Electroencephalographic analysis in left hemiparesis: a case study

Análise eletroencefalográfica na hemiparesia à esquerda: um estudo de caso

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ABSTRACT

The aim of the present study was to evaluate changes in alpha, beta and gamma bands of distinct cortical regions in variable absolute power due to the execution of feeding motor gesture, through the actuation of mirror neurons system (MNS) and motor imagery (MI). A subject, male, 60 years old, right-handed, with left hemiparesis was subjected to five electroencephalographic measures in different experimental conditions: initial rest, motor practice, mirror neurons system, imagery and final rest. In alpha, there was less mental effort during the condition MI in C3 and Cz. In beta, there was high activity in derivations C4, T3, and T4 during the MNS condition, indicating that these neurons are recruited during the observation and execution task. In gamma, during MI, there was high activation of C4. The MI and MNS promoted cortical activation of regions altered by cerebral damage and can be used in rehabilitation of individuals with stroke.

Keywords: motor imagery, mirror neuron system, EEG, hemiparesis.

RESUMO

O objetivo do presente estudo foi avaliar alterações nas bandas alfa, beta e gama em regiões corticais distintas, na variável potência absoluta decorrente da execução do gesto motor de alimentação, por meio do acionamento do sistema de neurônios espelhos (SNE) e imagética motora (IM). Um sujeito do sexo masculino, 60 anos, destro, hemiparético à esquerda, foi submetido a cinco medidas eletroencefalográficas em condições experimentais distintas: repouso inicial, prática motora, sistema de neurônios espelho, imagética e repouso final. Em alfa, verificou-se menor esforço mental durante a condição IM nos eletrodos C3 e Cz. Em beta, houve elevada atividade nas derivações C4, T3, e T4 na condição SNE, indicando que esses neurônios são recrutados durante a observação e execução da tarefa. Em gama, durante a IM, verificou-se alta ativação de C4. A IM e SNE promoveram ativação de regiões corticais alteradas pela lesão cerebral, podendo ser utilizados na reabilitação de indivíduos com AVE.

Palavras-chave: imagética motora, neurônios espelho, EEG, hemiparesia.

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INTRODUCTION

Electroencephalography (EEG) is a record of brain electrical activity in different regions of cerebral cortex[1]. In addition to the diagnostic use, such record has been used to examine the brain functions during protocols which involve real execution of motor tasks, as well as in motor imagery (MI)[2]. The MI applies in the kinetic functional recovery of motor disorders because there is a similarity in the execution time of imagined or effectively performed task (temporal congruence)[3] and to activate motor areas responsible for trained gesture[4]. Another form of cortical activation is the actuation of mirror neuron system (MNS) which consists in the activation of premotor and motor cortical areas by observation of a motor gesture[3,5,6].

In physical therapy, MI and MNS have been used as a therapeutic strategy aiming to activate brain areas with functional impairments. A stroke is the most common clinical condition that results in such disorders. Hemiparesis is the motor dysfunction most commonly observed, being characterized by a selective damage of activity in the muscles that control the trunk and limbs[7]. Aiming improvement of motor gestures changed by brain injury, the use of MI and MNS as therapeutic strategies promote training even when the subject is physically tired or have minimum resources.

Among the various existing resources to measure the effectiveness of the cortical activation by MI and MNS, the EEG allows to examine the presence of changes in the different frequency bands (alpha, beta, theta delta, and gamma). Among the variables that can look for each frequency band, the absolute power has been used for monitoring of cortical processes[8]. It reflects the amount of energy in a frequency band of a specific pair of electrodes and the larger the amplitude, the greater the power of the EEG signal, allowing checking if an area is more active than another. This allows the prediction signs of cortical atrophy and/or compensatory cortical reorganization in cases of neurological disorders[9]. In this context, the aim of the study was to evaluate changes in the alpha, beta, and gamma bands of distinct cortical regions with the absolute power variable based on the execution of feeding motor gesture, through the activity of mirror neurons system and motor imagery in a left hemiparesis case.

METHODS

The study was conducted in the Laboratory of Brain Mapping and Functionality of the Federal University of Piauí – (LAMCEF/UFPI) Parnaiba Campus. This laboratory was provided with controlled temperature (thermo neutral), was acoustically isolated, and had the appropriate equipment for the experimental condition. The experiment was approved by the Ethic Committee of the UFPI, under number 246.283/2013.

