Brain-mapping of the cortical activity of broca’s area during a speech mental processing task in individuals with right mono-hemisphericity

Celia Torres de Oliveira
Fonoaudióloga, Formación en el Concepto Neuroevolutivo Bobath, Programa de Posgrado Stricto Sensu, en Ciencia de la Motricidad Humana de la Universidad Castelo Branco, UCB/ RJ, Brasil.
kaluc@terra.com.br

Vernon Furtado da Silva
Ph.D, Programa de Posgrado Stricto Sensu, en Ciencia de la Motricidad Humana de la Universidad Castelo Branco, UCB/ RJ. vfs@recreio.castelobranco.br

João Rafael Valentim Silva
Laboratorio de Neuromotricidad II de la Universidad Castelo Branco, UCB/RJ/BRASIL. Profesor de Educación Física, Miembro Efectivo de la Sociedad Brasileña de Fisiología del Ejercicio, Programa de Programa de Posgrado Stricto Sensu, en Ciencia de la Motricidad Humana de la Universidad Castelo Branco, UCB/ RJ, Brasil.
professor_joaorafael@hotmail.com

ABSTRACT: The present study intends to map the inferior lateral frontal lobe while it is exposed to a task of mental processing in subjects of the masculine sex, right monohemispheric. The CLEM test, part of the protocol of Herris, and the quantitative electroencephalography were used. It was used the ANOVA “one-way” analysis for inter-hemispheric asymmetry and the independent “t” test for distribution of absolute power between pairs of homologous electrodes in the theta and alpha bands of frequencies (p ≤ 0.05). Although the data suggested a discrete tendency to the phenomena related to the cerebral hemispheric specialization, the modifications were not shown to be significant to this task.

Keywords: speech mental processing, Broca’s area, hemispheric specialization, hemisphericity.
Speech mental processing is one of the functions with greater cortical asymmetry, in which the left hemisphere has greater competence for this function in association with the right hemisphere, that removes the robotic aspect, favoring the flavor of interpersonal communication, through prosody (Kent, 2000).

It is known in the literature, that Broca’s area of speech processing is located in the left inferior lateral frontal cortex in the majority of individuals. Current works promote its involvement with the speech working memory, assisting in the phonological, syntactic and semantic storage, in the maintenance of closure of the analysis-synthesis which is essential to the mnemonic processes for the understanding of speech. (Baddeley, 1986; Gathercole e Baddeley, 1993; Fonseca, 1995)

However, studies had pointed to different cortical strategies for this hemispheric specialization, being that 15% of the population of accidents can use the right hemisphere or both for this function; the same happening in the feminine gender (Goldberg, 2002; Lent, 2002). Still, inquiries about human hemisphericity have concluded that 25% of the population can present a bigger preference in processing with one of the hemispheres, while others make it bi-hemispherically (Bogen, DeZuere, Tenhouten and Marsh, 1972 apud Fairwether & Sidaway, 1994); being that this dependence is not tied to the hemispheric structural content (Bradshaw et al. 1983; Kaiser et al., 2000).

Along these lines, researchers point that when a hemisphere processes information that it receives directly and commands the reply by itself, the reaction time of the individual tends to be shorter than that of one that receives information in the opposing hemisphere, and this is attributed to the time of passing through the comissure, making it slower around 20 to 100 ms. (Zaidel, 1983a, 1983b; Kent, 2000).

Being based on previous studies like those of Murray (1979) and Fairweather & col. (1994), this hypothesis foments recent inquiries in the line of research of human motricity that involves the hemispheric functionality and points to styles of sport education adequate to hemispheric characteristics, reaching bigger and better results in learning and motor performance, further emphasizing that education will have to consider the direct relationship between the content and the learner’s hemisphericity. Consequently, with these results emerges a need to correlate them to the format of speech performance, because this one is also a motor ability of the skeleton and muscular structures of the phonarticulatory organs.

Broca’s area, in speech processing, can be related to some alterations, like: to articulatory disorders inherent to motor sequencing, called dyspraxia, that can be classified as: developmental - when it happens to a child in his/her evolutive process; or acquired – caused by some type of injury (Kent, 2000). This way, it participates in the speech working memory, the subvocal assay, that is important in phonological storage, in which phonemes, when entering, are kept in serial order to be processed and interpreted (Kent, 2000; Gathercole et al., 1993; Fonseca, 1995). Therefore, the storage and auditory mental processing of inputs are factors that scientific inquiries have been delimiting in evolutive phonological deviations - delay in the speech-language and/or future reading and writing disorders.

