Aphasia Rehabilitation: Decision Support Model

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Aphasia impacts functional communication, daily activities, and social relationships. Aphasia is treated with traditional therapeutic methods, which involve repeating language tests and observing the progress of their responses. Technology is being used to investigate the activities of the brain. However, some of these technologies are very robust, have high costs for implementation, and require a team of specialized professionals to handle them. This paper aims to develop an aphasia screening model to support the conventional therapy used by speech-language pathologists in rehabilitation centers. The model was created in the first instance to test the instruments and procedures, focusing on the brain activation of aphasic participants through the criteria of lesion location (affected hemisphere) and hemiparesis (right or left side). Furthermore, secondly, to support conventional therapy in the rehabilitation process of the aphasic. The model used electroencephalography (EEG) as a non-invasive instrument and object naming task as a linguistic test, described in the adult language paradigm proposed in 2017 by the American Society for Functional Neuroradiology. We tested the method with 11 aphasic participants diagnosed with post-stroke aphasia in rehabilitation. We conclude that the results can support the health professional's decision in conventional therapy to adjust the conduct of language stimulation with a personalized and monitored approach throughout the rehabilitation process.

Keywords: Aphasia. Electroencephalography. Biomedical Signal Monitoring. Language Rehabilitation.

Introduction

Aphasia is a condition resulting from a lesion in the brain, commonly in the left hemisphere. It is considered "one of the most common neurological changes after focal lesion acquired in the Central Nervous System (CNS), in areas responsible for comprehensive and/or expressive language, oral and/or written" [1].

The aphasias' classification is based on the patient's performance, which is evaluated through tests to verify the fluency of speech, the ability to understand orders, the capacity to name objects, and the ability to repeat words [2]. Table 1 shows the types of aphasia, and the test parameters with their impacts.

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The aphasia assessment process involves language examination instruments and should address "different language levels and components, among them comprehension and expression" [3]. These language assessment instruments, used by neuropsychologists and speech-language pathologists for diagnosing aphasia, are also used as a treatment strategy.

Language assessment and rehabilitation involves analyzing the ability to name, repeat, comprehend, read, and write [4]. The definition of the battery of tests will depend on the theoretical approach used by the therapist. Not having a single approach hinders the sharing of data, which is essential for research integrity and scientific transparency. Therefore, members of the American Society for Functional Neuroradiology from many institutions have created a standard language paradigm that balances ease of application and clinical utility.

Beside this background, this study aimed to develop an aphasia tracing model to support the conventional therapy used by speech-language pathologists in rehabilitation centers.

Table 1. Types of aphasia.

Aphasia	Fluency	Comprehension	Nomination	Repetition
Broca	Non fluent	Normal	Disturbed	Disturbed
Wernickle	Fluent	Disturbed	Disturbed	Disturbed
Conduction	Fluent	Normal	+/- Disturbed	Disturbed
Anomic	Fluent	Normal	Disturbed	Normal
Transcordial Motor	Non fluent	Normal	Disturbed	Normal
Transcordial Sensorial	Fluent	Disturbed	Disturbed	Normal
Transcordial Mixed	Non fluent	Disturbed	Disturbed	Normal
Global	Non fluent	Disturbed	Disturbed	Disturbed

Our approach to supporting the rehabilitation process for aphasics is based on tracking electrophysiological stimuli, a method that can aid personalized, monitored rehabilitation.

The present research was approved by the Ethics Committee on Human Research of the Integrated Manufacturing and Technology Campus (CIMATEC) - Senai/ Bahia (CAAE: 29622120.2.0000.9287) and approved by the Health Secretariat of the State of Bahia - SESAB (CAAE: 29622120.2.3001.0052) with the Center for Prevention and Rehabilitation of People with Disabilities - CEPRED, as a co-participant center.

Materials and Methods

This is an exploratory study [5] that used the Descriptors in Health Sciences/Medical Subject Headings (DeCS/MeSH) and the platform Virtual Health Library (VHL) to find the decision model to be used [6].