Sample

Male subject, 60 years old, right-handed by Edinburgh inventory, with left hemiparesis due to stroke, without cognitive impairment, in treatment at the Neurofunctional Physical Therapy Unit at the Clinical School of UFPI. The subject was informed about the goals, experimental procedure involved methodology used, and signed the consent form.

Experimental procedure

The subject was investigated for cognitive impairment being submitted to the Mini-Mental State Examination (MMSE). He answered the Edinburg Inventory[10] to recognize the dominance of handedness. The modified Barthel Index was used to evaluate the functional potential and degree of assistance required for daily activities. Then, a questionnaire was applied to evaluate the ability to feel the imagined movement or just imagine it (*The Kinesthetic and Visual Imagery Questionnaire – KVIQ*)[11].

The first EEG record was performed with the subject at rest and with eyes opened. Then he watched a video of 4 seconds where the motor gesture to take a glass, lead it to the mouth, and put it back on the table in front was shown. The subject at the video was sat in a comfortable position. After that, he was submitted to three experimental conditions, namely:

Practice – The patient raised his right hand that was resting on the table, took a glass, led it to the mouth, then returned it to the initial location marked on the table, and rested his hand, returning to initial position.

Mirror neuron system – The subject watched a video with the motor gesture as described above.

Imagery – The subject imagined, in the first person, the same motor gesture of the video.

After the experimental conditions, the subject was submitted to another EEG record at rest. All the conditions were performed for 4 minutes and the individual was sat in a comfortable chair to minimize muscular artifacts.

The EEG signal was recorded using the equipment Brain-Net BNT-EEG, compatible with digital Electroencephalography, Brain Mapping and EEG-video (EMSA – Medical instruments, Brazil – Registered at Anvisa under number 10324590007), provided with a digital analog converter plate (A/D) of 20 channels for EEG and with 16-bit resolution. The electrodes were placed according to 10-20 system, including the reference electrodes placed in the ear lobes. The impedance levels of each electrode were analyzed and fixed between 5-10 kΩ and maintained at these patterns. The acquired signals presented, generally, a total amplitude (peak to peak) less than 100 μV. To ensure a more criterious selection snippets contaminated by muscle artifacts were excluded through automatic rejection algorithm by sill trespass.

The data were analyzed in the MATLAB® R2011a, converted to Microsoft® Excel Office 2007, and transformed to log 10. Then, the averages of the variable absolute power were calculated.

RESULTS AND DISCUSSION

The experiment investigated changes of absolute power in the band alpha (8-12Hz)[12] or (8-13Hz)[13,14], beta (12-30 Hz), and gamma (≥ 30Hz) frequencies in a subject during the execution of a motor gesture of leading a glass to the mouth. Such changes were analyzed in areas of the scalp that represent the primary sensory motor cortex (T3, C3, Cz, C4 and T4), and related functionally with perception, preparation and motor execution[15], and in areas related to mechanisms of motivation, planning, cognition and execution of voluntary movements (F7, F3, Fz, F4 and F8)[16].

Functional correlations concerning the alpha band

The alpha band (8 a 12 Hz) and the central cortical regions supposedly are involved with mental consolidation mechanisms of motor tasks. The cognitive mechanisms associated with this band are essential for acquisition and execution of motor skills[16]. As larger the magnitude of cortical activation represented by this frequency band, greater the synchrony and less mental effort, with consequent better motor performance[1,2].

The absolute power values verified in central regions were elevated in all experimental conditions, and the results were most evident in areas corresponding to C3, Cz and C4 (Figure 1). The cortical activity observed in these derivations, that in the cortex correspond to areas that receive somatic information and control limb movements[16], specifically the hands[17], may indicate lower mental effort during the imagery condition. The absolute high power in C3 (precentral gyrus)[18] can be justified because this area possibly assists the region corresponding to C4 derivation (pre-central gyrus)[18] during task execution. This suggests little spatial vision interference. In other words, the spatial-temporal coordination to carry the hand toward the mouth[19] did not required considerable mental effort values.