Such theoretical descriptions raise the following questioning: if the direct relationship between pedagogic strategies and hemisphericity makes possible the acquisition and retention of a skillful-motor task; possibly any interventive process must raise considerations that can reinforce this hypothesis. Since the present study is restricted to speech processing, will this format be able to contribute to a more effective and qualified education? For such a question, the logic for this conjecture, initially, is to trace a congruent line between hemispheric specialization and hemisphericity, in the relative use of the inferior frontal lobe as a basis for this hypothesis, since Broca’s area is located there.

Thus, this study aimed to investigate the existence of cortical activations of the inferior lateral frontal lobe during a mental repetition...
task of simple and random words of the Portuguese language, with respect to the presentation of symmetry or asymmetry, verifying if this follows the phenomena of hemispheric specialization and/or brain hemisphericity.

METODOLOGY

Universe
The universe of the present research included young individuals of the masculine sex of the city of Rio de Janeiro and the city of Petrópolis. An explanation was made referring to the object and methodology of the present study to get the acceptance and signing of the term of consented participation in the procedures of the experiment. After this agreement, times and places for the experimental procedure were defined.

Sample
The sample group was composed of ten subjects, being nine from the city of Rio de Janeiro and one from Petrópolis, Brazil, an age group from 16 to 38 years. These subjects had been previously diagnosed as right mono-hemispheric, without cognitive, auditory or speech and language deficits, right-handed, without strabismus or any kind of mental health problem, and not making use of psychotropic or psychoactive drugs.

Experimental procedure
The selection of the sample went through three stages of exclusion.

First stage: CLEM Test.
This test was applied on the basis of the protocol for the CLEM test of Fairweather et al. (1994), in an individual stage, repeated in several days to get the sample group and carried out in a closed room measuring approximately 5x4 m, without decoration and of light color.

The subjects, one at a time, were seating in a chair at a distance of 2 m from a black curtain with an orifice for the lens of the video camera. This isolated the video camera and its operator, and also a tape recorder with the questions of the procedure. Just below the lens, on the curtain, a white card was placed measuring 5x10 cm and two amplifying speakers, in a lateral distance of 50 cm each to the camera.

Before the test it was explained to the subjects that each question was intended to verify “how” they responded to the different types of problems and not the “correct answers”. After the explanation the camera and the tape recorder were set in motion, initially presenting some warming-up questions like name, age and, after that, the specific procedure of the test.

The white card acted as a point of control to the subjects’ gaze, preventing deflections of the head to undesired directions, while they listened to and answered the five analytical and spatial questions for an analysis of the hemisphericity. Between questions it was granted a rest of five seconds, to help focus the subjects’ attention in the following question.

The joint movement of the subjects’ eyes was filmed, and later we made an analysis of this tape. For this much, it was designed immediately after each question in the “clock face” protocol, the angle pattern of this movement during the processing of the questions. Taking as reference to diagnosis the angle designed by the conjunction of the eyes, hemispheric preference, according to the numerical system of Borg (1983), according to Fairweather et al.. (1994).

Subjects diagnosed as right mono-hemispheric were selected and summoned to participate in the second instrumental stage.

Second stage:
A. Speech and language performance observation form - FOPFL: this form was applied on the basis of the protocol of Jakubovics, (2002), in an individual stage. The values of the FOPFL were codified into “adequate” or “inadequate”, in relation to the subject’s adhesion to the research.
B. Hand functional laterality dominance observation form - FO-DLFM: this form was applied on the basis of the protocol of psychological evaluation described by Herris, in an individual stage, being used only items of hand dominance in each task. The evaluation was codified by the computation of the functional dominance of the hand.

Subjects suitable to the profile of this research were summoned to participate in the last instrumental stage.

**Third stage:**

Detecting the eletroencephalographic signal.

Subjects were warned about the procedures of the EEG, preventing unnecessary doubts and interruptions. The room used in the research was prepared with sound isolation and the light was switched off during the detection of the EEG signals. The subjects sat down comfortably in a high-backed armchair, keeping their eyes closed and relaxed to minimize muscular artifacts. Above this armchair, a tape recorder was placed in the central position of the skull, preventing the tendency to favor sound asymmetry for any ear. The recorded tape contained 8 minutes of auditory exposition of random simple words, with pauses of 3 seconds between them. Here, care was taken to choose words that did not make possible any semantic association between them during the task.

