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Artigo Científico

A study of brain reaction to spatial stimuli in students with different background knowledge

Um estudo da reação cerebral à estímulos espaciais em estudantes com diferentes formações

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Abstract

Based on neurology and cognitive science, many studies have been made to understand the human mental model, in order to learn how human cognition works. It is especially relevant when the problem is related to learning processes that involve complex contents and spatial-logical reasoning, related to superior education. This paper focuses on EEG techniques to help understand cognitive pathway in subjects from different backgrounds when they are exposed to an external stimulation of logical and spatial reasoning. It can be used to access aspects of human cognitive processing, through the changes of rhythm of the brain bands frequency, which indicate that some type of processing or neuronal behavior is happening. The EEG signals were captured using an ADC (Analogical Digital System) board with the LabVIEW system - National Instruments. The research was performed using Design of Experiments – DOE and signal processing was done (math and statistical techniques) showing the relationship between cognitive pathway by groups and intergroups. © Cien. Cogn. 2010; Vol. 15 (3): 023-032.

Keywords: brain signal processing; brain response; cognitive measures; spatial stimulation.

Resumo

Muitas pesquisas apoiadas pela neurologia e pelas ciências cognitivas têm auxiliado sobremaneira o entendimento sobre o modelo mental humano, permitindo compreender como funciona a aprendizagem humana. Estas descobertas são especialmente relevantes quando o tema está relacionado ao processo de aprendizagem que envolve a compreensão de conteúdos complexos e raciocínio lógico-espacial, relativos à educação no ensino superior. O presente artigo apresenta resultados referentes a experimento utilizando a técnica de eletroencefalografia – EEG que nos ajudam a entender que voluntários de diferentes áreas cognitivas apresentam padrões de sinais cerebrais diferentes quando expostos a estímulos externos relacionados a raciocínio lógico e espacial. Os diferentes padrões encontrados nos

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sinais cerebrais, referentes ao processamento cognitivo humano, identificados pelas alterações de ritmos ou faixas de frequência, tanto quanto a quantidade de energia associada à resposta dada ao estímulo, podem indicar que algum tipo de processamento ou comportamento neuronal distinto está ocorrendo. Os sinais do EEG foram acondicionados e convertidos usando sistema de conversão analógico-digital da National Instruments (LabVIEW system). A pesquisa foi modelada pela técnica de Projetos de Experimentos (DOE) e os sinais foram processados usando modelagem matemática por Fourier e estatística ANOVA mostrando a relação entre diferentes padrões cognitivos nos grupos de voluntários estudados. © Cien. Cogn. 2010; Vol. 15 (3): 023-032.

Palavras chave: *processamento de sinal cerebral; resposta cerebral; medidas cognitivas; estimulação espacial.*

1. Introduction

The study of organization patterns and how human thoughts work have enabled the creation of new hypotheses about the learning processes, which affect the cognitive and motor systems. Considering that the development of cognitive skills, such as spatial manipulation of objects, logical and abstract construction and full complex knowledge depends on innate pre-requisites as well as on interaction with cultural and geographic environments, family, etc. It is an important issue of educational research to find new ways to observe how innate and cultural knowledge are acquired.

Based on theoretical principles of cognitive Psychologists, such as Pinker (1997) and Gardner (1999), pointing to the possible cognitive differences between individuals (in terms of prevalent or preferred kinds of processing information); and also supported by cognitive science and the empirical observation of cognitive behavior of students of scientific and technological areas; and considering that these students should engage in complex cognitive and advanced processes during the course, one can suppose they already have (a priori) or have developed a specific profile of a professional in their area. This research has been developed in order to find evidences of it and as part of a doctoral thesis in the Post Graduation Program of Computers in Education (PGIE), of the Federal University of Rio Grande do Sul (UFRGS), along with the Research Group in Biomedical Engineering from the University of Caxias do Sul (UCS - CARVI - Brazil). We have been developing methodology with the objective to identify pathways of brain signals for specific cognitive activities in subjects with different cognitive profiles.

2. Theoretical considerations

The advances in and investigative techniques on cerebral sign patterns, associated to cognitive demands, have allowed education to discover new methodologies and derive theoretical postulations that can help formulate new models for innovative pedagogical practices, correlated to different cognitive profiles. The latest educational processes compiled finds from researchers that pointed to different kinds of learners and different motivations circumscribing them. To learn about people's cognitive functioning regarding cognitive aspects related to spatial abilities can enable significant improvement in the inter-relationship between subject and learning object. Considering how important it is to understand human learning processes and to design better teaching processes for areas of scientific and technological knowledge as well as human and social sciences, the research proposed herein is aimed at the understanding of how mental models are formed, especially on matters related to spatial abilities (Gardner, 1999).