The task execution was investigated aiming to evaluate whether the MI and MNS actuation contribute to a significant activation of cortical areas affected by stroke or not, considering[20] that only the unaffected hemisphere could be influenced by mental techniques such as MI. Another study, however, using Functional Magnetic Resonance to investigate the reorganization of motor system after observation of an action (video therapy) in a subject with stroke, identified bilateral activation of the premotor cortex and supplementary motor area. In other words, there was activation of both hemisphere, the not committed one as much as the functionally committed[21], data that corroborate the results of this study.

The absolute power verified during the final rest (FR) pointed to higher cortical activation for this condition when compared to the initial rest (IR). These results suggest consolidation of motor learning by the subject, once the increase of absolute power in the alpha band after motor learning can be interpreted as reducing the mental effort for neuronal activation in the specified region[22-24]. The cortical activation observed during MI and FR showed less mental effort to task in these experimental conditions, in other words, greater efficiency and neural synchrony for information processing, directing attention only to relevant details[1], and suggesting that individuals were relaxed for task execution.

In central areas of the derivations C3, Cz, C4, and frontal, F3, Fz,F4 (Figure 1) during MNS condition, high absolute power values were observed indicating that these neurons were activated when the subject watched the action on video, despite being relaxed. This indicates that action was understood in advance, facilitating the following step, which involved the actual execution of the task[5,25]. When submitting patients with stroke to mirror neurons therapy[26] a bilateral activation of the cerebral hemispheres was verified, being greater in the hemisphere functionally affected, due to the inter-hemispheric interaction. These data corroborate the findings of this study, where greater neural activity in the derivation C4 when compared to C3 was found.

The cortical activation verified in F3 and F4 (middle frontal gyrus)[18,27] that correspond to manual planning areas (Figure 2), suggests less mental effort during task execution[16]. The frontal lobe in both hemispheres is appointed as an important structure for learning unilateral procedures[23]. This may explain the activation of regions responsible for moving the contralateral limb during task execution. Furthermore, the results suggest that the relaxation state in which the individual was, indicated by the high amplitude of F4 in practical condition, results of automation learned movement.

Functional correlations concerning the beta band

The beta band (12-30 Hz) seems to be mostly related to motor and premotor activities[9,28] and has a considerable value to analyze normal or abnormal movements. The cortical activation in frontal areas represented by this band is related to activity of attention, considering that beta has a faster rhythm and lower amplitude[16,28].

The results of this study indicated high activation of C4 during MI (Figure 3), indicating considerable mental activity for the act of imagining the task, results that verified less magnitude during the actual

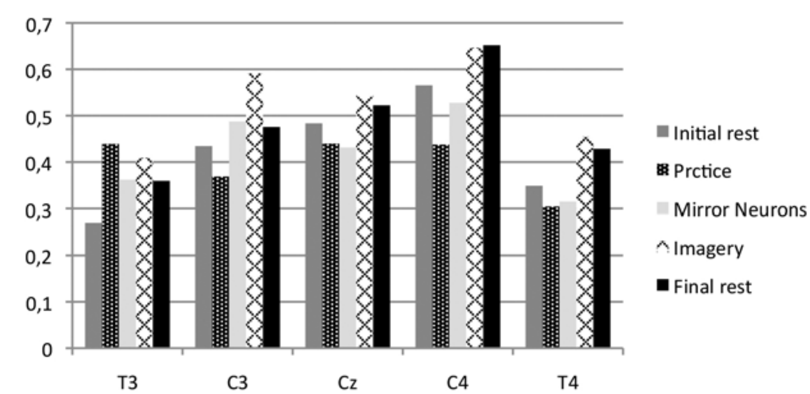

Figure 1. Averages of absolute power of alpha in central electrodes.

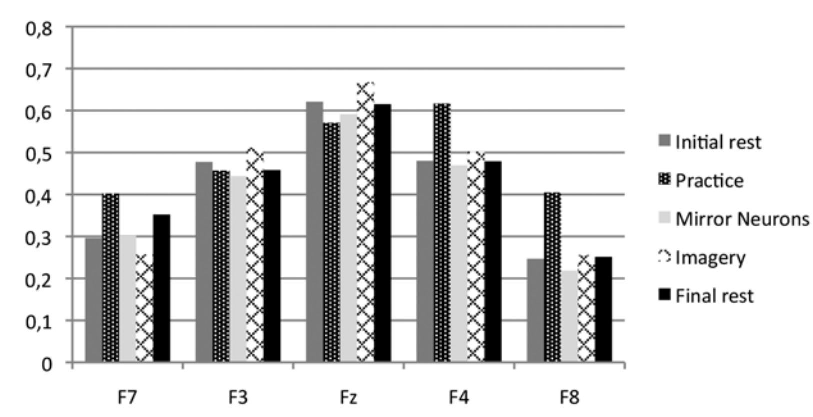

Figure 2. Averages of absolute power of alpha in frontal electrodes.