We used the model EEG, an electrophysiological monitoring method based on brain electrical activity, and incorporates Fourier analysis, which has several scientific applications, among them signal processing with the separation of data into frequency intervals and brain regions.

The model was created to evaluate the instruments and procedures, focusing on brain activation in aphasic participants through the criteria of lesion location (affected hemisphere) and hemiparesis (right or left side).

Population and Sample

The study population was made up of participants diagnosed with post-stroke aphasia, according to their medical records, that were undergoing rehabilitation treatment and were recruited by the speech therapy team in the adult neurological rehabilitation sector of CEPRED in the city of Salvador, Bahia, Brazil, following the inclusion and exclusion criteria.

The sample comprised eleven aphasic participants (8 women, and 3 men). The average age of all the participants was 54 ± 7 years. Of these participants, 10 had brain damage in the left hemisphere, and one had right hemisphere damage, all with hemiparesis (difficulty moving half of the body) (Table 2). None of the participants had hearing impairment.

Inclusion Criteria

- Participants of both genders,
- Over 18 years
- Diagnosed with post-stroke aphasia, and standard or normal-corrected vision.

Exclusion Criteria

- Participants with mental disorders identified by a healthcare professional were not invited to the study.
- Participants with unstable cardiovascular disease or other serious illnesses that

Table 2. Participants descriptions.

ID	Gender	Age	Hemiparesis	Hemisphere affected	Type of Aphasia
P01	Female	53	Right	Left	Broca
P02	Female	51	Right	Left	Broca
P03	Female	53	Right	Left	Anomic
P04	Female	45	Right	Left	Transcortical motor
P05	Female	63	Right	Left	Broca
P06	Female	45	Right	Left	Transcortical motor
P07	Male	58	Right	Left	Broca
P08	Male	63	Right	Left	Broca
P09	Female	59	Right	Left	Broca
P10	Female	45	Left	Right	Global
P11	Male	60	Right	Left	Global

ID: Identification; P: participant.

prevented them from performing the tasks were also not part of the research.

Non-Invasive Method

We used electroencephalography (EEG) as a non-invasive and accessible method, a device with 16 channels, with electrodes placed according to the international 10-20 positioning system for electroencephalographic analysis. We choose this device (Figure 1) because it is wireless, designed for human brain research, and already validated by other researches [7-11].

We used 16 electrodes for the analysis of this study: 4 electrodes positioned in the frontal lobe, 2 in the left hemisphere (F7, F3), and 2 electrodes in the right hemisphere (F4, F8) in the five frequency ranges: Theta (4-8 Hertz), Alpha (8-12 Hertz), Low Beta (12-16 Hertz), High Beta (16-25 Hertz) and Gamma (25-45 Hertz).

Figure 1. Emotiv Epoc+.

Test Task: Object Naming

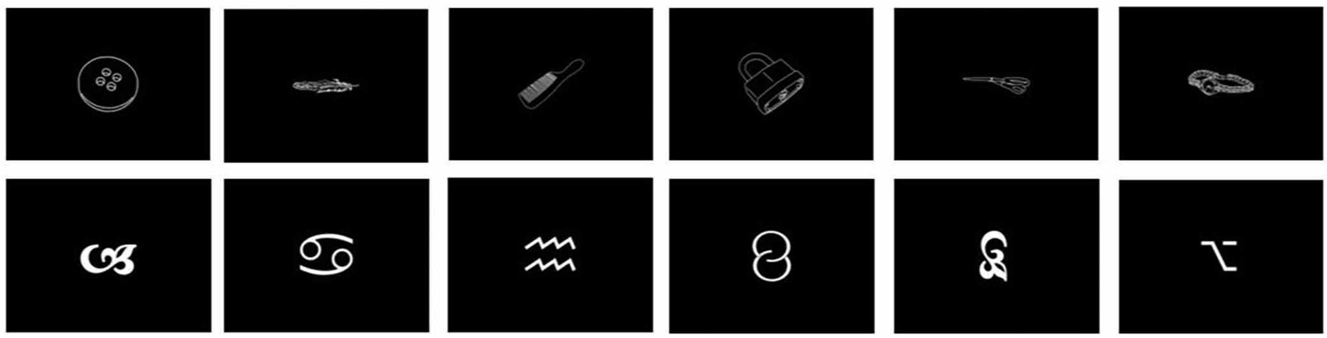
In this task, natural objects are presented on the video monitor. For each object on the screen, the participant must think of its name (Figure 2). At the end of the sequence of objects, there is a segment with six symbols, which not be named. Thus, we have 36 stimuli objects and 36 control symbols. The object naming task activates the frontal region more strongly than the temporal region [4].

