nature 1995;377:155-158.
7. Sommer M, Classen J, Cohen LG, Hallet M. Time course of determination of movement direction in the reaction time task in humans. J Neurophysiol 2001;86:1195-1201.
8. Georgiadis M, Cramon D. Motor-learning-related changes in piano players and non-musicians revealed by functional magnetic-resonance signals. Exp Brian Res 1999;125:417-425.
9. Schmidt RA. A schema theory of discrete motor skill learning. Psychol Rev 1975;84:225-260.
10. Gong P, Nikolaev A, Leeuwen C. Scale-invariant fluctuations of dynamical synchronization in human brain electrical activity. Neurosci Lett 2003;336:33-36.
11. Alegre M, Labarga A, Gurtubay IG, Iriarte J, Malanda A, Artieda J. Movement-related changes in cortical oscillatory activity in ballistic, sustained and negative movements. Exp Brain Res 2003;148:17-25.
12. Pfurtscheller G, Graimann B, Huggins JE, Levine SP, Schuh LA. Spatiotemporal patterns of beta desynchronization and gamma synchronization in corticographic data during self-paced movement. Clin Neurophysiol 2003;114:1226-1236.
13. Cunha M, Bastos VH, Veiga H, et al. Alterações na distribuição de potência cortical em função da consolidação da memória no aprendizado de datilografia. Arq Neuropsiquiatr 2004;62:662-668.
14. Portella CE, Silva JG, Bastos VH, et al. Procedural learning and anxiolytic effects: electroencephalographic, motor and attentional measures. Arq Neuropsiquiatr 2006;64:478-484.
15. Cunha M, Machado D, Bastos VH, et al. Neuromodulatory effect of bromazepam on motor learning: an electroencephalographic approach. Neurosci Lett 2006;407:166-170.
16. Oldfield R. The assessment and analysis of handedness: the Edinburgh inventory. Neuropsychology 1971;9:97-113.
17. Miller EK. The prefrontal cortex: complex neural properties for complex behavior. Neuron 1999;22:15-17.
18. Miller A, Tomarken A. Task-dependent changes in frontal brain asymmetry: effects of incentive cues, outcome expectancies, and motor responses. Psychophysiology 2001;38:500-511.
19. Mars RB, Coles MG, Grol MJ, et al. Neural dynamics of error processing in medial frontal cortex. Neuroimage 2005;4:1007-1013.
20. Gotlib IH, Rosenfeld CJP. Frontal EEG alpha asymmetry, depression and cognitive functioning. Cogn Emotion 1998;12:449-478.
21. Sakai K, Hikosaka O, Miyauchi S, Takino R, Sasaki Y, Putz B. Transition of brain activation from frontal to parietal areas in visuomotor sequence learning. J Neurosci 1998;5:1827-1840.
22. Boettiger CA, D'Esposito M. Frontal networks for learning and executing arbitrary stimulus-response associations. J Neurosci 2005;25:2723-2732.
23. Fitzgerald PJ, Lane JW, Thakur PH, Hsiao SS. Receptive field properties of the macaque second somatosensory cortex: representation of orientation on different finger pads. J Neurosci 2006;26:6473-6484.
24. Hluschuk Y, Hari R. Transient suppression of ipsilateral primary somatosensory cortex during tactile finger stimulation. J Neurosci 2006;26:5819-5824.
25. Gandolfo F, Li C, Benda B, Schioppa C, Bizzi E. Cortical correlates of learning in monkeys adapting to a new dynamical environment. Proc Natl Acad Sci 2000;29:2259-2263.
26. Neuper C, Pfurtscheller G. Event-Related dynamics of cortical rhythms: frequency specific and functional correlates. Int J Psychophysiol 2001;43:41-58.
27. Stancak A Jr, Pfurtscheller G. Event-related desynchronisation of central beta rhythms during brisk and slow self-paced finger movements of dominant and nondominant hand. Brain Res Cogn 1996;4:171-183.
28. Iacoboni M, Zaidel E. Interhemispheric visuo-motor integration in humans: the role of the superior parietal cortex. Neuropsychology 2004;42: 419-425.
29. Assmus A, Marshall JC, Ritzl A, Noth J, Zilles K, Fink GR. Left inferior parietal cortex integrates time and space during collision judgments. Neuroimage 2003;20:82-88.
30. Schubert T, Von Cramon DY, Niendorf T, Pollmann S, Bublak P. Cortical areas and the control of self-determined finger movements: an fMRI study. Neuroreport 1998; 9:3171-3176.
31. Inoue K, Kawashima R, Sugiura M, et al. Activation in the ipsilateral posterior parietal cortex during tool use: a PET study. Neuroimage 2001;14:1469-1475.
32. Brashers-Krug T, Shadmehr R, Bizzi E. Consolidation in human motor memory. Nature 1996;382:252-255.