NEUROPHYSIOLOGICAL ASSESSMENT (P300) OF INDIVIDUAL WITH APHASIA IN COMPARISON WITH NEURO-TYPICALS

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CERTIFICATE

This is to certify that this dissertation entitled **"Neurophysiological assessment (P300) of individual with aphasia in comparison with neuro-typicals"** is a bonafide work submitted in part fulfilment for the degree of Master of Science (Speech-Language Pathology) of the student Registration No: 18SLP025. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any diploma or degree.

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This is to certify that this dissertation entitled **"Neurophysiological assessment (P300) of individual with aphasia in comparison with neuro-typicals"** has been prepared under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier to any other university for the award of any diploma or degree.

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DECLARATION

This is to certify that this Master's dissertation entitled **"Neurophysiological assessment (P300) of individual with aphasia in comparison with neuro-typicals"** is the result of my own study under the guidance of Dr. Hema. N, Assistant Professor of Speech Sciences, Department of Speech-Language Sciences, All India Institute of Speech and Hearing, Mysuru and has not been submitted in any other University for the award of any Diploma or Degree.

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Dedicated to

Almighty God,

My Family,

Guide

&

My Well-wishers....

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CHAPTER I

Introduction

Event-related potentials (ERP) that are regarded to be the psychophysiological technique of studying attentive processes, language, and memory functions in the typical and clinical population, help to produce data that is not accessible from behavioral studies. ERPs are brain responses to induced stimuli, which are primarily visual and auditory, presented repetitively at randomized intervals, and subsequently processed by software (computer) tools. The potential produced in reaction to the stimulus has varying amplitudes till 5μV microvolt and adequate electrode placement and positioning enables to process various stimuli from various electrodes to extract the target response from continuing electroencephalographic (EEG) recordings (background activity). The recording will be carried out in an electrically shielded and sound-attenuated room, where the noise levels are within permissible limits. The auditory evoked potential is the most commonly used technique for obtaining P300. P300 is a positive ERP waveform with a maximum peak of around 300 ms post-stimulus. The P300 often vary concerning the mode of response, such as auditory or visual, or other language modality. The literature reveals that the integrated stimulus, for example, audio-visual mode show better responses when compared to a single stimulus. The P3 wave is evoked by a task known as the oddball paradigm. During this task, a series of one type of frequent stimuli (standard stimulus) is presented along with a different type of non- frequent (target) stimulus (Squires et al. 1976). The task of the experimental subject is to react to the presence of the

target stimulus (for example- auditory) by a given motor response. These evoked potentials are categorized into exogenous potentials (N100, P200, and N200) because they are greatly affected by physical stimulus features (intensity, frequency, and others) and endogenous potentials (P300), which reflect only cognitive abilities.

The P300 element is described as the largest and most solid positive peak that occurs between 250 and 500 milliseconds after a rare (occasional relevant-'target') stimulus that generally occurs after the two negative N100 and N200 elements and the positive P200 component. The auditory P300 is an evoked potential of a positive long latency peak, which helps in the central nervous system's research of the aural cortex. It helps to depict the cortical activity that includes discriminative, integrative, and attention abilities, allowing the finest indicator of cortical processing velocity through auditory stimulation.

The P300 element can be subdivided into two sub-components, P3a and P3b, reflecting distinct operations, as mentioned by Squires et al. (1975), with the former being more linked to passive attention and the latter being linked to active attention and memory in particular. Therefore, many studies have suggested that ERPs are considered as the best indices for assessing changes in cognitive brain functions. The oddball paradigm consists of infrequent tones that elicit a frontal subcomponent of P300, namely, the P3a, which is deemed as an electrophysiological indicator of the orienting response (Squires, Squires & Hilliard, 1975).

The P3a is a front-centrally maximum favorable ERP wave elicited by deviant or unexpected events (Squires, Squires, & Hillyard, 1975, Pfefferbaum, Christensen, Ford, & Kopell, 1986) and is regarded as an attentive switching electrophysiological marker, i.e., the orienting response (Squires, Squires & Hilliard, 1975). P3a is produced by a complicated cerebral network, which includes prefrontal, cingulate, temporoparietal and hippocampal areas (Sutton, Braren, Zubin, & John, 1965), and is recorded in extensive anterior and posterior scalp areas (Courchesne, Hillyard, & Galambos, 1965). Smaller peak latency, more front-oriented scalp topography, and different elicitation conditions differentiated it from P300 and in P3b were elicited by expected events, and responses are elicited from temporoparietal regions, i.e., in the posterior regions of the brain.

The P300 studies, so far in clinical practice, is used as a psychophysiological tool for early diagnosis of many neurological disorders, including Alzheimer's disease (Olichney & Hillert, 2004), schizophrenia (Heidrich & Strik, 1997; Kirino, 2004), epileptic patients (, Mazzini, 2004), alcoholism and drugs (Polish, 2004). The consequence of this neurological damage and the older population is frequently noted to be abnormal in their cognitive functions. Amplitude and latency are measured in the typical and clinical population for the peak and widely researched parameters. Information processing influences the P300 parameters such as latency and amplitude and also influences the cognitive skills such as attention, stimulus assessment, judgment, memory processing, and input auditory stimulus decision making.

Auditory P300, a positive parietocentral peak that occurs after stimulus starts at about 300ms when a participant detects an occasional target stimulus

in an active oddball paradigm in a periodic fashion of standard stimuli (Desmedt et al. 1965; Sutton et al., 1965). The P300 reflects simultaneous activity in several areas of the brain, including temporoparietal, neocortical, and higher limbic systems (Halgren, Baudena, & Clarke et al., 1995). P300 amplitude is also the level of attention dedicated to a particular task and linked with superior mental efficiency (Gonsalvez & Polich, 2002). Therefore, P300 amplitude can be considered as a measure of Central Nervous System activity reflecting incoming data processing when integrated into the depictions of stimulus memory and the context in which the stimulus exists. Consequently, variation in the amplitude of P300 is assumed to represent the degree or quality of the information processing. However, there is a need to assess the activation of the same neocortical and limbic areas in the brain of individuals with aphasia before they initiate speech-language therapy. Therefore, it is independent of the reaction time of the behaviour (Kutas, McCarthy & Donchin, 1977; Polich, 1986).

However, these characteristics make the P300 a useful tool for cognitive function evaluation: since P300 latency is a measure of the processing time needed before response generation, it is a delicate temporal measure of the neuronal activity underpinning the attention allocation and the immediate memory process. Besides, P300 latency is negatively correlated with mental activity in normal individuals, with shorter latencies associated with superior cognitive outcomes. The neuropsychological tests, best correlated with P300 latency, are those that evaluate how quickly subjects can allocate and retain careful resources. Results showing that P300 latency rises as cognitive capacity reduces from dementing disease also support this

connection. Thus, in both neuro-typical and clinical populations, P300 latency is directly correlated with cognitive ability. But, there is no clear evidence of these changes during speech-language therapy in individuals with aphasia associated with varied neuropathological changes, aphasia symptoms with or without cognitive issues during the acute stage of transient ischemic attack (stroke).

The aim of the study by Helm-Estabrooks (2002) was to illustrate the status of cognitive abilities in a specific group of people with mild to severe aphasia and 13 individuals with right-hand left hemisphere stroke (5 females and 8 males) from different locations across the United States and the results suggested that scores acquired in a cohort of four non-linguistic cognitive-linguistic quick tests (CLQT) tasks chosen to briefly assess visual attention and memory, executive functions and visual-spatial skills. The analysis of the individual profiles of task results exemplified the poor relationship between linguistic and non-linguistic tasks. For illustration, one of the two patients with overall non-linguistic scores above the normal age cut-off had mild language deficits, and the other had severe deficits. Of the six patients with severe linguistic deficits, three had relatively low non-linguistic skills, had non-linguistic scores near or above normal, two had significantly impaired non-linguistic skills, and one had a moderate impairment. This would tend that next to language, executive functions are cognitive skills most susceptible to a consequence of brain injury associated with aphasia. And concludes that in aphasics with varying severity, there are varying non- linguistic deficits are seen in aphasics; thus, there is critical need to study the cognitive attributes in subjects with aphasia objectively. However, there is a need to assess the

activation of the neocortical and limbic areas in the brain of individuals with aphasia at the initiation of speech-language therapy.

1.1 Need for the Study

An early sign of P300 could be useful from dementia-related studies in assessing cognitive function. P300 peak latency in dementia patients was prolonged compared to age-matched, healthy participants (Goodin et al., 1978). Consequent clinical studies have shown that P300 amplitude declines and increase its latency in the presence of cognitive deficiency (e.g., Polich et al., 1986; O'Donnell et al., 1992; Potter & Barrett, 1999). P300 may serve overlapping functions in research on cognitive dysfunction in a normal and clinical population. It is considered as the clinical assay of a disease-associated marker. Polich and Herbst (2000) have demonstrated that measurements of P300 in terms of measurement variability are comparable to standard clinical laboratory procedures.

Another role of P300 is to provide helpful data to discriminate between disorder subtypes or mechanisms of pathophysiology. By referring patient information to normative values and a thorough comparison of disease subtypes, each of these features can be obtained from P300 results. In creating a differential diagnosis and planning interventions, such data could be useful. Impaired attention may be the omnipresent clinical symptom of neuropsychiatric illness (Mirsky & Duncan, 2001), and P300 is a delicate measure of attention resource allocation ability (Johnson et al., 2004). Altered P300 might not be specific to a particular neuropsychiatric condition; however, it is a possibly helpful clinical research instrument due to its sensitivity to impaired attention and elicitation ease. P300 was used widely in

investigating psychiatric and neurological conditions and also in normal and abnormal development concerning research of fundamental information processing. Studies have, therefore, confirmed the usefulness of ERPs as prognostic indicators in patients with severe brain injuries of different etiologies and levels of consciousness.

P300, together with other ERP measures, retains better evaluation in communication-impaired people to monitor cognitive function (D'Arcy et al., 2000). Hence, there is a need to imply the neurophysiological assessment (P300) for comparing the neuro-typical individuals with the individuals with aphasia to obtain the neurophysiological data to distinguish between the normal population and the individual with aphasia.

1.2 Aim

The aim of the present study was to conduct a neurophysiological assessment (Event Related Potential-P300) in individuals with aphasia in comparison with the neuro-typical individuals.