Amongst the several concepts applied to the mental model, the most adequate one for this research refers to the formation and strengthening of the neuronal net through the presence of more synapses associated to stimulus that modify the concepts and the relationship between the subject and his environment (Merrill, 2000). The learning process is directly linked to the formation and changes to the mental model of a subject learner according to the stimuli that he is subjected to. Moreover, according to the literature, the majority of the subjects can easily alter, remodel and create new mental models when the external stimulus is visual (Shepard and Metzler, 1971; Desimone and Duncan, 1995; Kastner and Ungerleider, 2000).

Many researchers have shown it is possible to identify and measure different patterns of cerebral signals, related to external visual stimuli, when subjects are submitted to tasks of recognizing simple geometric images (circles, squares, triangles) presented in virtual format of 2 and 3 dimensions accordingly (Guizhi, 2006). Relations between cognitive phenomena and human biological mechanisms were more deeply observed and interpreted thanks to technology in the prospect area for cerebral activity, through non-invasive methods such as quantitative electroencephalograms (EEGq) (Ribeiro *et al*., 2005). EEG sources are electrical potentials generated by cortical neurons, which respond to several stimuli on the depth of the brain. Cerebral activity is captured on the surface of the scalp by means of electrodes. The observation of significant alterations in the cerebral signal in healthy subjects, in relation to knowledge of a visual pattern that concern tasks that involve visual stimulus, occur mostly in the frontal and parietal regions, when the signal is measured between 300-600 ms after the stimuli is applied (Bledowski *et al*., 2004; Luck, 2005; Schumacher *et al*., 2005; Gazzaniga, 2006).

By using specific software for the treatment of signals obtained from the EEG, it has become possible to build maps of cerebral activities at certain moments, making it easier to understand electrical potentials on the surface of the brain. Consistent research show the correlation between certain kinds of waves with alert activities and cerebral processing, such as Beta activity which is characterized by its low amplitude and which appears on the frequency band from 14 to 40 Hz (Guizhi, 2006; Luck *et al*., 2000; Roberts and Bell, 2000). With quantitative analysis of the cerebral electric activity, which uses technological resources on the evaluation of the EEG, it is possible to overcome the visual exam of the plotting that comprises a significant subjective component (Fonseca *et al*., 2003). The analysis of EEGs has also indicated that, during the presentation of stimuli, specific changes take place on cerebral signals, represented by a significant increase in the synaptic activity of millions of neurons simultaneously. These potentials evoked by a stimulus take place in a synchronized way. The result from the electrical potentials of a neuronal population is known as Event-Related Potentials (ERP) (Luck, 2005), which consists on a series of positive and negative waves that can be identified either numerically or according to their latency. The main ERP components are N1, P2, N2 and P3. Each component is identified by the letter that indicates whether the wave is negative or positive and by the number that indicates the time of the occurrence, measured in tenths of seconds (Veiga *et al*., 2004).

In the experimental investigation, the purpose was to look for indicators (quantification of energy allocated in brain activity, measuring response time to the stimulus, larger magnitude in the frequency band of the brain electrical rhythm, evoked on the experiment) of the brain signals that would be synchronized with the exercise proposed and that could subsidize the hypothesis that there are significant differences between engineering students and students from human and social fields, regarding spatial-logical abilities. The visual stimuli used in the experimental investigation is related to the concept of a "Mental Imagery" facility, which is responsible for the ability to mentally rotate visual forms, as proposed by Shepard and Cooper (1982).

3. Materials and methodology

Theoretical assumptions that support this research (Gardner, 1999; Pinker, 1997), and those matters that have already been mentioned concerning a possible relationship between results from variables related to the investigation on measures of cognitive abilities, especially and particularly, spatial abilities and the different attention patterns given to virtual visual stimuli lead to carrying out experiments supported by electroencephalography (EEG), developed by the Biomedical Engineering Research Group at University of Caxias do Sul (Carra *et al*., 2007). The investigation on the spatial-logical reasoning process during the perception of different visual patterns on volunteers with two different areas of knowledge was carried out as Design of Experiments – DOE (Montgomery, 2000). Design of Experiments is a technique used to plan experiments. It encompasses which data will be used, in what quantity and in which conditions it must be collected for a specific experiment, basically trying to satisfy two main objectives: the best possible results with statistical precision at the smallest expense (Montgomery, 2000).