The language paradigm chosen was proposed by the American Society for Functional Neuroradiology and is used as the standard language paradigm because it strikes a balance between ease of application and clinical utility [4]. These factors were essential for the present study.

Tools

We used the software EmotivPro 3.3.0.433 to check the connection of all the electrodes, which should appear in the interface with a green

Figure 2. Object naming task.



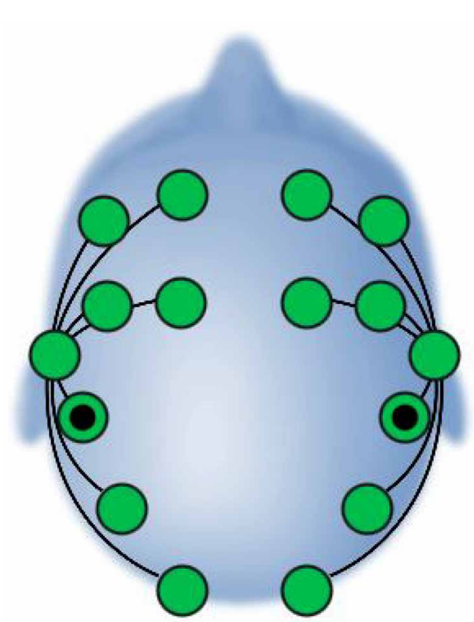
color (Figure 3), showing the connection. If any electrode is not green, the researchers must adjust by removing strands of hair under the electrode or rehydrating it with saline solution. The collection only begins after the green connection of all the electrodes.

We used Matlab to process the data, version 9.12 (R2022a), where we work with calculus, matrices, signal processing, filtering, and graph construction.

Decision Support Model

The model presented in Figure 4 was created to evaluate the instruments and procedures, focusing on brain activation in aphasic participants using the criteria of lesion location (affected hemisphere) and hemiparesis (right or left side). In the second instance, speech pathologists support the decision of rehabilitation procedures in a personalized way.

Figure 3. Interface showing good electrode connection.