execution. This can be justified because the subject is right-handed, thus finding difficult to imagine the movement with the left hand. The T3 analysis (middle and superior temporal gyro)[18], in practical condition, indicated greater worry of the individual to identify the space and time needed to direct the object to the mouth during the execution of the task, indicating that this area helped the function of the region corresponding to the derivation C4. The tasks simulation by individuals who do not have prior experience with its implementation requires more cognitive effort, resulting in activation of cortical regions of the right hemisphere for support[2].

In electroencephalographic measures found in a pilot study in which a violinist performed a musical score there was a significant activation of the beta band in T3 derivation. The goal of this experiment was to identify changes that occur during the process of acquisition of cognitive-motor task. The results found were similar to the present study, in which the subject, also showed higher degree of activation in T3 in this frequency band during practical condition. This suggests that the beta band is related to the processing of external and internal information due to the demanded of attention it represents[29]. The cortical activity identified in electrodes C4, T3 and T4 during MNS condition was justified because these neurons are recruited not only during observation of motor task, but also during its execution[5].

In practical condition, the frontal areas analyzed showed high absolute power values, indicating greater planning for task execution, and these values were higher for regions corresponding to the F4 derivation. The areas represented by F3 (middle frontal gyrus) and F7 (inferior frontal gyrus)[18,27] presumably acted as co-adjuvants in this execution (Figure 4). These data corroborate the theory that learning occurs asymmetrically, suggesting that during this process the right hemisphere appears more active and after the completion of learning, while the left hemisphere is more required for the recovery of learned tasks[1].

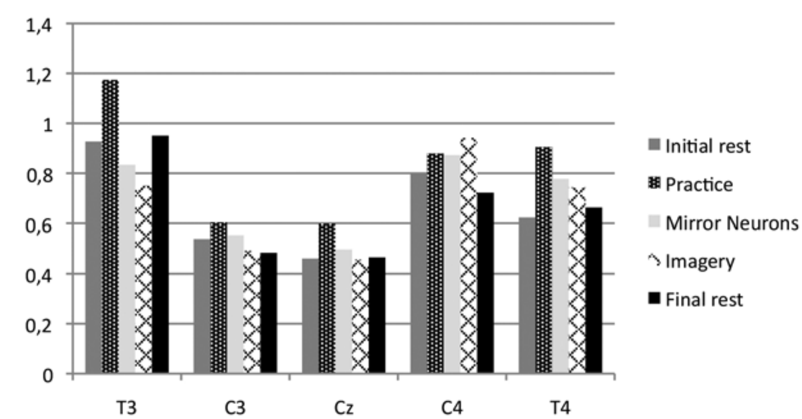

Figure 3. Averages of absolute power of beta in central electrodes.

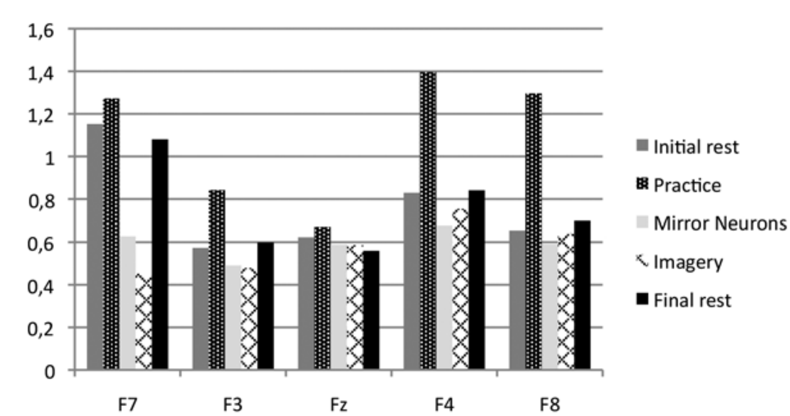

Figure 4. Averages of absolute power of beta in frontal electrodes.