Experiment Project

The parameters of the Design of Experiments are hereby defined:

Subjects: 40 (fourty) young volunteers (20-25 years old) participated in this experiment; they were undergraduate students from two different areas of knowledge: electrical and mechanical engineering students and social sciences students. In each area of knowledge, there were twenty (20) participants equally divided between males and females. The number of participants follow the guidelines of sampling in the Design of Experiments. The study was approved by the local ethics committee;

Kinds of stimuli: the stimuli presented consisted of three images showed on figure 1. These images represent 3D objects and these were arranged two by two totaling a group of six figures (stimulus) that was presented to each subject during 800ms with intervals of 10s, in the research;

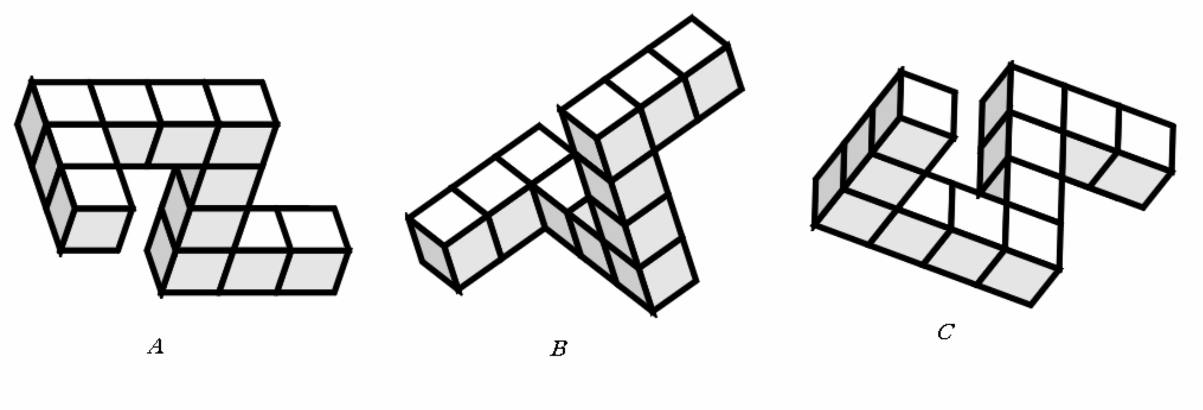

Figure 1 - Virtual visual stimuli.

Response variables: the response variable to be considered is the cerebral signal measured in the experiment that is related to the alteration in the latent cerebral signal, after applying the visual stimuli. The measurement is the amplitude parameter of electroencephalographic waves converted in magnitude in the frequency domain (analysis in the frequency domain) and the quantification of energy allocated in brain activity (analysis in the time domain). Differences related to potential evoked from spatial and visual stimulus are associated to the occurrence of different amplitudes and frequencies (magnitude levels between the signals), considered as different forms of allocating resources;

Controllable factors: as for the definition of controllable factors we chose to carry out a complete factorial project with 6-controllable factors at several levels (Ten Caten, 2007). The factors identified as controllable and having priority in this research are the subject's areas of knowledge in two levels, time intervals in four levels and researched scalp areas in 8 levels (we chose to evaluate only the most significant points in relation to the evoked signal for a visual stimuli) (Buschman and Miller, 2007; Sakai, 2008). Table 1 resume factors and number of levels for each one;

Fators	Level numbers	Level specific
A:knowledge area	2	**AE**:engineers students; **AH**: not engineers students
B: gender	2	**F**: woman **M**: man
C:kind of stimulus	6	Figures 1, 2, 3, 4, 5 e 6
D:scalp areas	8	T3, P3, T4, P4, PF1, PF2, F3 e F4
E:time intervals	4	0-200ms, 200-400ms, 400-600ms e 600-800ms
F:participants	40	PE1..10 (engineers students - man) PH11..20 (engineers students - woman) PE21...30 (social-human students - man) PH31..40 (social-human students - woman)

Table 1 - Controllable factors.