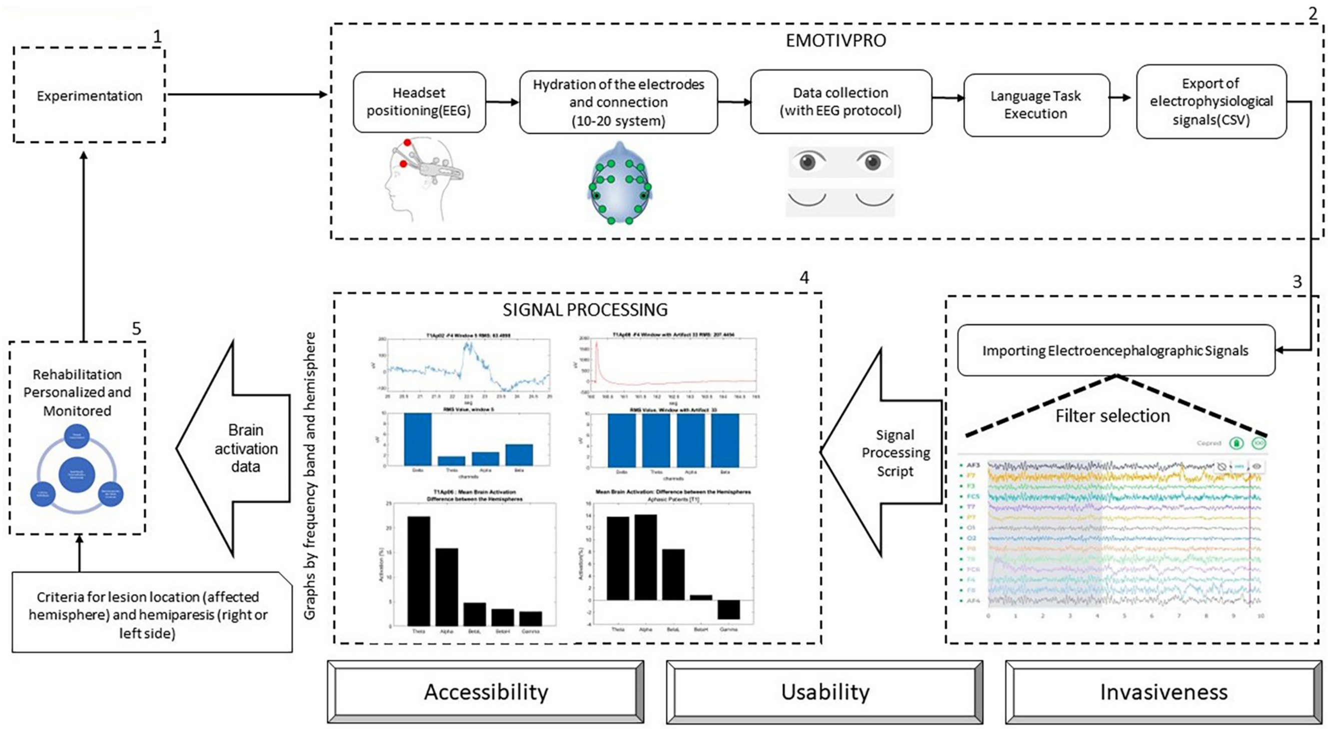
After positioning the device on the participant's head and verifying the connection of all the electrodes, data collection begins with the EEG protocol, with the subject's eyes open and closed for 40 seconds. Once the protocol is finished, the "1" key is pressed to identify the exact beginning of the task. Each participant generated a data file exported from the EEG platform (EMOTIPRO) in CSV (Comma-separated values) format and imported it into Matlab.

We convert the signal to microvolts(uV) and process the signal with different techniques, starting with removing the DC level from the signal to avoid signal distortion. The asymmetric response to the fault is called DC Offset and is a natural phenomenon of the electrical system, applying a filter and decomposing the signal using the Fourier transform.

We created an algorithm to fragment the signal into "windows", making it possible to analyze the stimulus and control intervals. We used the calculation of the RMS value of the signal in each window (the practical value, also known as the RMS value from Root Mean Square).

We developed algorithms to generate the results in a graphical format. We normalized the power per electrode (F7, F3, F4, and F8), generated graphs with the frequency bands for each aphasic participant alone, and graphed the participants' average. We calculated the mean and median

Figure 4. Decision support model.



power in each frequency band for each of the four electrodes, generating graphs for each aphasic participant. Moreover, finally, we calculated the difference in brain activation between the left and right hemispheres, plotting the graphs. We used lesion location and hemiparesis criteria to infer the language-dominant hemisphere's location. With the generated graphs, the healthcare professional can analyze the brain activation during the execution of the task.

Figure 5 shows how the continuous monitoring of brain signals can support conventional therapy in the rehabilitation process of aphasic patients. Based on the analysis of the graphics generated by the decision support model (Figure 4), the speech therapists may decide to adjust or maintain the language stimulation conducted in the following appointments and throughout the rehabilitation.