This theory can be complemented by the idea that learning is a specific process for each skill, and the structures that are not directly responsible for implementing the action have their activity reduced with practice, producing an energy saving, directing it to the most important areas in the task execution. Thus, the asymmetry of right to left occur mainly in the areas directly involved in the task[1,30], results found in this study, as greater values of activation were found in derivations F4 and F8 (right hemisphere) when compared with F3 and F7 (left hemisphere), indicating that the activity of corresponding area F4 suggests motor learning of performed task.

Another EEG study evaluated the hypothesis that visual perception, passive emotional facial expressions (neutral, happy, or sad) are related to coordination of the two hemispheres. The results showed that there was no preponderance of information flow from one hemisphere to the other. This suggests that there is a great exchange of information between the hemispheres, and not just unilateral right hemisphere activation in the development of emotional content[31]. The beta band, as mentioned before, is related to motor activity. This may explain the high magnitudes found in this frequency band at frontal electrode during the practical condition (Figure 4). In addition, it can also justify the results found in MNS condition in which neuronal activation for task, performed and observed, but with less amplitude when compared with the results obtained in practical condition.

Functional correlations concerning the gamma band

The gamma activity (≥ 30Hz)[13,15,32] relates with the information processing and cognitive function, occurring in the thalamus, auditive, visual and motor cortex. These rapid oscillations occur during behavioral tasks that require greater wakefulness, and during responses to sensory stimulation[33], probably, serving to connect various information and coordinate sensory and motor activity[32]. Activation of this frequency band was also reported to encoding, retention, and recovery of information, regardless of sensory modality[13] and has been related to the sensorimotor processing while performing tasks involving visual discrimination and motor preparation[15].

The lowest absolute power in gamma in the central areas (Figure 5) indicated low brain activation in all experimental conditions except the one found in derivations T3, T4 and C4 in which there was high activity in cortical areas responsible for motor function during the motor practice. This can be explained by limitation or difficulty that the individual found to evoke or plan the movement, as it was executed with the non-dominant limb and functionally affected, requiring greater attention to its execution[33]. The results observed during MI in derivation C4, in which there was high cortical activation, indicated greater work to evoke memory related with the motor action, due to the involvement of central areas in preparing motor perception and movement execution[15].

The area corresponding to C3 presented low magnitude, indicating that the subject has not labored to evoke motor memory[33] of the right limb, but for the opposite limb, while evoking this memory in low magnitude in motor practice condition. In all bands, alpha, beta and gamma, T3 showed high activity, once it represents the cortical

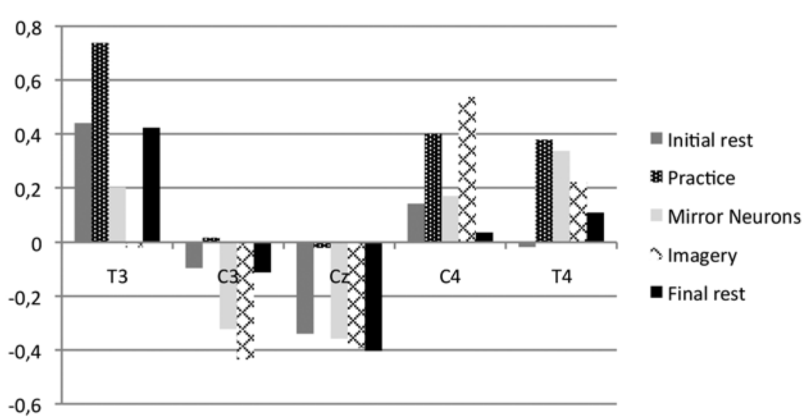

Figure 5. Averages of absolute power of gamma in central electrodes.

area responsible for the realization of movement to the right[18]. However, as the subject used the left limb, it was necessary to increase the mental and practical effort, working in cooperation with the area that effectively commanded the movement.

In the gamma band, in all electrodes of frontal areas (Figure 6), the activity during practice suggests that the subject evoked memory on the previously watched video[33]. During the visualization of the task on video, activation of mirror neurons in lower proportion when compared to motor task was found. In imagery condition there was little activation on F7, F3, FZ, possibly because the subject did not imagine the movement for the right hand, but for the contralateral limb represented by F4 and F8, cortical areas responsible for the selection of movements, preparation and voluntary control of action and attention, and executive functions such as planning, respectively[15].