1.3 Objectives

1. To conduct a neurophysiological assessment (Event Related Potential-P300) and measure the latency and amplitude of individuals with aphasia in comparison with the age matched neuro-typical individuals.
2. To obtain the topographical representation of Event Related Potential (P300) response of individuals with aphasia in comparison with the neuro-typical individuals.

CHAPTER II

Review of Literature

In the findings of late 1960s, presentation of stimulus produces a resultant significant increase in the synaptic activity in millions of neurons simultaneously in a synchronized manner. This was analyzed on a careful analysis of the electroencephalogram (EEG). This combined electrical response of the neuron is known as event-related potentials (ERPs). Event-related potential (ERP) are those potential that should be elicited by their induced stimulation which can neither be the visual, tactile, auditory, these event-related potentials could be categorized as exogenous and endogenous based upon the principle of generation. According to (Donchin, Ritter, & MCCallum, 1978), exogenous depends on the physical factors that are likely to vary due to the external factors like stimulus type, intensity, frequency. In contrast, the endogenous potential depends upon intrinsic factor-like cognition. The cognitively evoked response is the P300 since the response from the participants primarily depends upon the discrimination between the rare and common stimuli in the oddball paradigm (Sutton et al., 1965).

In the recording of P300, the specially designed paradigm is used called as the oddball paradigm, the paradigm includes 2 category of stimuli i.e., frequent and occasional stimuli, where the subject's task is to discriminate and attend to the infrequent stimuli, which is used across the research and various clinical setups. In the literature, it was reported that, if the subject attends to the infrequent stimuli, which is associated with large P300 components that are with higher amplitude in the sites of posterior electrode

rather than an anterior site which shall be correlated with the cognitive process that includes context updating, context closure, and event categorization is very well documented by Donchin and Coles (1988) and Kok (2001).

2.1 Components of P300

P300 consists of two crucial elements, namely P3a, P3b, which are seen, imposed to a single wave, even separated with distinguished peaks. P3a peak is present when the subject passively listens, whereas P3b is obtained when the subject is actively listening (Bennington & Polich, 1999). The latency of the P3a element is shorter, and the amplitude is reduced than compared to P3b, which is considered as the attention- dependent element. At the functional level, according to Polich and Herbst (2000), P3a is related to an “attention orienting complex,” whereas P3b is related to psychological constructs such as controlled “cognitive closure”, or “response-related decisional stages”, “information processing”, and “context updating”. Concerning the allocation topography (Friedman et al., 2001), P3a has a frontal allocation**,** and P3b has a parietal allocation, that associate with the cognitive functions like context updating, context closure, and event categorization.

In *context updating*, the subjects always have some "expectancies," "schemata," or "models" of a situation. If a stimulus causes that subjective context to change (be "updated," "revised"), this elicits a P3. P300 reflects a process invoked when the updating, or 'refreshing,' of representations in working memory is required. In *context closure*, the hypothesis assumes that this structured and repetitive design of tasks is not only necessary for measuring P3 reliably but is also a favorable condition for evoking P3s at all:

P3s are emitted by subjects when dealing with a repetitive, highly structured environment. Subjects combine the successively presented stimuli into meaningful contexts. P3-eliciting stimuli are those events that close these contexts and the process of closing is reflected by P3. Besides perceiving every single stimulus and responding to it, subjects maintain an internal template of the context, which includes maintaining an expectancy of the event that will close the context. Thus, when the stimulus is the expected one, stimulus evaluation leads to response selection on the one hand and closure of the present context on the other. *Event categorization* is conceived of as a process that leads to the decision that the external stimulus matches (or does not match) with an internal representation of a specific event or category of stimuli. A suitable example of such a category is target stimuli. Event categorization involves both perceptual and central processes, as the meaning of a stimulus or category of stimuli (e.g., "it's a target" or "it's not a target") can only be established after some contact between the perceptual system and the memory system has taken place.

2.2 Generators and Scalp Distribution of P300 Assessment

The topographic distribution of P300 measures was studied in the study which elucidates the relationship between the amplitude, latency and age dependence of the P300 wave often differs with the electrode site and evaluation of the topographic distribution of P300 latencies showed that P300 latencies depended on the electrode area of P300 scalp distribution, defined by a shift in amplitude over midline electrodes (Fz, Cz, Pz.) increased from frontal (Fz) site along the parietal mid-sagittal plane (Pz) (Johnson, 1993). P300 potentials have been obtained from the primary auditory cortex and poly

sensory cortex association according to the study by (Buchwald, 1990) and temporo-parietal cortex is added up with the generation of P300 (Picton & Hillyard, 1974).

The P300 can provide insight into the various cognitive processes underlying it. Various methodologies, such as intracranial recordings, lesion studies, and functional imaging studies, have shown that the areas of the brain involved in the generation of P300 are complex with the concurrent activation of overlapping sites. P300 is widely spread with the maximum amplitude detected at the centro-parietal area, and the amplitude reduces as the non-inverting electrode is positioned to more anterior locations (Bennington & Polich, 1999). For *identification tasks*, P300 is maximum for frontal-central and *discrimination tasks*, the largest of which is just posterior to the vertex (Simon, Vaughen & Ritter, 1976).

The review mentioned in the above sections was discussed with reference to the "Generators and Scalp Distribution of P300" in neurotypicals, and there is a need and an interest to study the same on the clinical population specifically on persons with aphasia. In a study by Onofrj et al., (1995), the participants included were 6 subjects with frontal, parietal and temporal lobe lesions, and 4 subjects with primary progressive aphasia (PPA) and 56 age-matched controls were recorded for linked earlobe reference (LER) using auditory oddball paradigm. The computed average reference (AR), latencies, amplitudes, and scalp distribution was recorded. These findings were found to be within the normal limits for both the LER and AR recordings. When LER was used, the distribution of P300 scalp in patients with neurological lesion was normal, whereas when the P300 was recorded using average reference, it

was found that the distribution of scalp recording was statistically different from the normal distribution in all patients with the neurological lesion. However, positive P300 was observed in the control group, and in the patients with the neurological lesion, it was found to correspond to the affected side of the brain.

From the latest review article by Pavarini et al. (2018), there is no ERP study in individuals with aphasia nor a study depicting the Generators and Scalp Distribution of P300 in aphasia. Instead, there are studies reported on generators and scalp distribution of P300 in the elderly population and other neurological conditions. The review of 26 articles revealed that in P300 evoked potential assessment, there was prolonged latency and reduction of the amplitude as the age advanced, and the process of aging that occurs was naturally. In the neurogenic condition like Parkinson's disease, cognition loss, depression, and Alzheimer's disease, latency showed major variability when compared to the healthy older individual than the amplitude measure with reference to stimulus used (auditory + visual) and also with respect to the parameter and setting of the stimulus. P300 measures varied, but no explanation w.r.t scalp distribution potentials were documented. Thus, in the literature, there are no studies that documented the scalp distribution in individuals with aphasia. Hence, the present study was planned to elucidate the P300 topographic findings in individuals with aphasia in comparison with the neuro-typical individuals.

2.3. Variables of P300 Assessment

2.3.1 Stimulus Specific

A P300 response varies regarding the mode of the stimulus. Picton (1984) observed that a visual stimulus that was used to evoke P300 was delayed with 90ms in contrast to auditory stimuli. Polich and Pitzer (1999), observed that P300 evoked potential are not stimulus-specific, as P300 waves can be evoked by any stimulus like auditory, visual, somatosensory, olfactory, and even the gustatory stimulus. However, the amplitude, latency, and the source of generation vary with the stimulus modality applied (Bennington & Polich, 1999; Johnson, 1989).

Knott et al., (2003), studied the impact of the modality of stimulus used in P300 in younger and older adults group, and observed greater amplitude, prolonged latency when compared with the auditory mode of stimulation, age effect was also seen with contrast to the stimulus modality, in the younger group, latency suddenly changed at around 12 years of age, whereas the latencies of the P300 which was evoked by the visual stimulus was found with steady decrease with age and concluded that the latency of the visual modality of stimulus is slow, shorter latency then the auditory and as the age increase, it (visual evoked P300) was observed to be longer than auditory evoked P300 in older children and no such trend was noticed in amplitude parameter.

A study was conducted in which the intensity was used as the variable, the effect of intensity variation and P300 outcome was measured, the results revealed that, when the intensity was increased from 15 to 65dB, the variable influenced the latency rather than the amplitude of P300 (Papanicolaou et al.,

1985). In contrast, Vesco (1993) found that when the intensity of the stimulus varies, the amplitude is influenced by the intensity of stimulus variability. Bennington & Polich (1999) did a comparison study between a passive and active task in the normal population, the active task included finger raising on the stimulus attended, and passive task included daydreaming, results reveal that amplitude was greater for the active task when compared to the passive task.

Regarding the sound environment favorable for the P300 recording, Arikan et al., (1999) compared the white noise versus the music culturally adequate to find the effect on P300, the oddball paradigm was used, and the result is that amplitude decreased in white noise due to its SNR characteristics.

2.3.2 Subject-specific

The two tasks namely, numbering the stimulus and pushing the button with the thumb was studies, it was observed that the latency was longer and amplitude was increased in the P300 evoked potentials according to Donchin & Coles (1988). They reported that the highest amplitude value of 20 mV was significantly correlated with the greatest attention allocated to the target stimuli and thus conclude that the P300 amplitude can be considered as the index of CNS processing attributed to the attention processing (Polich, 1998; Donchin & Coles, 1988).

The P300 evoked potential has an effect on sleep, and it was observed to be prolonged. The latency was prolonged, and the amplitude was decreased when the subjects were subjected to sleep deprivation (Danos et al., 1994). In some conditions like when the subject transforms from alert wake state to drowsiness and followed by stage I sleep, P300’s evoked potential amplitude

reduction was clinically observed in the wave morphology (Koshino et al., 1993). The stage I sleep is described as when one finds themselves floating in and out of consciousness. During this non-rapid eye movement sleep, one may be partially awake, and their mind begins to drift off. This leads to light sleep and is a period of drowsiness.

The effect of memory (Long term memory) on electrophysiological assessment is also studied. The relationship between memory and the P300 evoked potential was researched by Johnson et al. (1984) on the normal population. The task was to memorize the list of words before initiation of the P300 recording, and on behavioral assessment, the task of the subjects was to list out the memorized words. Following this behavioral task, a P300 recording was carried out in both non memorized words and memorized words. It was found that the larger amplitude for the non-memorized words and reported shorter latency for the memorized list of words where the subjects were made to memorize in the initial phase of the behavioural task. So concluded that the memory rehearsal method affects the P300 amplitude and latency measures.