Results and Discussion

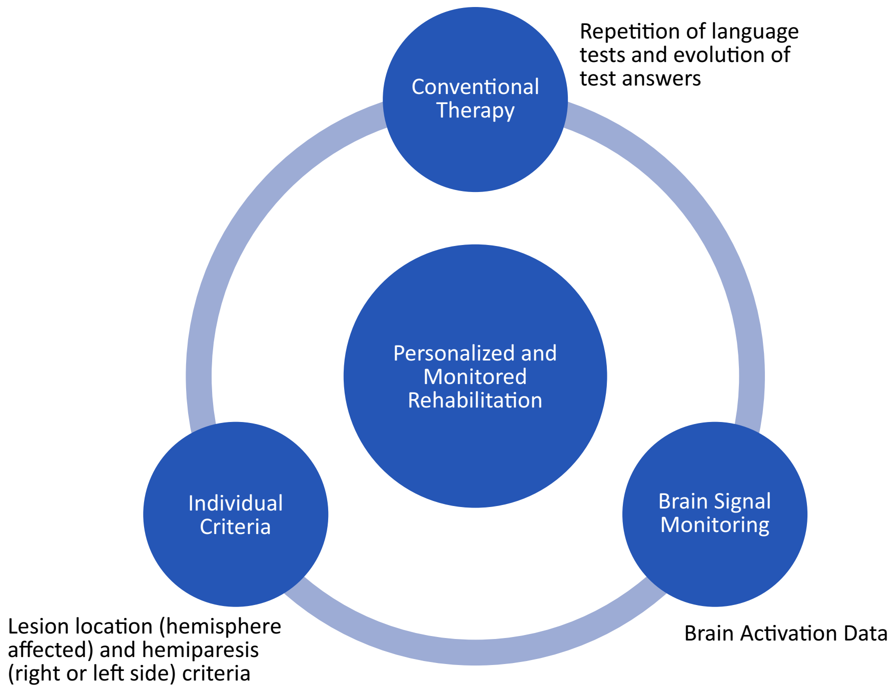
In our analysis, we did not include the data from participants (P10 and P11) with global aphasia because both failed to meet the guidelines of the research protocol, frequently diverted the focus of attention to looking at their hands, to objects in the room, and verbalized a few words. Thus, we considered only aphasics with preserved comprehension, with nine participants in the final sample.

In Figure 6, we observed that for all four participants (b, c, d, e), greater electrical activation was identified in the right hemisphere (bars up) than in the left hemisphere (bars down) at all wave frequencies (Theta, Alpha, Beta, BetaH, Gamma).

In the participant P2 (Figure 6b), for example, a 35% greater increase in activation of the right side of the brain, which is the non-language dominant hemisphere, is observed on average. The value on the y-axis shows the difference in the percentage of electrical activation between the brain's two hemispheres.

Participant P01 and Participant P09 (Figure 6a and Figure 6f) also showed increased electrical activation on the right side of the brain, with a single frequency (Theta and Gamma, respectively) with

Figure 5. Personalized and monitored rehabilitation.



higher electrical activity in the left hemisphere, although with values close to zero.

Thus, an increase in electrical activity was evidenced during task execution in the right hemisphere, which in this sample refers to the non-dominant hemisphere of language. This result may reveal language migration to the contralateral hemisphere.

In Figure 7, we observed that participant P06 (Figure 7g), had greater electrical activation in the right side of the brain, at the frequencies Theta, Alpha, and Beta L, and participant P07 (Figure 7h) had greater electrical activation in the right hemisphere at Theta and Alpha, and at the latter frequency with a value very close to zero.

Figure 8 shows that a single participant had greater electrical activation in the left hemisphere (bars down) at all wave frequencies.

Our study evidenced that four participants showed increased electrical activation in the language non-dominant hemisphere at all brainwave frequencies (Figure 6, b,c,d,e), and 2 participants with a single frequency with increased activation in the left hemisphere (Figure 6, a,f). It also evidenced one participant (Figure 7g) with increased electrical activation in the right hemisphere at Theta, Alpha, and BetaL frequencies and one participant (Figure 7h) with increased electrical activation in the right hemisphere at Theta, Alpha, and the latter near zero frequencies. Finally, it evidenced a single participant (Figure 8) with all frequencies with increased electrical activation in the left hemisphere of language.