Experiment project: the subjects were invited to participate and agreed upon all the procedures during the experiment. Volunteers (subjects of the research) remained on a chair with back and head rest, in the most comfortable sitting position. The chair was positioned at a distance of 90 cm in front of a 15" screen, used to present the visual stimulus. Volunteers were connected to the ten lines of the collecting system (EEG) by a cap with electrodes. Points used on the cap (FP1, FP2, F3, F4, P3, P4, C3, C4, T3 e T4) correspond to the international 10-20 system (Jasper System), used to standardize capturing and identification of the results, according to Figure 2;

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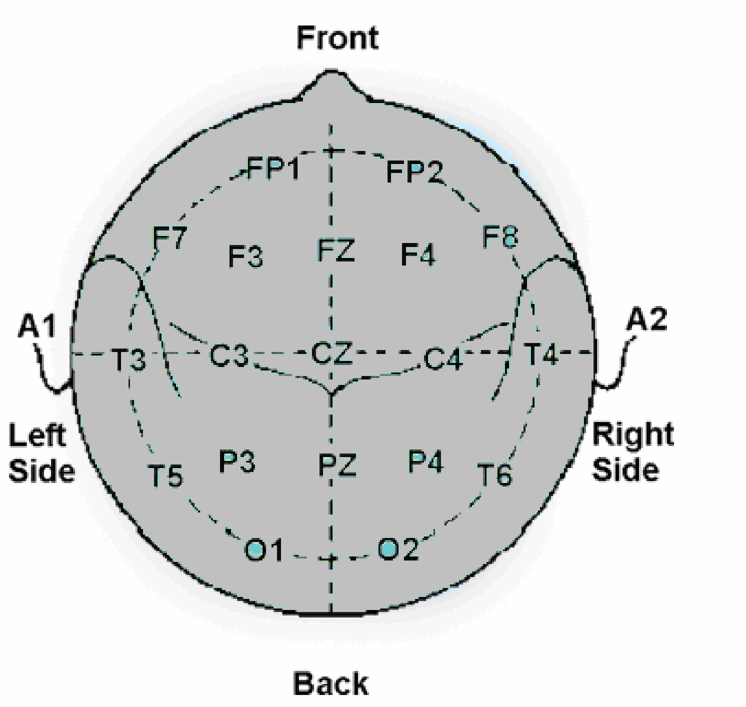

Figure 2 - International system 10-20.

The collected data followed the experimental blockage restriction guidelines. The research's subjects followed the pre-established program, considering as blockage factor only the areas of knowledge, since in order to collect signals, it is necessary to collect them simultaneously from the different areas of the scalp, and being that the procedure follows a protocol that requires the use of a cap with electrodes, the use of a gel, etc, it becomes necessary to collect all the stimuli related signals simultaneously.

4. Result analysis

The task executed was to visualize and analyse six sequences of spatial and logical stimuli, each one of them displayed at 800ms with intervals at 10s. During the interval of 10s, the volunteers were asked if the figures were or were not equals. Sequences were drawn before executing the experiment to prevent variable error effects as a result of a subject's fatigue or indisposition at the time of visualizing the images.

In the captured signals, on each measured point on the scalp, a high-pass 0.01Hz filter and amplifiers were used with a total gain of 21000 times. After processing the signals in the analogical system, they were also acquired digitally through the LabVIEW system - National Instruments., with an acquisition rate of samples/s. That research was performed using the experiments technical project – DOE. The signal processing was done (math and statistical techniques), with an acquisition rate of 1000 samples/s. The digitized signals were filtered with a low-pass filter at 55Hz.

The signals collected during spatial-logical stimulus exposure (each 800ms interval time) were digitized and processed according to the mathematical model of Fast Fourier Transform (FFT). In that period of time, the frequency BETA (8-14Hz) is manifested, indicating volunteer's maximum attention to the proposed stimulus. These results indicate the amount of energy demanded by the brain signal at the moment of the experiment and it is possible to

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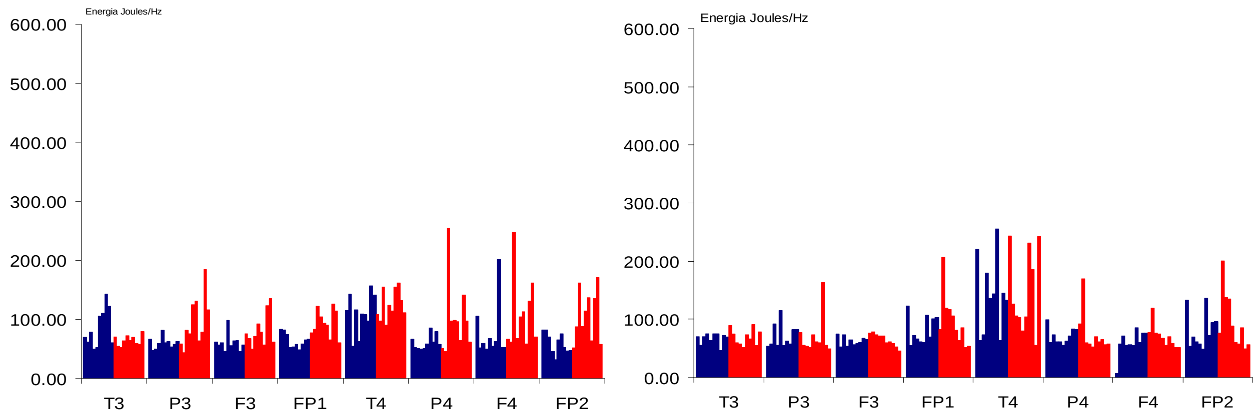
estimate that, in this rhythm, there might be an intense vigilance stage, as part of a cognitive process.