The effect of acute alcohol consumption with the measures of P300 assessment was also studied by (Porjesz & Begleiter, 1981) and found that they have declined amplitude compared to the group who did not consume alcohol. Lukas et al, (1990) added that acute alcoholism could disturb and change the neural generator for P300 generation to more inferior brain regions.

2.4 P300 and Cognitive Processes in Other Neurological Disorders

P300 is considered one of the most important tools in the evoked potential of the ERP studies, which focuses on the study of cognitive functions in the typical individual with typical cognitive function in comparison with the clinical population with cognitive processing deficit. According to Ford (1999), P300 acts as a biomarker in the evaluation of the schizophrenic individual, with the findings that there would be a reduction of the amplitude of the P300 component.

The evaluation of clinical population in the clinical settings have provided an insight that the P300 was considered as the better tool for early identification of many neurological disorders (Olichney & Hillert, 2004) like Alzheimer's disease and Schizophrenia (Kirino, 2004) and Epileptic patients (Mazzini, 2004). Future direction by a review article (Pavarini et al., 2018) includes that to elucidate in older individuals to evaluate relationships among education and P300 measures, education, and gender. No normative data are obtained from the articles concerning the P300 measures (latency and amplitude) for clinical populations.

2.5 P300 and Cognitive Processes in Neuro-typical Individuals

Research conducted on 115 neuro-typical individuals in the age range of 10-70 years and dividing into two groups based on the 'age,' i.e., above 40 constituting one group and below 40 years constituting another group. The P300 was recorded for all the individuals, and the results revealed that the mean latency was 361.5±32.9 msec (range 295 to 438 msec) whereas the mean amplitude was 9.32 ±5.11 uV (range 2.47 to 20.41 uV). There was a significant variation in latency between the two age groups. The possible

reason for this could be as the age increases, the neural firing decreases, and these results in poor latency resembling the longer time taken by the neurons to stimulate for the task. With reference to gender, males and females showed no significant difference in the latency of P300. In the 40 years and above age group, the amplitudes were lower, but the difference was only significant for males. There was an adverse correlation between the amplitude and latency of the P300 ($r= -0.20$). A significant positive correlation between age and P300 latency was observed, whereas the P300 amplitude showed a significant negative correlation in less than 40 years of age (Shukla et al., 2000).

Another study was to generate normative data of auditory P300 event-related potential in the Indian population (Uvais et al., 2018) they had included 155 healthy participants in the age range of 10 -50 years. They had been further divided into four groups like 10-19 years, 20-29 years, 30-39 years, and 40-50 years. The recording was done in three different sites Fz, Cz and Pz and the results reveal that the Mean and Standard Deviation of the P300 amplitude and latency of Fz, Cz, and Pz for the four age groups ranged from 4.97 to 7.84 (Fz), 7.90 to 11.77 (Cz), 9.46 to 16.17 (Pz) the amplitude and 349.61 to 366.81 (Fz), 348.31 to 358.06 (Cz) and 350.29 to 354.23 (Pz) the latency. The study showed significantly higher amplitude on 10-19 years compared to other age groups in Fz and Pz position; however, it has also been mentioned that the amplitude was higher on 30-39 years age group in the Cz position. The study also mentioned that there was a significant decreasing trend of P300 amplitude at Fz ($P<0.001$), Cz ($P=0.002$), and Pz ($P=0.015$) across ages. There were no such trends seen for P300 latency.

2.6 P300 Assessment in Clinical Conditions like Aphasia

A study was done by Peach (1991) on six participants with the diagnosis of aphasia (3 males and 1 female) and was compared with 2 age-matched normal (one male and female) participants in the age range of 69-72 years. The individuals with aphasia were subgrouped as 2 subjects diagnosed as fluent and 2 diagnosed as non-fluent, and each of the aphasia participants was administered with object naming task after completion of language testing and ERP recordings. The results indicated that responses from the aphasic group were variable and found that the latencies were prolonged in the aphasic group when compared to the healthy control group.

Another study by Korpelainen et al., (2000) included 38 aphasic patients (23 men and 15 women), with mean and SD age 67.1±7.2 years, range 44±78. All participants had an acute brain infarction, and P300 was recorded using an auditory oddball paradigm among these 38 brain infarct patients who reported mild neurological deficits at 3 and 12 months post-stroke period. In comparison with aphasic patients, 29 healthy control subjects were also considered. The results indicated that slight prolongation of the latency of the P300 was seen in patients with brain infarction, and the delay was observed related to the existence and extent of post-stroke depression assessed with the Zung Depression Scale and the DSM-III criteria. It was noted that the infarction did not influence the amplitude of the P300 or its distribution on the scalp**.** Outcomes for subjects with hemispheric cerebral infarction and patients with cerebral infarction were identical. The findings for patients with left-and right-sided lesions and also the normal physiological correlation between the

participants' age and latency of P300 was lacking at 3 months post-stroke, but it was detectable at 12 months post-stroke.

Individuals (right-handers) with left hemisphere damage (total 17 in number) diagnosed with global aphasia with the mean age of 65 years were considered for the study by Nolfe. et al., (2006). P300 recording was carried out for this clinical population in comparison with the 20 age-matched neuro-typical individuals. The mean time interval between the stroke onset and the first P300 documenting was 12.9 days (SD, 5.8). The recording was carried out with 16 scalp electrodes in accordance with the international standard 10–20 system; recordings were rendered once a month at the very same time after breakfast in a day. Stimuli were produced through binaural headphones; an inter-stimulus interval of 2 sec had been used. The pre-recorded stimulus series has been addressed without guidelines. The stimulus included was the oddball paradigm, which consisted of high-pitch (1 kHz) uncommon stimuli and low-pitch (0.5 kHz) common stimuli, and language abnormality was evaluated by the Aachen Aphasia Test (AAT) in the version validated for the Italian population. Two subjects were examined in particular: (i) Token test; (ii) Comprehension and the results indicate that seven patients (41 percent) had P300 responses in the right hemisphere at the early part of rehabilitation, taking into account parietal and temporal derivations; six of them (35 percent of the total group) had P3 responses, and finally, three (18 percent) had P300 responses in all derivations. Specifically, in temporal-parietal derivations, the P300 wave had greater and well-defined amplitude. In these clients, moreover, the voltage of the P300 component in the frontal area is negligible. On the other hand, the participants lacking the P300, however, presented the P100–

N200 complex and well-defined amplitude on the frontal areas but absent on temporal-parietal derivations. Compared to the controls, the mean latency of the patients was significantly increased in all of the examined channels. By contradistinction, amplitude distinctions have only reached statistical significance in the P3 derivation.

The P300 amplitude scalp topography, quantified at discharge in patients with this ERP component at enrolment, shows the same information calculated in subjects without any P300 responses at baseline. With reference to the clinical prognosis for recovery of comprehension, all participants were classified as suffering from global aphasia, at both baselines and at discharge (therapy termination time). After 3 and 6 months, two AAT sub-items, notably comprehension and Token Test, had been administered at the baseline. Global aphasic patients who had a P300 response in the first month had a better AAT comprehension advancement over time than those without P300. Nevertheless, there was no objective evidence of latency and amplitude improvement found over time. But, the computerized P300 amplitude maps computed at a patient therapy termination might be of importance in offering insights for assessing recovery after stroke in global aphasics, and the grand average map shows the evolution of global aphasia towards Broca's aphasia in these participants. In reality, they had a great recovery of comprehension. In contrast, the group of participants lacking early P300 had no improved performance of comprehension, and the authors conclude that the usefulness of the P300 response in the clinical assessment of post-stroke aphasia since its early existence can predict a rapid recovery of language comprehension. The ERP experiments can track the progress pattern further than the first months as well

as provide data on the areas most affected. This research was the only one to monitor ERPs monthly. Further ERP researches must follow the recovery pattern further than the first 6 months after the stroke.

Aerts et al. (2015) conducted a single case study to examine the effect of language therapy integrating behavioral and neurophysiological findings and discussed the clinical outcomes in patients with aphasia during acute and post-acute stages of stroke. The subject was a 47-year-old man with moderate non-fluent aphasia who had undergone three treatment periods in the first four months after his stroke. The initial assessment period occurred 10 days after the stroke. First, he obtained an intensive 30-hour language treatment in 3 weeks, followed by a 30-hour conventional treatment in 7 weeks. Then, in three weeks, the subject received a second, intensive language therapy of 30 hours. It was followed by a period of six months with no sort of language treatment. Behavioural and neurophysiological measures were gathered after each treatment and treatment period. The effect of therapy was investigated by equating the duration of treatment with the duration of the treatment without differentiating between intensive and conventional treatment. In the second analysis, a comparison was made between both the intensive treatment periods and the traditional therapy program, and the tasks included the phoneme discrimination task. The standard phoneme was /bə/ and the deviant phoneme was /gə/ (covering place of articulation- PoA), /pə/ (covering voicing), and /mə/ (covering manner of articulation- MoA). Stimuli were developed in such a manner that perhaps the standard and deviant stimulus differentiated only in one phonemic contrast. The standard and deviant phoneme appeared at a probability of 0.80 and 0.20, respectively. The stimulus was provided in a

random fashion wherein two deviants cannot adopt one another without getting one standard in between. All the phonemes spoken had a duration of 150msec. The results indicate that participant's responses for phoneme discrimination had shown smaller amplitudes, particularly in comparison to the normative group for all phonemic contrasts (PoA, voicing, and MoA) in P300. Participants showed shorter P300 latencies for PoA, longer P300 latencies for voicing, and the largest P300 latencies for MoA compared to the normative group. After the complete therapy period, the P300 assessment for PoA, voicing, and MoA showed increased amplitude, while PoA and voicing had increased. After the treatment-free period, P300 PoA, voicing, and MoA amplitude reduced, and it infers that participants reveal a marked improvement in both behavioral and neurophysiological measures after that complete treatment period, that was maintained across the treatment period. Intensive treatment led to better language results, as stated by behavioral and neurophysiological improvement, as opposed to the behavioral degradation of auditory discrimination against pseudo words.

Therefore, researches utilizing ERPs that are promised on oddball-paradigm support to describe, assess, and track phonological issues and auditory comprehension deficits in clients with aphasia to a larger extent. It's been discovered that perhaps the P300 is a decent non-invasive indicator to compare the clinical population with that of neuro-typical and monitor recovery patterns in initial stages of aphasia and long-term follow-up phases and compare between two therapy approaches too (Aerts, van Mierlo, Hartsuiker, Santens & De Letter, 2015).