The detection of the EEG signal was carried through at three consecutive moments:

- the moment before - the detection of the EEG for 8 minutes at rest - without stimulation;
- the second moment - More than 8 minutes of continuous EEG detection, during the accomplishment of a task to listen to the words and mentally repeat them, and
- the moment after – with 8 more minutes without stimuli, remaining only the subject and two testers (one to collect the signal and to observe artifact moments and another to handle the tape recorder) during the instrumentation.

**Acquisition of the data**

For the detection of the eletroencephalographic signal, the device Braintech 3000 was used (EMSA - Medical Instruments, Brazil), a system that employs an analogical-digital converting board (A/D) of 32 channels with a 12-bit resolution, placed in one ISA slot of a Pentium III, with a 750 Hz processor. Electrophysiological signals have been filtered between 0.01 (pass-low) and 100 Hz (pass-high), having a rate of sampling of 200 Hz. It was also used the so called detection software “EEG Captação” (Emsa-Delphi 5.0), with a Notch filter of 60 Hz and stop filters of 0.3 Hz (pass-high) and 25 Hz (pass-low).

The International system 10/20 (Jasper, 1958) was used in the positioning of 19 monopole electrodes throughout the scalp (areas: frontal, temporal, parietal and occipital) and an electrode in each ear (bi-auricular reference). The values of impedance of each electrode have been kept between 5-10 K ohms (Ω). Since the acquired signals would have to be at a total amplitude (peak to peak) of less than 100 μV, they have been amplified with a gain of 22,000. Moreover, visual artifacts have been inspected with the use of the visualization program “EEG Telas” (Emsa-Delphi 5.0); to this end, with the purpose of reducing data artifacts, a monitoring was made with regard to the sweeping and blinking eye movements, since these movements could be caught by the electrodes F7 and F8.

**Analysis of data and calculation of the dependent variables**

The EEGq signals have passed, initially, through a visual inspection to identify and eliminate stretches with artifacts against the best interest of the research. After that, they had been processed by the Neurometrics program (NxLink, Ltd., USA), that extracted the neurophysiological variables of interest to the experiment: and interhemispheric asymmetry and distribution of power, both in the theta and alpha band.

Interhemispheric asymmetry occurs when there is no balance in the distribution of absolute power among homologous electrodes (i.e., electrodes in the same position, but in opposing sides of the head). The basic mathematical formula for the calculation of the asymmetry is: \% Asymmetry = (L-R/L+R) x 100. L stands for the left homologous electrode, while R stands for the electrode to the right. The values of asymmetry, therefore, stand for the difference between values of power for pairs of homologous electrodes. Positive values occur when the power of the left hemisphere is greater than that of the right, and negative values occur when the power of the right hemisphere is greater.

Power is a measure of amplitude. In other words, the greater the amplitude, the greater is the amount of energy distributed through the scalp. Specifically, the Absolute Bipolar Power variable was used (score Z). This variable represents an estimate of the power between pairs of specific electrodes inside a given frequency band. The variable also indicates deviations from normal values: a negative signal indicates that lesser power, or energy, is expected; and a positive signal indicates that more energy is expected, in relation to a normative group.

**Graph 2 - Variation of absolute power in regions T3-F7 and T4-F8 in the theta band**

![Graph 2 - Variation of absolute power in regions T3-F7 and T4-F8 in the theta band](image)
Statistical analysis

To verify if the values of asymmetry generated by the Neurometrics program were statistically different at the three moments (i.e., before, during and after treatment), a “one-way” ANOVA was applied to electrodes F7-F8 and T3-T4 (homologous pairs) individually in the alpha and theta bands of frequency.

To verify if the activations of Broca’s area and its respective homologous area were statistically different, a t-Test (independent measures) was applied for the values of absolute power generated by the Neurometrics in electrodes T3-F7 (left hemisphere) and T4-F8 (right hemisphere), at each moment separately in the alpha and theta bands of frequency.

RESULTS

The results are divided in the shape of neurophysiological variables in two bands of frequencies: - theta - related to the attention demand; and - alpha - related to the cognition demand, inter- and intra-hemispheres cortical activations being analyzed.