The response variable analyzed is identified as the magnitude in the (FFT) frequency domain of the time window of the signal that was collected, which corresponds to the change of brain signal due to spatial-logical stimulation.

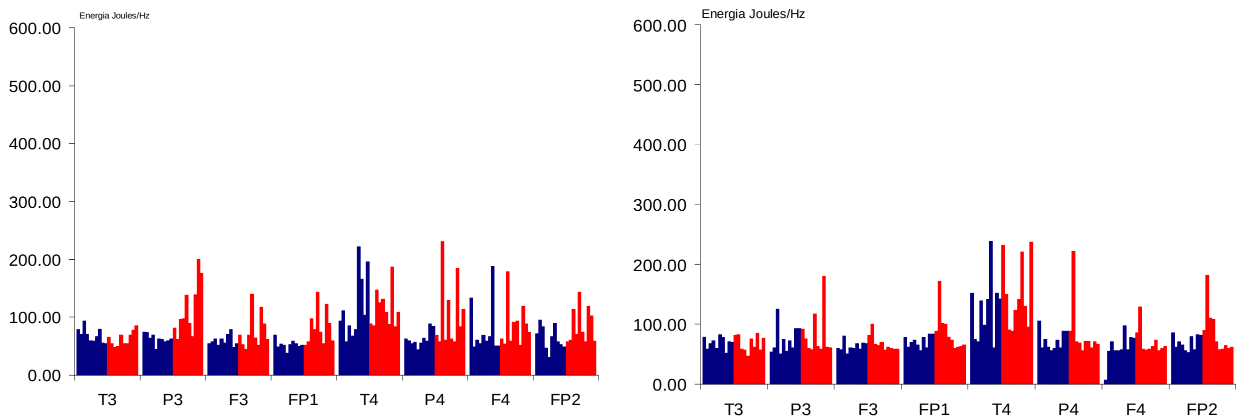
The signals collected during spatial-logical stimulus exposure (each 800ms interval time) also were digitized and processed according to the mathematical model of Digital Fourier Transform (DFT). In that case, the interval times were divided by four periods (200ms each time). The results were interpreted as a quantification of energy allocated in brain activity by scalp points.

Variance analysis on the data resulting from the variable were interpreted as a quantification of energy with quadratic sums. Data was statistically analyzed utilizing alpha significance level of 0.05 (5%). The sequence of figures then represents energy demanded in each scalp point at intervals of 200ms. For all figures present, we used the blue color to represent engineering students and red color to represent students of social and human sciences.



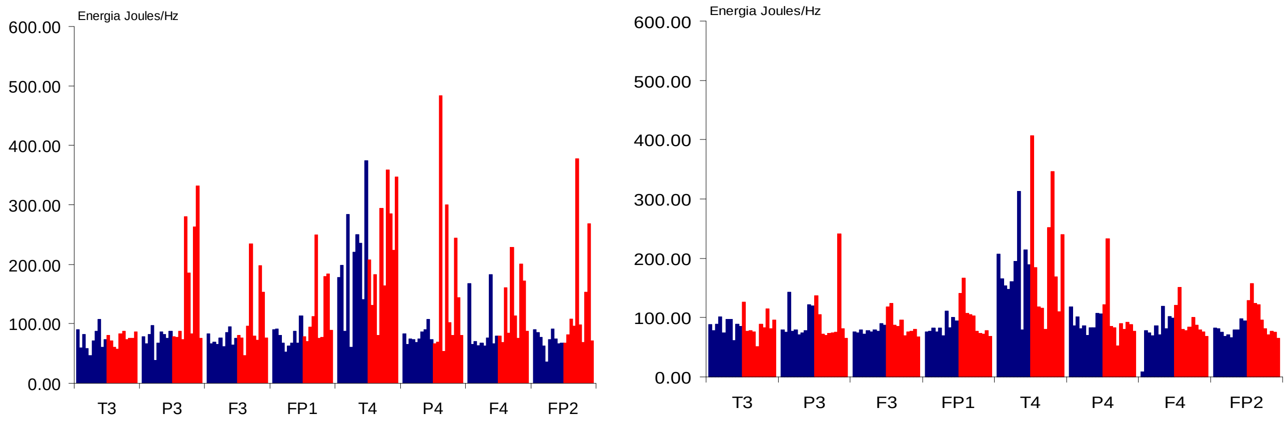
(a) (b)