Conclusion

In our sample, 6 out of 9 participants showed increased electrical activation in the non-language dominant hemisphere. This fact may reveal a migration of language counter-lateral processing. In this group, 2 out of 9 aphasics had increased activation in both hemispheres at different wave frequencies. Finally, 1 in 9 participants had all frequencies increased in the left hemisphere, the injured side of the brain.

The decision support model proposed in this study tested the applicability of the EEG and the

Figure 6. Difference in electrical activation between hemispheres.

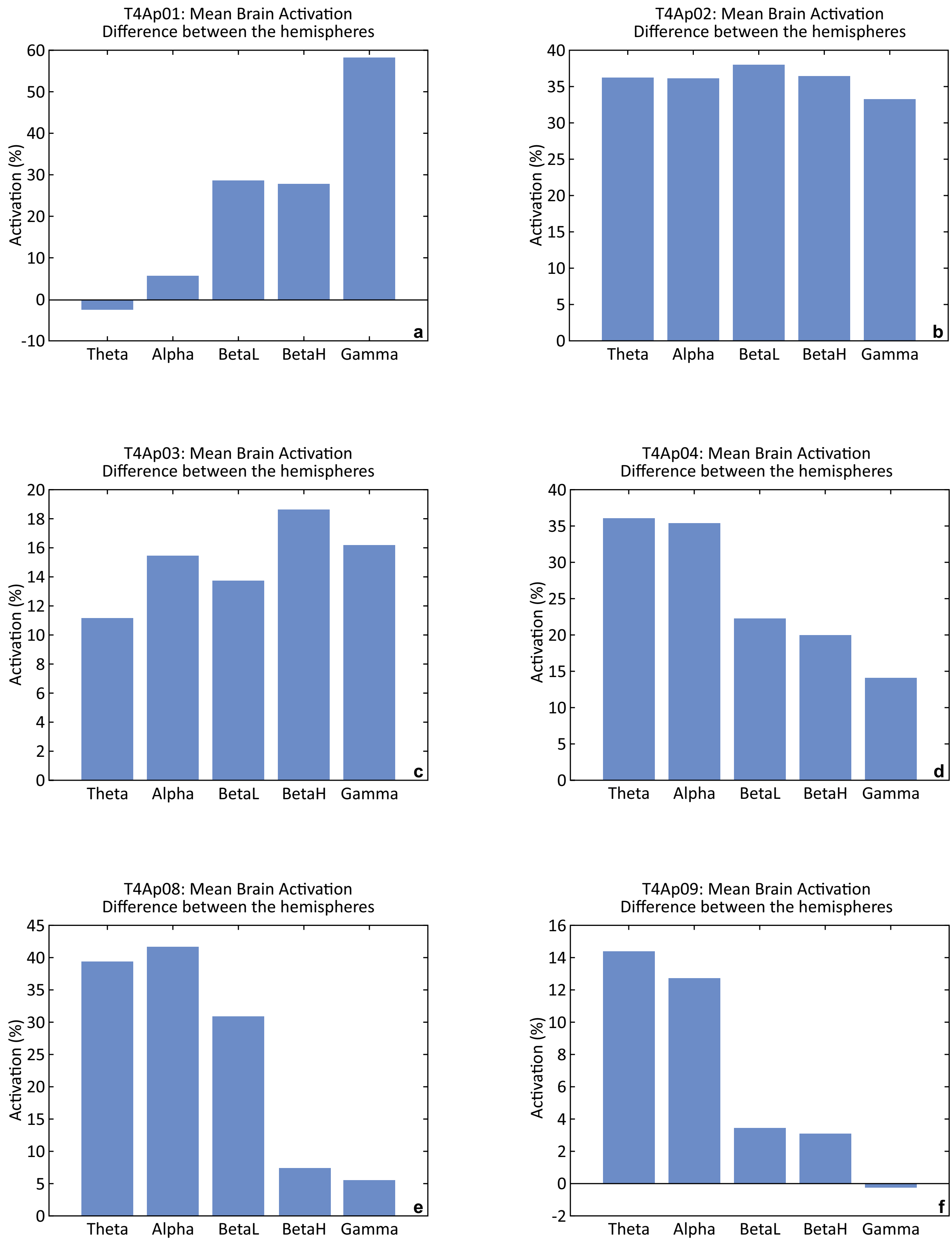
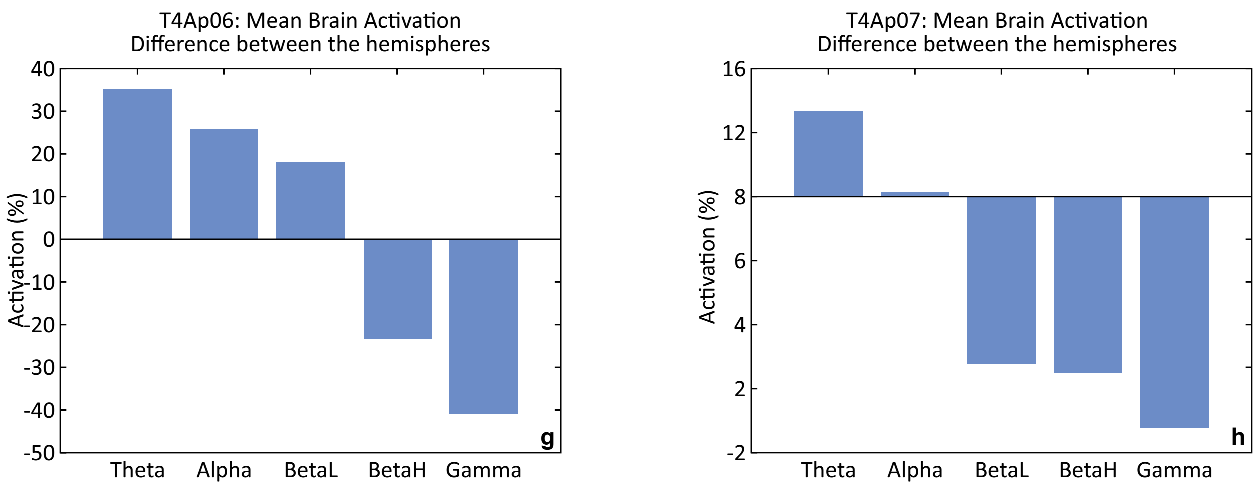