Neurophysiological variables

Theta band:
Graph 1 describes the average values of the inter-hemispheric asymmetry variable, which suggested a greater activation of the right hemisphere at the three experimental moments, even though it has not been observed a statistical difference between conditions F7-F8 (p = 0.842) and T3-T4 (p = 0.739).

Graph 2 illustrates the difference of absolute power distribution at the three distinct moments, at the left hemisphere areas T3-F7, and in the right hemisphere in the T4-F8 in the theta band. The results have not showed significant differences between electrodes T3-F7 and T4-F8, in the pre-task (p = 0.710), during (p = 0.564) and after-task (p = 0.948).

Alpha band:
Graph 3 describes the average values of the variable of inter-hemispheric asymmetry, that suggest a greater activation of the right hemisphere at the three experimental moments, although a statistical difference between conditions F7 - F8 (p = 0.975) and T3-T4 (p = 0.940) has not been observed.

Graph 4 illustrates the difference of distribution of absolute power at the three distinct moments, in the regions of the left hemisphere in electrodes T3-F7, and right hemisphere T4-F8 in the alpha band. The results have not showed significant difference between electrodes T3-F7 and T4-F8, at pre-treatment (p = 0.322), during (p = 0.504) and after-treatment (p = 0.665).

DISCUSSION

With regard to the inter-hemispheric asymmetry in the theta band in electrodes F7-F8, it was made possible a discrete increase in the average of score Z at the moment of the task. Such alteration, although not statistically significant, can be related to the fact that the theta rhythm showed activation for sustained attention during the execution of a skillful-motor task (Smith et al. 1999). These electrodes were in the inferior frontal lobes in both hemispheres, therefore this trend agrees with the current literature, when suggesting greater activation during speech working memory, using the subvocal component for the mental execution of the motor sequencing of a word (Mazoyer et al. 1993).

In electrodes T3-T4, however, placed in the temporal area, a trend is observed as to a lesser demand at the moment of the score task, a fact that possibly is linked to lesser attention in the use of the phonological lexicon during the task, for being simple words known by the subjects and not getting any statistical difference (MacNeilage, 2001; Lent, 2002).

As to the inter-hemispheric asymmetry in the alpha band for electrodes F7-F8, it was possible to observe a tendency of increase in the average of score Z, although statistically not significant. The alpha rhythm is related to the use of cognition during the learning of a skillful-motor task, so the repetition of the task demands a bigger cortical activation of this rhythm (Smith et al, 1999). Such fact can be underlined by the increase of tendentious values during and after the mental task of subvocal repetition, a task of Broca’s area, being these electrodes, in this area, on the two hemispheres.
show these difficulties at the alert level. However, evidences findings are due to the prominence of peaks of cortical tracing. It must be underlined that Smith et al. (1999) say that these neurosciences (Kent, 2000; Kandel et al., 2003).

As to the asymmetry in this band of frequency for the pairs of electrodes T3-T4, area responsible for the phonological lexicon, it was possible to observe a discrete oscillation with a trend to the decrease of the average of score Z only at the moment of the task. Although not significant, this decrease stresses the fact related to the alpha rhythm in automatic tasks, tending to diminish the cortical activation (Smith et al. 1999) when using simple words known by the lexicon of the subjects, which favors the lesser demand for a return to the lexicon to its understanding. This supports the greater cortical demand to the neural population in Broca’s cortical region, for the necessary attentional focus to the performance of the skillful-motor sequencing of the task (Mazoyer et al. 1993; Paus et al. 1993; Frith et al., 1991).

As it is, two facts can be confronted, although this discussion is based on a trend with no statistical difference. The first, already described above, suggests that opposing the inter-hemispheric analysis measurements of theta and alpha frequencies strengthens the use of Broca’s area in its participation in the speech working memory that refers to the subvocal component, stressing the phenomenon of hemispheric specialization in this area; and the second, of greater weight, shows that all values have been negative, a greater distribution of power in the right hemisphere under experimental conditions prevailing; this suggests the idea of a better right hemisphericity working ability in these individuals, supporting the hemisphericity phenomenon (Zaidel 1983a, 1983b; Fairweather et al., 1994).