Figure 3 - Amount of energy demanded of 0-200ms by scalp points in man (a) and woman (b).



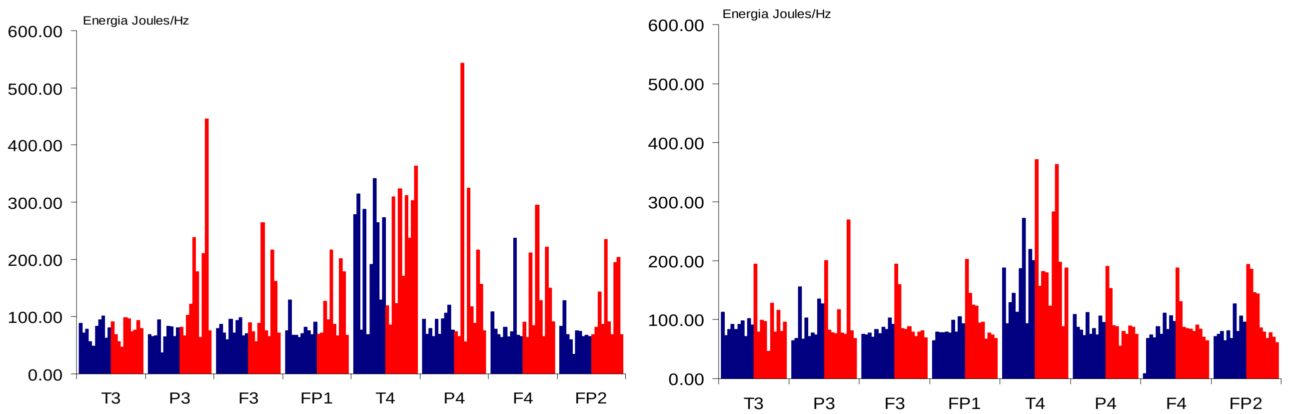
(a) (b)

Figure 4 - Amount of energy demanded of 200-400ms by scalp points in man (a) and woman (b).



(a) (b)

Figure 5 - Amount of energy demanded of 400-600ms by scalp points in man (a) and woman (b).



(a) (b)

Figure 6 - Amount of energy demanded of 600-800ms by scalp points in man (a) and woman (b).

These finds can be considered as indicators of cognitive pathways of different subjects of different knowledge areas and different sex. Of course these kinds of experiments are to be explored more in depth.

5. Conclusion

Electroencephalography applied in the research made it possible to analyze brain signals evoked from the experiment with spatial and logical stimuli and to measure those signals in different scalp points, in a non-invasive way, on different subjects belonging to two large areas of knowledge: scientific technological (engineering students group) and students of social and human sciences.

Concerning the issue of investigating resource demand and allocation in terms of electrical signals for the identification of on the same subject and between different subjects, the results point significantly towards a difference in cognitive effort among the subjects, above all those pertaining to different areas of knowledge, when they are subjected to the same spatial and logical stimulus. What is observed is that the attention process in the subjects of the experiment, focused on the visualization of objects with different patterns, takes place in a diverse form for that group.

In the male group, the graphs show that there are significant statistical differences in the measure of energy allocated in cerebral points: frontal, prefrontal and parietal (area of space reasoning) regarding spatial-logical abilities between engineering students and social-human sciences students, after a period of 400ms. The right temporal point (memory location) was evoked with the same intensity by both groups.

In the female group there was no noticeable difference on the demands of brain signals between groups at any particular point. However, the amount of energy measured in the right temporal lobe is larger than other points for both groups.

The study carried out intended to aggregate value to scientific and technological areas through scientific methodology applied to educational matters, with multidisciplinary approach, including cognitive sciences, neuroscience and psychometrics, as well as the development of technology for monitoring experimental activities in this area of research.

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