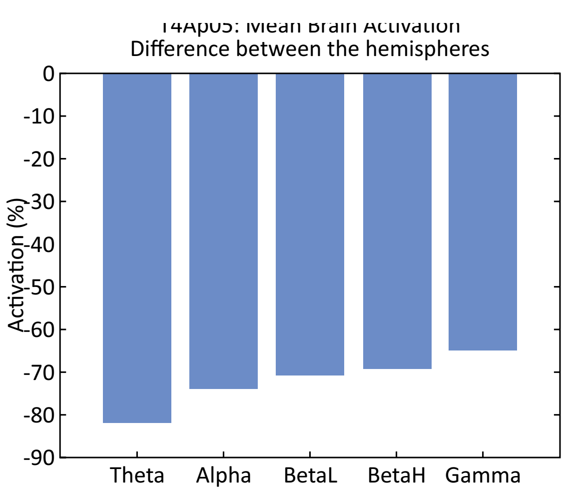
Figure 7. Difference in electrical activation between hemispheres.



study method and had some positive implications, such as the possibility of graphical visualization of which areas are more active in the brain, especially if there is an activation in non-language dominant areas, which may indicate improvement in the participant's rehabilitation, including provoking greater involvement of the aphasic.

The adoption of the proposed model may serve as support for conventional language therapy in deciding the therapeutic approach and to promote personalized and monitored rehabilitation.

Figure 8. Aphasic participants (AP05) have greater activation in the left hemisphere.



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