CHAPTER III

Method

3.1 Participants

A total of 8 individuals participated in the present study. Among them, 4 individuals with aphasia were selected based on the availability of cases in the Department of Clinical Services, All India Institute of Speech Hearing, Mysore as a clinical group. These participants had a diagnosis of 'Aphasia' by the Neurologists and the Speech-Language Pathologists after the administration of Western Aphasia Battery (Chengappa & Kumar, 2008). These individuals had just initiated their speech and language therapy and had attended less than five sessions before recruiting them for the present study. The other 4 individuals were neuro-typical, recruited from in and around Mysore as participants of the control group. These were relatively matched with the chronological age, gender, and educational background of individuals with aphasia. The demographic details of all the participants of the clinical and control group and are as follows in Table 3.1.

Table 3.1

Demographic Details of Participants in Clinical and Control Group

Sl No.	Participants	Age	Gender	Educational Status	Aphasia type	WAB scores				AQ scores	Neuro-imaging findings	languages known
						SS	N	R	AVC			
1.	A	25yrs	M	Secondary Education	Global Aphasia	0	0	0	1.2	2.4	MRI: 27.08.19 Acute onset of aphasia and right sided weakness CT SCAN without contrast: 05.09.19: I11 defined hypodensities in left peri-rolandic cortex and temporo occipital cortex- sub acute infarcts.	Kannada, English
2.	B	65yrs	M	Nil	Broca's Aphasia	0	0	0	8.5	17	Hyperacute infarct involving frontal operculum and posterior frontal regions	Konkani, Kannada, English & Hindi
3.	C	28yrs 11 months	M	Not mentioned Occupation: Fertilizing Manager (Agricultural dept.)	Global Aphasia (Resolving to Broca's Aphasia) Re-Evaluation:18.12.19 Broca's Aphasia	0	0.4	0.2	3.35	7.9	Left fronto-parieto-temporal lobe chronic infarct with gliosis	Kannada, English, hindi, telugu, tamil.
						0	0	0	4.4	8.8		

4.	D	45yrs	F	Secondary Education	Broca's Aphasia	2	0.8	0.3	7.85	21.65	MRI: 31.08.17 Acute non heamorhagic left MCA territory infarct with mild mass effect, no gross midline shift. Question focal thrombosis in the M2 segment of the left cerebral artery CT: 06.09.17 Mild interval decrease in the size and mass effect of subacute infarct of the left MCA territory involving the left gangliocapsular region, insular cortex, peritotemporal lobe.	Kannada
5.	1	28yrs	M	Master's Degree	NIL	NA	NA	NA	NA	NA	NA	Kannada, English
6.	2	70yrs	M	Bachelor's Degree	NIL	NA	NA	NA	NA	NA	NA	Kannada, English
7.	3	62yrs	M	Diploma	NIL	NA	NA	NA	NA	NA	NA	Kannada, Hindi
8.	4	65yrs	M	Degree	NIL	NA	NA	NA	NA	NA	NA	Kannada, English

The individuals with aphasia (participants) followed special inclusionary criteria and the same are listed below:

- The post morbid duration was six months or above.
- Handedness was checked using Edinburgh handedness inventory- Revised (Williams, 2010), and the four individuals with similar (left/right) handedness (after the post morbid condition) only were considered for the present study.
- Aphasia quotients were falling below 93.8 on the administration of Western Aphasia Battery (WAB) (Kertesz, 1982). Specifically, individuals with aphasia had to have a score of AQ in the range of 5 – 10 on the comprehension subsection of WAB.
- Individuals with aphasia were monolingual or bilingual, and the languages known by the individuals were noted down.
- They had no complaint of any otological problems or ototoxicity. In order to identify any such issues, a detailed general case history was taken.
- Individuals with aphasia underwent a routine audiological evaluation before participating in the study. Air conduction thresholds were less than or equal to 30 dBHL in both the ears on Pure Tone Audiometry. (Clinical audiometer-Madsen OB922, (Version 2.64) with TDH 39 earphones enclosed in

MX-41/AR supra oral ear cushions used to estimate the air-conduction thresholds, and Radio Ear B-71 bone vibrator)

- Individuals with aphasia had no other associated clinically significant neurologic disorders other than stroke. Participants, if taking any sedatives and memory dietary supplements, were asked to suspend them for 72 hours before testing.
- Individuals with aphasia had no associated neurogenic speech disorders like apraxia or dysarthria, and if present, the same was noted during the evaluation processes.

3.2 Research Design

The present study was a standard group comparison, wherein the neurophysiological assessments (ERP measurement of P300) of individuals with aphasia was compared with that of the neuro-typical individuals.

3.3 Data Collection Procedure- Electrophysiological Experimental Paradigm

3.3.1 Testing Environment

The recording was carried out in a sound-attenuated and electrically shielded room, where the noise levels were within permissible limits (ANSI S3.1-1999). For the same, the recording room of the Department of Speech-Language Sciences was used.

3.3.2 Instrumentation

The following instrument was used to record the stimuli and collect data.

1. Net Station 5 Electrical Geodesic Inc. (EGI) Geodesic EEG Software (version 5.4.2) instrument was used to record Event-Related Potential (ERP) (128 Channels).
2. The recorded stimuli which are scaled and RMS normalized was used to obtain the evoked potentials, viz., P300.

3.3.3 Stimuli

The E-prime software version 2.0.8.90 (Psychology Software Tools, Inc., Sharpsburg, PA, USA) on a Hewlett Packard Z240 Tower Workstation (Intel Core i5at 3.20 GHz and 8.00 GB RAM) running Windows 7 Pro was used for the preparation as well as the presentation of the stimulus. The EGI equipment supports two machines for carrying out the experiment. The Net Station software records multiple tracks of the stimulus along with the EEG data. Another computer generates and presents the stimuli, and it sends simple triggering or complex stimulus identification information to Net Station software. The speech stimuli used for testing were syllables /ḍa/ and /ga/, where the frequent one was /da/ and the infrequent one (target) was /ga/. These audio stimuli were presented from an audio speaker centred 85 cm above the participant connected to a Creative SB X-Fi audio card. Speech sounds were presented free field at 70 dBSPL, measured by a Sound Level Meter (SLM). The interstimulus interval was 2000 ms. A total of 250 sweeps was presented. Participants were instructed to listen to the stimuli. The response to the task depended on the capability of the

participants. A 700 msec time window was used, and analysis was based on the numerical values of the latencies (ms) and amplitudes (μV). P300 identified as a positive deflection after the N1-P2-N2 complex was considered as responses for further analysis.

3.3.4 Recording

3.3.4.1 Planning. The participants had to arrive at the recording room with freshly washed (not wet) hair and had not used any hair products (for example, gels or hair spray) when they had come for recording. Before the participant arrives, the electrolyte solution had to be prepared, and the necessary items like measuring tape, pipettes, syringes, and three clean towels had to be kept ready.

3.3.4.2 Preparing the Electrolyte Formulation. As per the Electrical Geodesic Inc. (EGI) recommendation, HydroCel Saline (Potassium Chloride electrolyte solution) was used for standard recordings, the steps includes.

1. 10 cc (2 teaspoons) of powdered potassium chloride (KCl) had to be added into the rinse/electrolyte bucket.
2. 1 litre of warm distilled water had to be added to it.
3. Add 5 cc (1 teaspoon) of Johnson's Baby Shampoo.
4. The ingredients had to be stirred vigorously until the KCl is completely dissolved.
5. The solution had to be kept for 5 minutes.

3.3.4.3 Head Measurement. The head measurement had to be found out before applying the Geodesic Sensor Net to the subject's head. The head circumference was measured by running the tape along the side of the head, above the ear, toward the back and 2.5 cm above the external occipital protuberance (Inion), around the other side and above the other ear, and back to glabella. One end of measurement tape was placed on the glabella, and the other end was placed on the Inion, and the midpoint was marked. Similarly, the midpoint between the preauricular joints was marked. The point at which these two intersect is the vertex point, otherwise called Cz in the international 10-20 system (Silverman, 1963). The net of the appropriate adult size was selected based on the measurement obtained. Marking the Vertex was as follows:

1. The subject was asked to hold one end of the measuring tape to the nasion.
2. The tape was run over the top of the head until it reached Inion, and the midpoint was located. The midpoint was marked using a marker on the subject's head.
3. The distance between the preauricular points was measured by extending the measuring tape across the top of the head. The midpoint was located, and it was marked on the head. The intersection point of these two lines gave the location of the vertex.

3.3.4.3.1 ***Net Application.*** The net soaked in the electrolyte solution (as it has sponge inserts), and was safely applied on the participant's head in such a way that the Cz electrode came on the vertex marked on the head. The participants were asked to remove earrings, glasses, and hair ties as it would

become uncomfortable for them. The sensor net can be applied under ten minutes and without scalp abrasion, recording paste, or gel, as the high-density hydrocel geodesic sensor nets and associated high-impedance amplifiers have been designed to accept impedance values ranging as high as 100 KΩ.

3.3.4.3.2 ***Soaking the Net in the Electrolyte***. The net was not soaked for a longer time, and care was taken so that the connectors would not get wet.

1. The sensor end of the net had to be dipped into the "electrolyte" bucket.
2. The sensors of the net had to dip in electrolytes for at least 5 minutes to ensure adequate wetting of the sponges.
3. A towel had to be given to the participants to catch the electrolyte drips.
4. A towel had to be draped over the participant's shoulders.
5. The net had to be lifted vertically out of the electrolyte bucket and had to be held in the same position such that the excess electrolyte drip back into the container.

Then the net was placed on the participant's head in such a way that the electrode mentioned as Cz was coming on the vertex. It had to be ensured that all the electrodes were placed correctly on the scalp of the participant. The chin strap had to be moved underneath the participant's chin and was secured using the cord lock. Participants had to rest on the reclining chair while they had to remain awake throughout the procedure. It was ensured that the inter-electrode impedance was ≤ 50KOhms prior to testing. If the impedance was more, the electrolyte solution was put on the sponge on the electrodes.