As to the absolute power in the theta band in electrodes T3-F7, corresponding to the left hemisphere, it was possible to observe oscillations in the average of the score Z. Such alteration, although not statistically significant, can be explained by the fact that the theta rhythm is controversial in the literature – its action in the alert state is better known, in case of fatigue increase, increase of sleepiness, attention decrease, explicit in books of current neurosciences (Kent, 2000; Kandel et al., 2003).

It must be underlined that Smith et al. (1999) say that these findings are due to the prominence of peaks of cortical tracing in more posterior regions during a task in which subjects show these difficulties at the alert level. However, evidences oppose these interpretations, indicating that theta is generated in the region of the anterior cingulated cortex, that is, it is also related to the degree of control of conscience to keep an attentional set, when investigated in the medial frontal area; but in posterior areas and in unmotivated tasks it can be decreased due to its importance to the state of relaxation, or momentary disinterest about the task. Being so, the results suggest a tendency to diminish the attention at the moment of the task, returning to the biggest power next to the initial one, because more extensive regions of neural activations are being measured and disinterest is stressed, as to some of the subjects at the end of the experiment, when they perform such task.

When measuring the variation of absolute power in the selected electrodes, for being T4-F8 located in the right hemisphere in the inferior lateral frontal area and also in the higher temporal area, it was possible to observe a decrease in the average of the Z score at the three moments. These analyses across the hemispheres can be tendentiously explained by the fact that in the left hemisphere there is a potentiation of Broca’s area in the hemispheric specialization during a task of speech working memory, which may have influenced, at the moment of the task, a greater dispersion of energy scattered due to disinterest; but in the right hemisphere there remained biased higher scores, favoring, perhaps, hemispheric specialization, being this not the competent hemisphere to this task, not existing, therefore, statistical differences (Banich, 1997; Kent, 2000).

About the distribution of absolute power in electrodes T3-F7, in the left hemisphere, and T4-F8 in the right hemisphere, in the alpha band related to cognition, it was possible to observe discrete oscillations with a decrease in the average of the Z score, at the moment of the task, in both hemispheres. This fact can be attributed to the possibility of both hemispheres to present simultaneous cortical activation at the moment of the task, referring to the attenuation of cognition and returning to the similar values at the initial moment. This characterizes a possible trend of attenuation of the activation in both hemispheres, due to task simplicity, because the alpha rhythm is related to consolidation during the task, reflecting cortical idleness during automatized processes, in perceptive, cognitive or motor skills of the task (Smith et al., 1999).

Thus, it is stressed the fact that, one more time, the task shows a positive trend in the evaluation of the activation of Broca’s area, in its role of working memory and automatized sequential movements, keeping a synchronism in the experimental conditions between the distribution of power in both hemispheres and reasserting the discrete increase of distribution of power for the right hemisphere made evident by less negative values. This favors that it can be hypothesized, although with no statistical difference, that the basic idea must be stressed for congruence between hemispheric specialization (left to speech processing), and the subjects’ hemisphericity.

---

**Graph 4 - Variation of absolute power in the alpha band**

As shown in the graph, there is a tendency of diminished power over time (from Pre to Durante to Pos) for electrodes T3-F7 and T4-F8. This suggests a decrease in the average of the Z score, indicating a possible trend to diminish the attention at the moment of the task. The left hemisphere shows a decrease in power, while the right hemisphere maintains higher scores, favoring the right hemisphere's specialization for this task. This graph supports the idea of hemispheric specialization, with the left hemisphere more active in tasks related to speech working memory.
CONCLUSION AND RECOMMENDATIONS

The results, although not bearing significance, have shown an inclination to the hemispheric specialization and hemisphericity phenomena. Future investigations must be supported by a bigger sample, to face the prevalence of results with negative values and the phenomenon of the transference of processing through the corpus callosum (Zaidel, 1983a; 1983b) in individuals with other hemispheric strategies, as left mono-hemispheres and bi-hemispheres, in different genders (Fairweather et al., 1994; Goldberg, 2002). This inquiry will be able to supply a diversified statistical analysis, mapping more significant references for the formulated hypotheses or suggested others.

Therefore, under the experimental conditions proposed and in the sample selected for the present study, there is no evidence that the phenomenon of hemispheric specialization exerts significant influence in the activation of the homologous area to Broca’s in the right inferior frontal lobe of the cortex.

REFERENCES

MACNEILAGE, PF. The frame/content theory of evolution of speech production. Departament of Psychology, Ms. University of Texas at Austin. 2001.