CONCLUSION

Based on the exposed above, it is understood that the use of MI and consequent activation of MNS promoted activation of cortical regions changed by cerebral injury. Thus, these resources can be used like tools in the rehabilitation of individuals affected by stroke, highlighting the need of new research with a larger number of participants and involving the use of such tools in the practice rehabilitation of patients with stroke, verifying the efficacy of such resources in the functional recovery kinetics of these individuals.

Grant: National Council for Scientific and Technological Development (CNPq), Brazil.

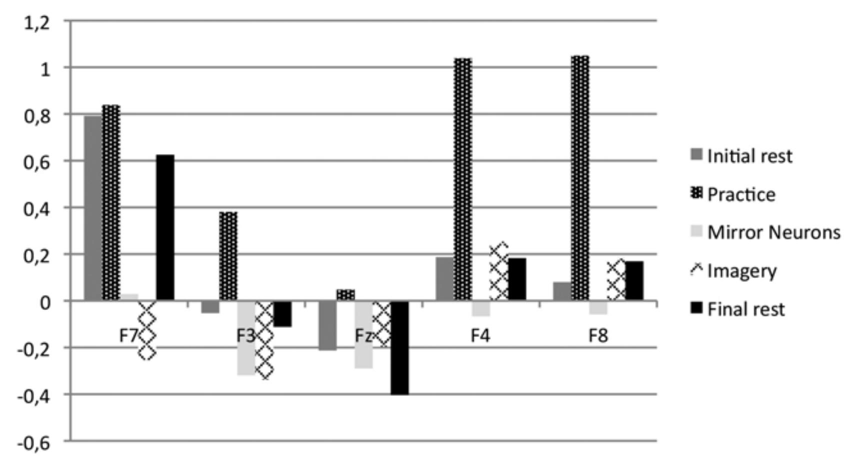

Figure 6. Averages of absolute power of gamma in frontal electrodes.

REFERENCES

1. Luft C, Andrade A. A pesquisa com EEG aplicada à área de aprendizagem motora. Rev Port Cien Desp. 2006;6(1):106-15.
2. Stecklow MV, Infantosi AFC, Cagy M. Alterações na banda alfa no eletroencefalograma durante imagética motora visual e cinestésica. Arq Neuropsiquiatr. 2007;65(4-A):1084-8.
3. Lameira AP, Gawryszewski LG, Pereira Jr A. Neurônios espelho. Psicologia USP. 2006;17(4):123-33.
4. Stecklow MV, Catelli Infantosi AFC, Cagy M. EEG changes during sequences of visual and kinesthetic motor imagery. Arq Neuropsiquiatr. 2010;68(4):556-61.
5. Rizzolatti G. The mirror neuron system and its function in humans. Anat Embryol. 2005;210:419-21.
6. Hickok G, Sinigaglia C. Clarifying the role of the mirror system. Neurosci Lett. 2013;540:62-6.
7. Trindade APNT, Barboza MA, Oliveira FB, Borges APO. Influência da simetria e transferência de peso nos aspectos motores após acidente vascular cerebral. Rev Neurocienc. 2011;19(1):61-7.
8. Fonseca LC, Tedrus GMAS, Martins SMV, et al. Eletroencefalograma quantitativo em escolares sadios. Arq Neuropsiquiatr. 2003;61(3-B):796-801.
9. Bastos VH, Cunha M, Veiga H, et al. Análise da distribuição de potência cortical em função do aprendizado de datilografia. Rev Bras Med Esporte. 2004;10(6):494-9.
10. Oldfield RC. The assessment and analysis of handedness: the Edinburg inventory. Neuropsychologia. 1971;9:97-113.
11. Malouin F, Richards CL, Jackson PL, Lafleur MF, Doyon ADJ. The Kinesthetic and Visual Imagery Questionnaire (KVIQ) for Assessing Motor Imagery in Persons with Physical Disabilities: A Reliability and Construct Validity Study. JNPT. 2007;31:20-9.
12. Jensen O, Gelfand J, Kounios J, Lisman JE. Oscillations in the Alpha Band (9-12Hz) increase with memory load during retention in a short-term memory task Cerebral. Cortex. 2002;12(8):877-82.
13. Sauseng P, Klimesch W. What does phase information of oscillatory brain activity tell us about cognitive processes? Neurosci Biobehav R. 2008;32:1001-13.