The electrodes FCz and AFz were regarded as reference and ground, respectively during the online recording. Vertical (VEOG) and horizontal electrooculograms (HEOG), two additional electrodes, were used to monitor the eye movements. Particularly, VEOG was positioned at the right side of the right eye (Channels 8, 126, 25, 127), and HEOG was positioned below the left eye (Channels 125 and 128). Impedances for all electrodes were kept below 50 KΩ, during the whole task.

The ERPs that were used to record was P300. P300 was recorded as per the guidelines provided by Duncan et al. (2009). Few of the important guidelines that were considered in the present study are:

1. Use of oddball paradigm (passive paradigm, participants would only concentrate on stimuli without responses (Pokorny et al., 2013) - as it elicits robust P300 and reveals how the brain discriminates stimuli and process probability.
2. A minimum of 36 or more artefact-free trials with correction for ocular contributions.
3. The elicitor stimulus was delivered binaurally through speakers at 70 dB SPL. In order to elicit P300, the oddball paradigm was used. The summary of the protocol for recording is shown in Table 3.2.

Table 3.2

Summary of the Protocol for Recording P300

Stimulus Parameters	**Details**
Stimuli	Frequent Infrequent /ḍa/ /ga/
Frequent: infrequent ratio	4 to 1 (80:20)
Ear	Binaural
Transducer	Insert – ER- 3A/Speaker
Intensity	70 dB SPL
Inter-stimulus-interval	2000 ms
Total number of sweeps	250
Acquisition Parameters	
Filters	0.1 Hz -30 Hz
Electrode	Cap electrode
Montage	Hydrocel GSN 128 1.0

3.4 Data Analysis Procedure- Response Analysis

Artifacts were automatically detected and manually verified for exclusion from additional analysis (bad channel >200 microvolts, eye blinks >140 microvolts, and eye movement >100 microvolts). For every channel, 50% or greater bad segments were used as the criteria for marking the channel bad; for every segment, greater than 20 bad channels were used as a criterion for marking a segment bad.

Bad channels (fluctuations over 200 μV) were spherical spline interpolated from nearby electrodes. Data were baseline-corrected using a 100 ms window before the onset of all stimuli. Data were re-referenced from vertex recording to an average mastoid reference.

All processed, artifact-free segments were averaged by condition producing a single event-related potential waveform for each condition for all participants and exported for plotting and statistical analysis. For analysis, the P300 was defined to be the most positive peak between 300 and 700 ms following stimulus onset within a cluster of eleven central electrodes.

The obtained raw electroencephalogram (EEG) file from the Net Station Acquisition Program was subjected to preprocessing using the Net Station Tools program, and further analysis was carried out using the EEGLAB toolbox within the MATLAB software (The Mathworks Inc., MA).

3.4.1 Segmentation

The obtained continuous raw EEG data had to be segmented first. For this purpose, the Net Station Tools program was utilized. Initially, a segmentation tool was created using this program to segment the raw EEG data file. This segmentation tool was named “Speech segmentation” and “Tone Segmentation,” respectively. Within the speech segmentation tool, the parameters were set in such a way that segments containing the stimuli /da/ and segments containing the stimuli /ga/ were segmented. Each segment consisted of 100ms duration before the presentation of the stimulus and 1500 ms after the presentation of the stimulus. Thus, each stimulus was segmented in 250 segments (200 segments of frequent stimuli /da/ and 50 segments of infrequent stimuli /ga/). Similarly, Tone Segmentation Tool yielded 200 segments of frequent stimuli 1 kHz and 50 segments of infrequent stimuli 2 kHz.

3.4.2 File Export

Following the process of segmentation, the files had to be converted to Net Station Simple Binary format (.raw) to carry out further analysis using MATLAB. For this purpose, the Net Station Tools program was utilized. A file conversion tool was created to convert the segmented files into the “.raw” format. This was executed for the speech EEG files to obtain converted files in the “.raw” format.

3.4.3 Processing in MATLAB

EEGLAB plugin (Swartz Center for Computational Neuroscience, CA), which is an interactive MATLAB toolbox for processing continuous and event-

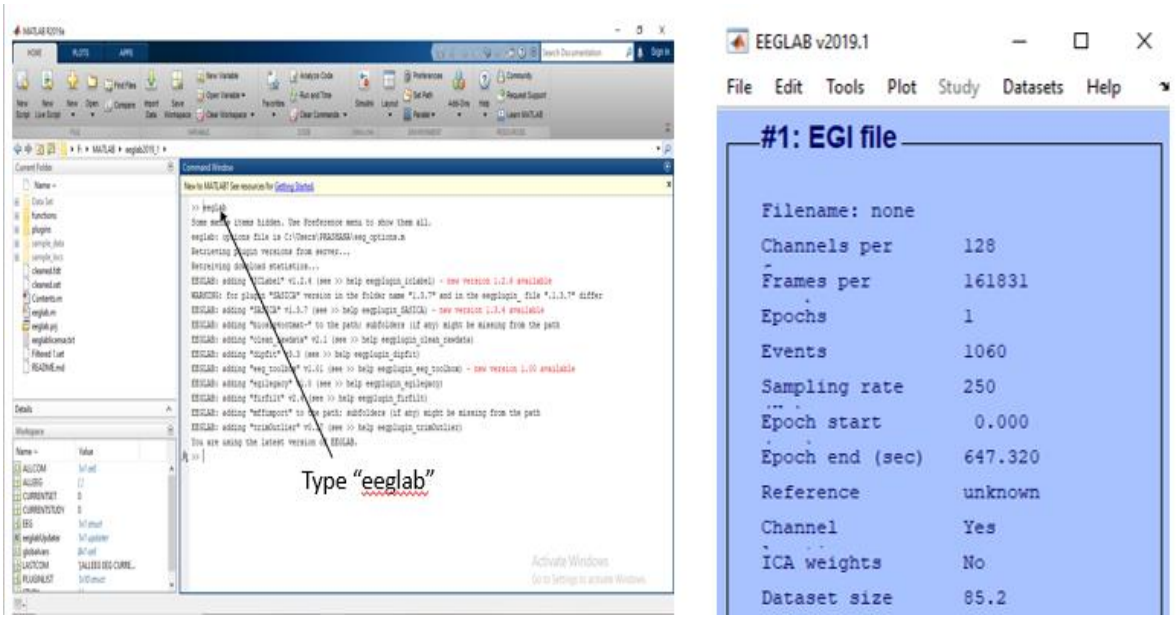
related EEG, was used for further analysis. Further analysis in MATLAB was carried out according to Makoto's preprocessing pipeline (https://sccn.ucsd.edu/wiki/Makoto%27s_preprocessing_pipeline).

The steps of processing in MATLAB are as follows:

Step 1: MATLAB was opened, and the EEGLAB toolbox was loaded into MATLAB by typing "eeglab" as shown in Figure 3.1.

Figure 3.1

Steps for Adding EEGLAB Toolbox to the Software

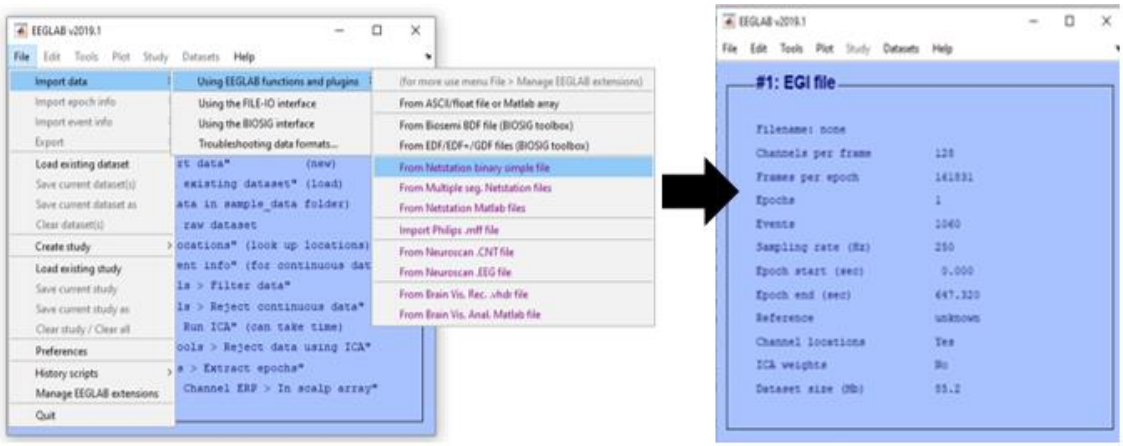


Step 2: Importing the binary EGI data file was done for initiating the analysis process, as shown in Figure 3.2.

File > Import Data > Using EEGLAB functions and plugins > From Netstation binary sample file > Select the raw data > Ok

Figure 3.2

Steps to be Followed for Importing the Data



Step 3: Importing channel locations (Geodesic Sensor Net Hydrocel 128) was done to plot the EEG scalp maps either in 2-D or 3-D template, and for approximating data source locations, the EEGLAB dataset must, therefore, hold information on the scalp locations of the recording electrodes. The channel location was imported and was applied, as shown in Figures 3.3 and 3.4.

Edit > Channel Locations > Read Locations > Sample locs – GSN Hydrocel 128 > Autodetect – Ok > Opt Head Centre > Autodetect > Ok

Figure 3.3

Steps to Import the Channel Location

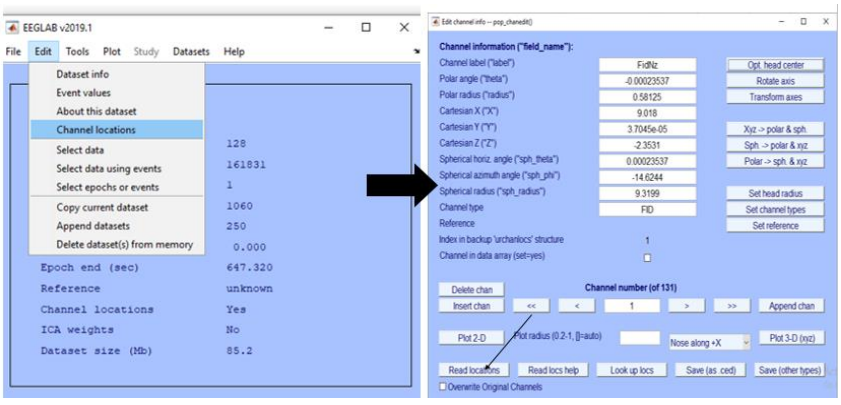
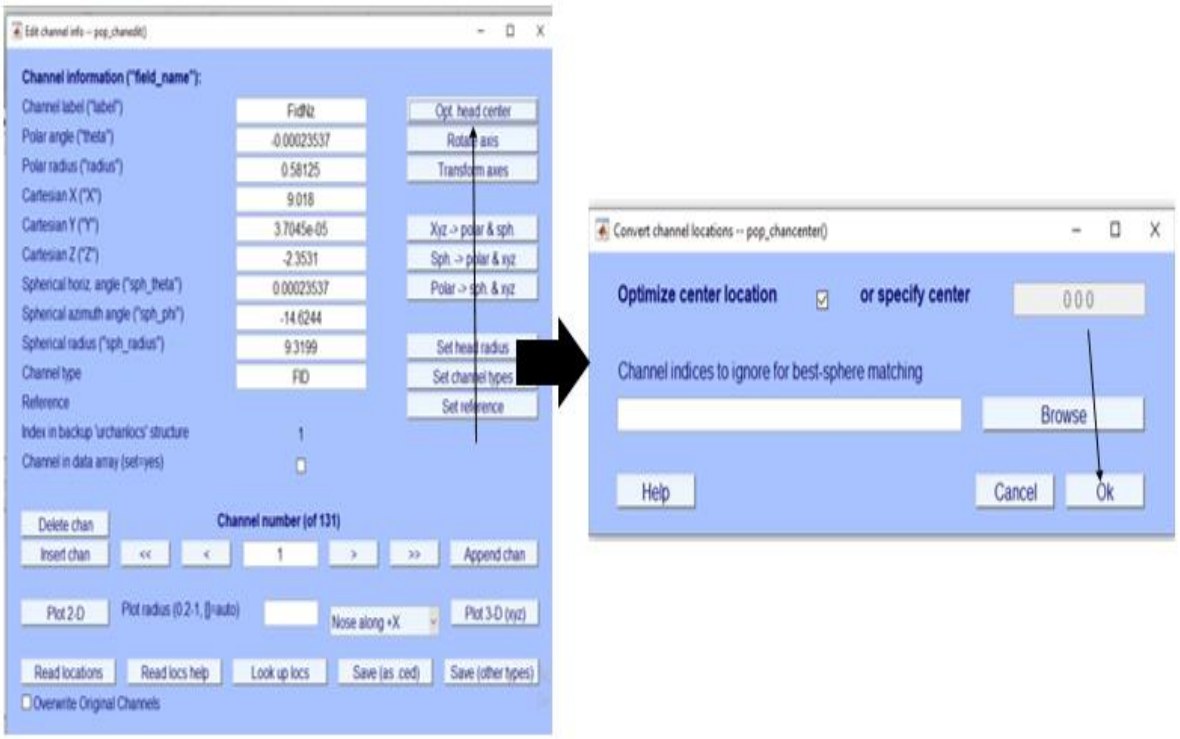


Figure 3.4

Steps to Apply the Channel Location

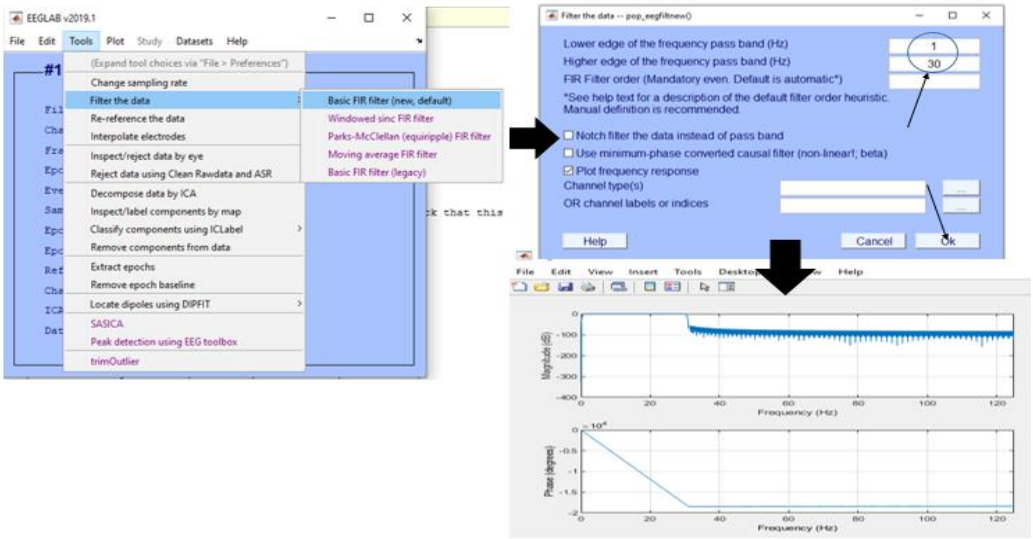


Step 4: Data was then subjected to Finite Impulse Response (FIR) Filtering with a bandpass of 0.1 Hz to 30 Hz as shown in Figure 3.5. It was strongly suggested that continuous EEG data be filtered before epoch or artifact removal, even though epoch data may even be filtered with this function (each epoch being filtered separately). Continuous data filtering mitigates the emergence of filtering artifacts at epoch boundary, and the data set is saved.

Tools > Filter the data > Basic FIR Filtering > Set Lower and Higher edge of the frequency passband as 0.1 Hz and 30 Hz respectively > Ok

Figure 3.5

The Steps to Follow for Filtering the Data



Step 5: Initially, the entire EEG data file was screened via scrolling manually through channel activities for bad channels and visual artifacts. These were removed manually. Following this, a clean raw data EEGlab plugin was applied for controlled objective rejection criteria as shown in Figure 3.6.

Tools > Clean the data using clean raw data and ASR. Figure 3.7 shows the rejected data in red colour and the retained data in blue colour.

Figure 3.6

The Steps Followed for Cleaning the Data

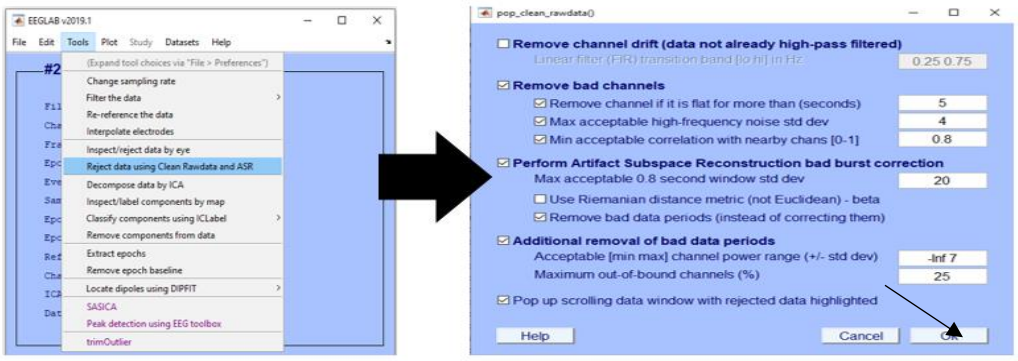
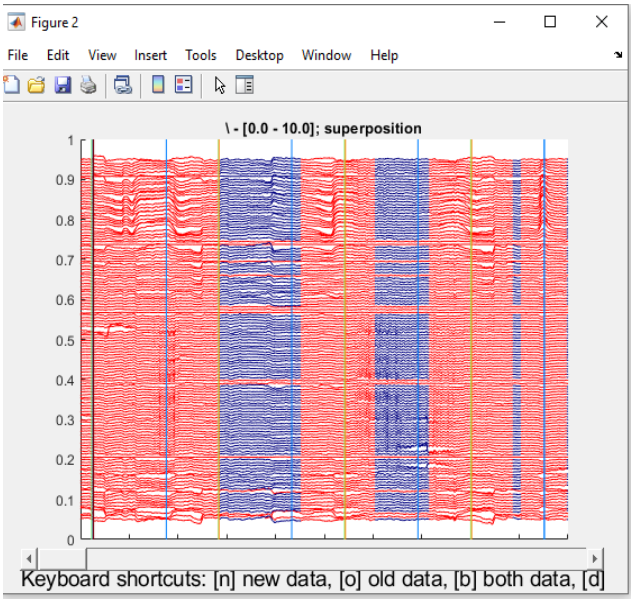


Figure 3.7

The Window with the Rejected and Retained data

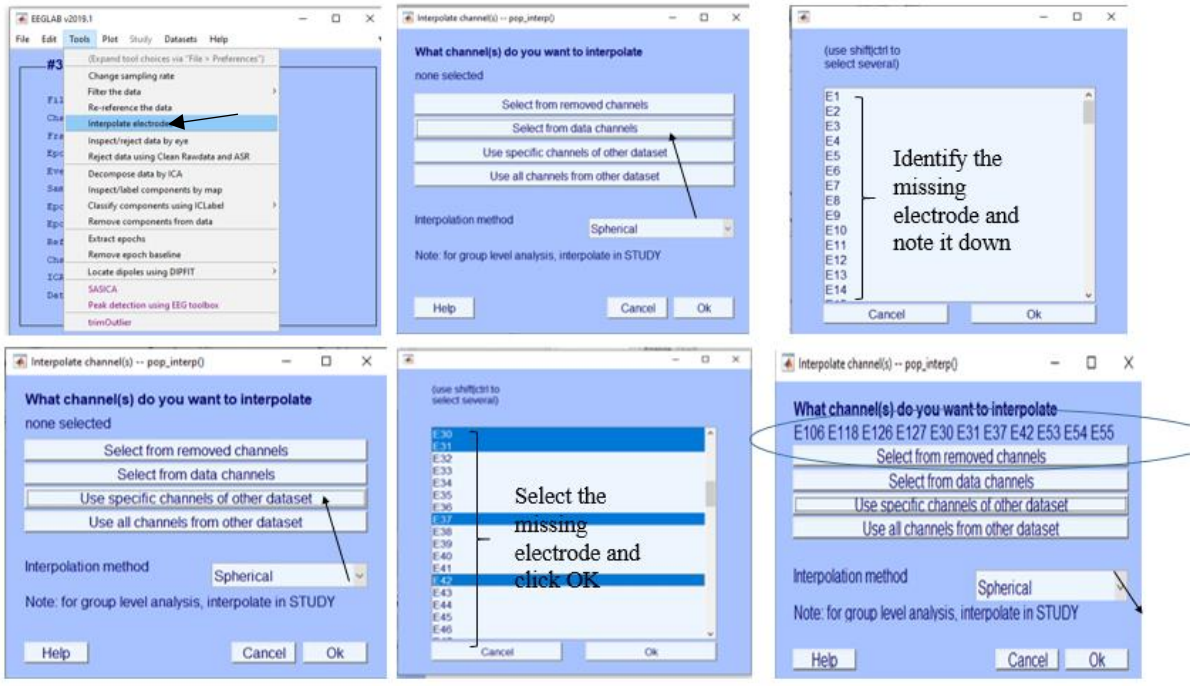


Step 6: Interpolation of all of the channels removed was carried out to reduce potential bias in the next average reference stage. For instance, if 64 channels exist and 16 channels are recognized as bad and rejected, but only from the right hemisphere, then the number of channels in the left vs. the right hemisphere is 32 vs. 16, with a mean bias towards the left hemisphere. To prevent such events, the channels were interpolated. In this procedure, when the cleaned data is processed, the researcher will note the missing rejected data as well as the channels selected in the filtered data set, and the dataset was saved as shown in Figure 3.8.