14. Teixeira S, Velasques B, Machado S, et al. Gamma-band oscillations in fronto-central areas during performance of a sensorimotor integration task: a qEEG coherence study. Neuroscience Letters. 2010;483(2):114-7.
15. Portella CE, Silva JG, Bastos VH, et al. Aprendizagem de procedimentos e efeitos ansiolíticos. Arq Neuropsiquiatr. 2006;64(2-B):478-84.
16. Yousry TA, Schmid UD, Alkadhi H, et al. Localization of the motor hand area to a knob on the precentral gyrus: a new landmark. Brain. 1997;120:141-57.
17. Homan RW, Herman J, Purdy P. Cerebral location of international 10-20 system electrode placement. Electroencephalogr Clin Neurophysiol. 1987;66:376-82.
18. Teixeira S, Velasques B, Machado S, et al. Gamma band oscillations in parieto-occipital areas during performance of a sensorimotor integration task: a qEEG coherence study. Arq Neuropsiquiatr. 2011;69(2-B):304-9.
19. Kimberley TJ, Khandekar G, Skraba LL, et al. Neural substrates for motor imagery in severe hemiparesis. Neurorehabil Neural Repair. 2006;20:268-77.
20. Ertelt D, Hemmelmann C, Dettmers C, Ziegler A, Binkofski F. Observation and execution of upper-limb movements as a tool for rehabilitation of motor deficits in paretic stroke patients: protocol of a randomized clinical trial BMC. Neurology. 2012;12:42.
21. Smith ME, McEvoy LK, Gevins A. Neurophysiological indices of strategy development and skill acquisition. Brain Res Cogn Brain Res. 1999;7:389-404.
22. 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(3-A):662-8.
23. Azevedo PA, Jakubovic BKM, Corrêa JB, et al. A influência da imagética motora nas ondas corticais alfa e beta em pré-adolescentes praticantes de futsal. Mov Percepção. 2010;11(6):1679-768.
24. Bae SH, Jeong WS, Kim KY. Effects of mirror therapy on subacute stroke patients' brain waves and upper extremity functions. J Phys Ther Sci. 2012;24:1119-22.
25. Yavuzer G, Selles R, Sezer N, et al. Mirror therapy improves hand function in subacute stroke: a randomized controlled trial. Arch Phys Med Rehabil. 2008;89:393-8.
26. Koessler L, Maillard L, Benhadid A, et al. Automated cortical projection of EEG sensors: anatomical correlation via the international 10-10 system. NeuroImage. 2009;46:64-72.
27. Diniz C, Velasques B, Bittencourt J, et al. Cognitive mechanisms and motor control during a saccadic eye movement task: evidence from quantitative electroencephalography. Arq Neuropsiquiatr. 2012;70(7):506-13.
28. Rocha ACB, Chiaramonte M, Zaroa MA, Timm MI, Daniel Wolff D. Observação das evidências cognitivas de aprendizagem motora no desempenho de jovens violonistas monitoradas por eletroencefalograma: um estudo piloto. Ciênc Cogn. 2009;14(1):103-20.
29. Hatfield BD, Haufler AJ, Hung TM, Spalding TW. Electroencephalographic studies of skilled psychomotor performance. J Clin Neurophysiol. 2004;21(3):144-56.
30. Vecchio F, Babiloni C, Buffo P, Rossini PM, Bertini M. Inter-hemispherical functional coupling of EEG rhythms during the perception of facial emotional expressions. Clin Neurophysiol. 2013;124:263-72.
31. Hughes JR. Gamma fast and ultrafast waves of the brain: their relationships with epilepsy and behavior. Epilepsy Behav. 2008;13:25-31.
32. Contreras D. Mechanisms of generation of fast (20-80 Hz) oscillations in thalamocortical circuits. Rev Neurol. 2002;35:135-41.
33. Bastin J, Lebranchu P, Jerbi K, et al. Direct recordings in human cortex reveal the dynamics of gamma-band [50-150 Hz] activity during pursuit eye movement control. NeuroImage. 2012;63: 339-47.