Tools > Interpolate electrodes > Select from data channels – Note down the channels that are removed > Use specific channels of other data set > Dataset Index – Give the number of Filtered Dataset > Select the removed electrodes > Ok

Figure 3.8

The Steps Followed for Interpolating the Electrodes

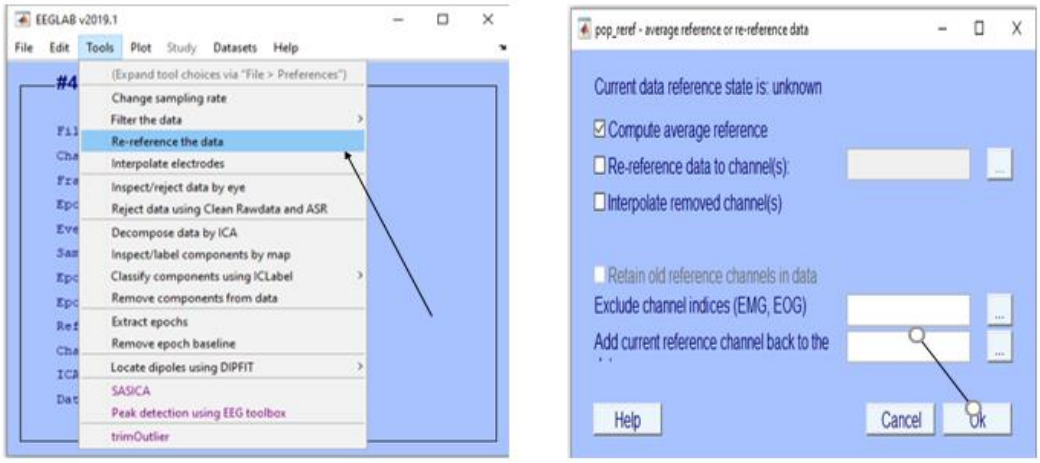


Step 7: The data were re-referenced to the average reference because when the EEG is produced on a cortex with a dipolar current distribution and without external sources, there are at all times the very same number of positive and negative potential changes due to the retention of the charge. Therefore, scalp topography should be null. By re-reference to average channel values, we presume that there is (really) no generation of charges that are monopolar sources and sinks, and also, the average reference is often very helpful in suppressing line noise.

Tools > Re-reference the Data > Compute average reference > Ok as shown in Figure 3.9.

Figure 3.9

The Steps Followed for Re-referencing the Data



Step 8: Independent Component Analysis (ICA) was conducted where the decomposition of data by ICA (including PCA) includes a linear change of base from data gathered by single scalp channels to a spatially transformed "virtual channel" premise. In other words, rather than collecting simultaneously recorded single-channel data records, the data is processed into a collection of simultaneously recorded spatial filter outputs applicable to all multi-channel data, and 64 components with maximum channel activity representation were derived and components were classified using the IC label.

Tools > Decompose data by ICA > Commandline option – 'pca', 64 > Ok (as shown in Figure 3.10) and the components were classified by following these steps: Tools > Classify Components > View extended component properties > Component indices to plot – 1:64 (as shown in Figure 3.11)

Figure 3.10

The Steps Followed for Decomposing the Data and the Components Obtained After Following the Steps

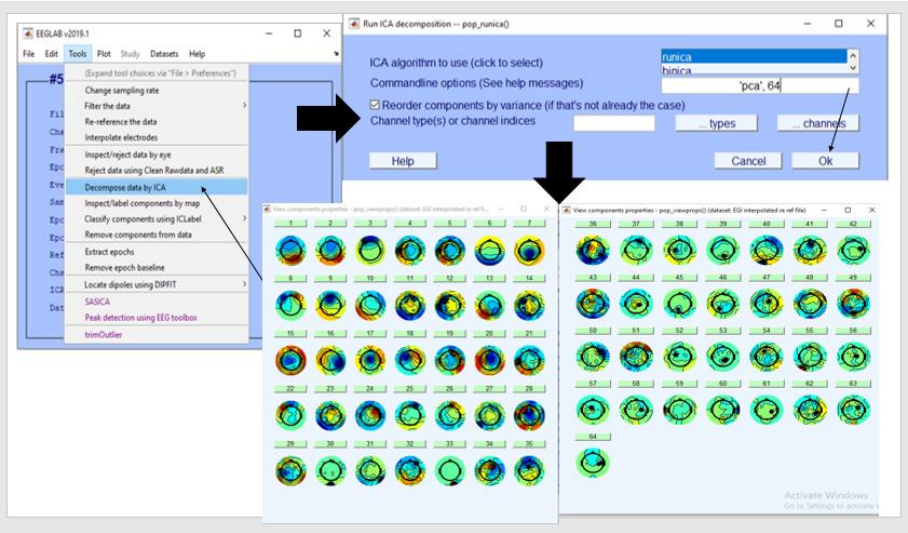
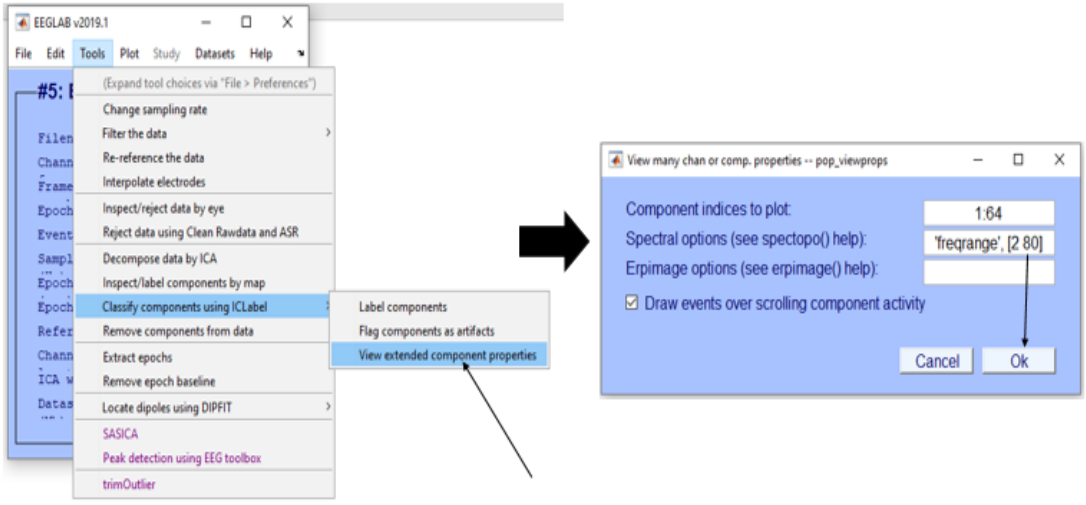


Figure 3.11

The Steps Followed for Classifying the Components



Step 9: SASICA plugin was applied to perform the automatic detection of artifactual components - The methods include 1). Autocorrelation, which identifies noisy elements with weak autocorrelation (usually muscular artifacts).

2). Focal components identify components that are too focal and are therefore unlikely to match neural activity (usually the wrong channel or muscle artifacts).

3). Signal-to - noise ratio works by detecting components with a weak signal-to-noise ratio among both arbitrary baselines as well as interest time windows. After applying the plugin another window pops up showing the artefacts in red colour which makes it easier to remove the unwanted components as shown in Figure 3.13.

Tools > SASICA > Autocorrelation – Enable; Focal components – Enable; Correlation with other channel(s) – Enable; Adjust selection – Enable > Compute (as shown in Figure 3.12)

Figure 3.12

The Steps Followed for Applying the Plugin.

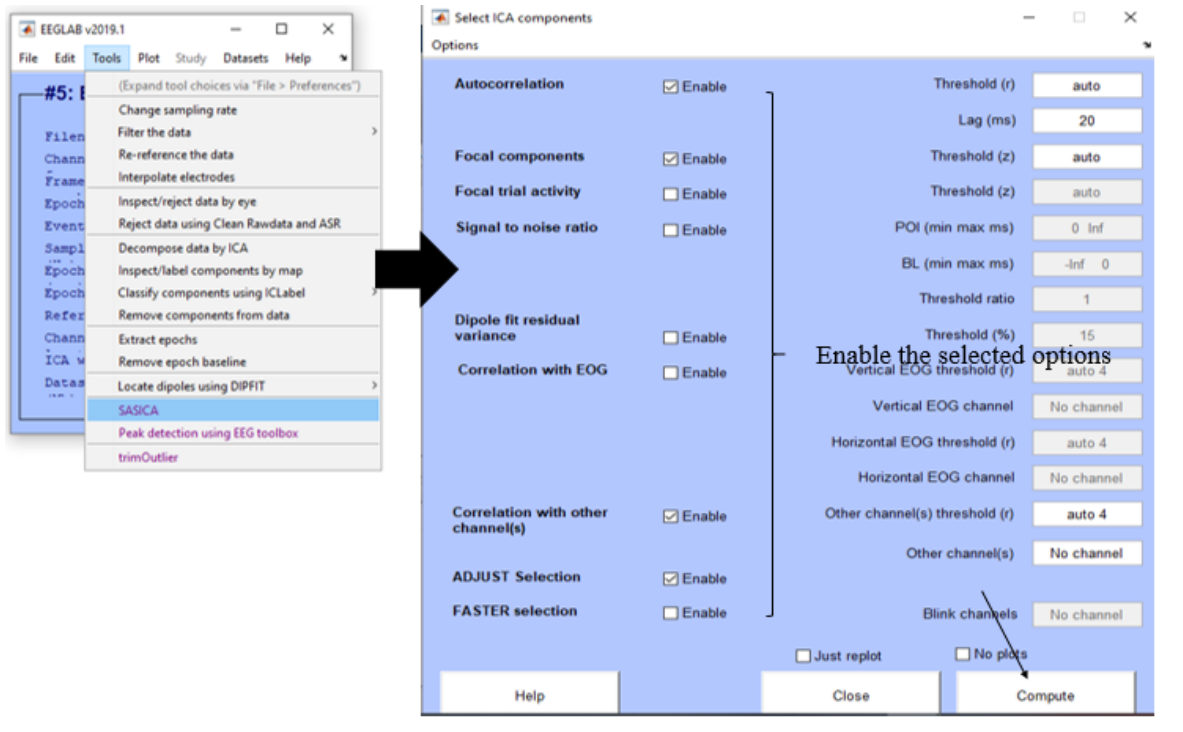
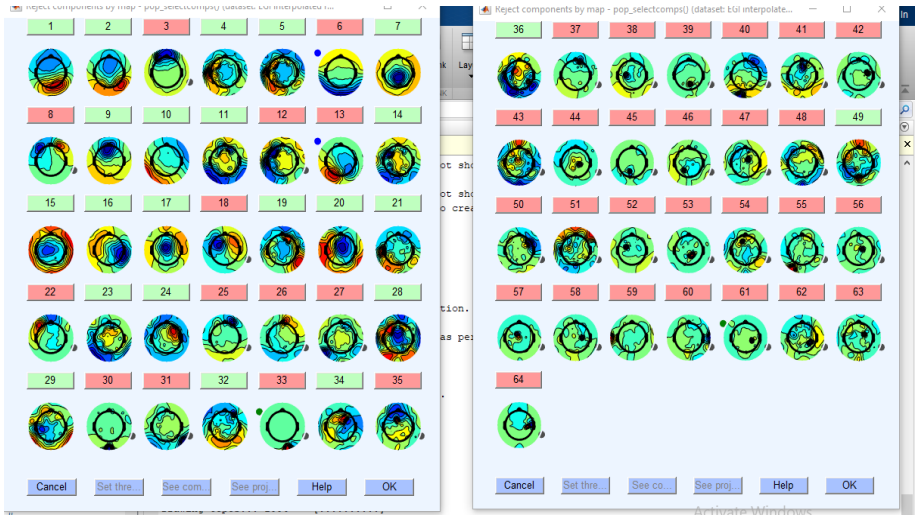


Figure 3.13

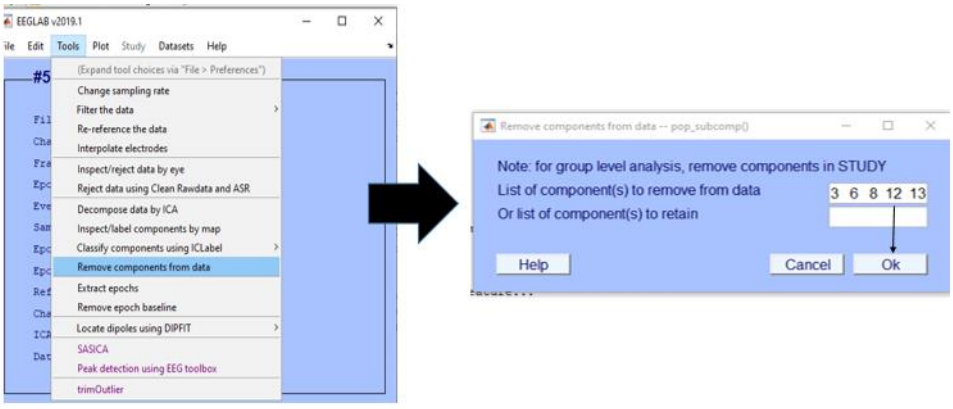
The Components with Artifacts in Red Colour



Step 10: Independent Components (ICs) with eye-related or muscle-related components were removed, and ICs with activities of interest from the Brain (confirmed with the presence of dipoles and ERP waves) were selected as shown in Figure 3.14. Tools > Remove components from data > OK > Accept > Save as a new file. After removing the unwanted components, the dataset was saved to extract epochs from this dataset.

Figure 3.14

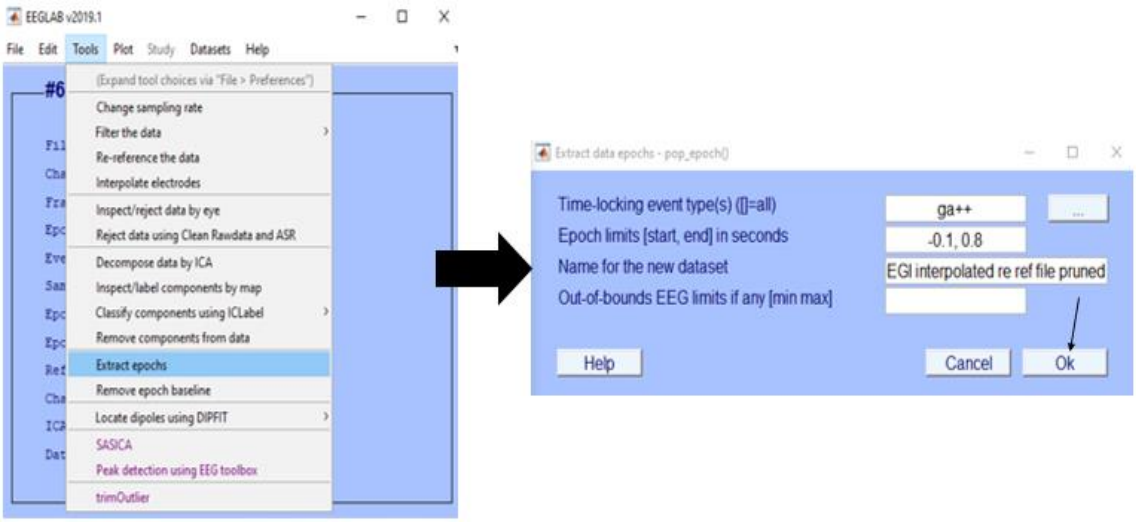
Steps Followed for Removing Unwanted Components



Step 11: Epochs were extracted from the retained ICs with the epoch limit of 0.1 seconds before the stimulus onset and 0.8 seconds after the stimulus onset for both the frequent and the infrequent events. The steps followed were as shown in Figure 3.15. Tools > Extract Epochs > Time locking event type – Select the event (for example ga) – Epoch limit – Mention as "-0.1 0.8" – Ok

Figure 3.15

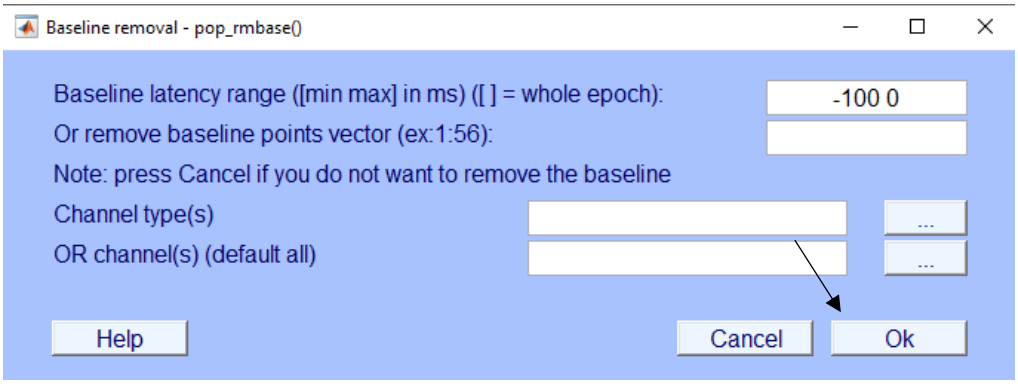
Steps Followed for Extracting the Epochs



Step 12: Baseline correction was carried out with a latency range of 100 ms, where Baseline correction is a common method used during the analysis of Event-Related Potentials, to account for irrelevant differences in the signal baseline. It is applied to an epoch data set by specifying a sub-window, where the mean value of the signal in that window is subtracted from the whole signal (by channel or component). The Figure 3.16 shows the baseline correction being applied.

Figure 3.16

The Window that Pops up after Step 11



Step 12: ERP image was plotted. The waveform of the P300 potential, as well as the topographical representation, was plotted. The figure 3.17 shows the steps that were followed for plotting the ERPs, and Figure 3.18 shows the P300 potential. Plot > Sum/Compare comp. ERPs. > Datasets to average – Give the dataset numbers – Ok

Figure 3.17

The Steps Followed for Plotting the ERP

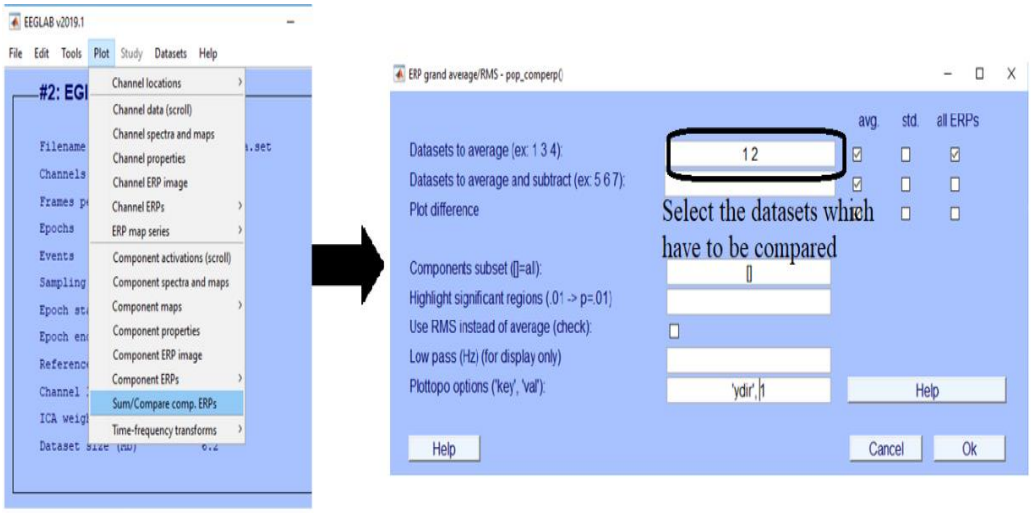
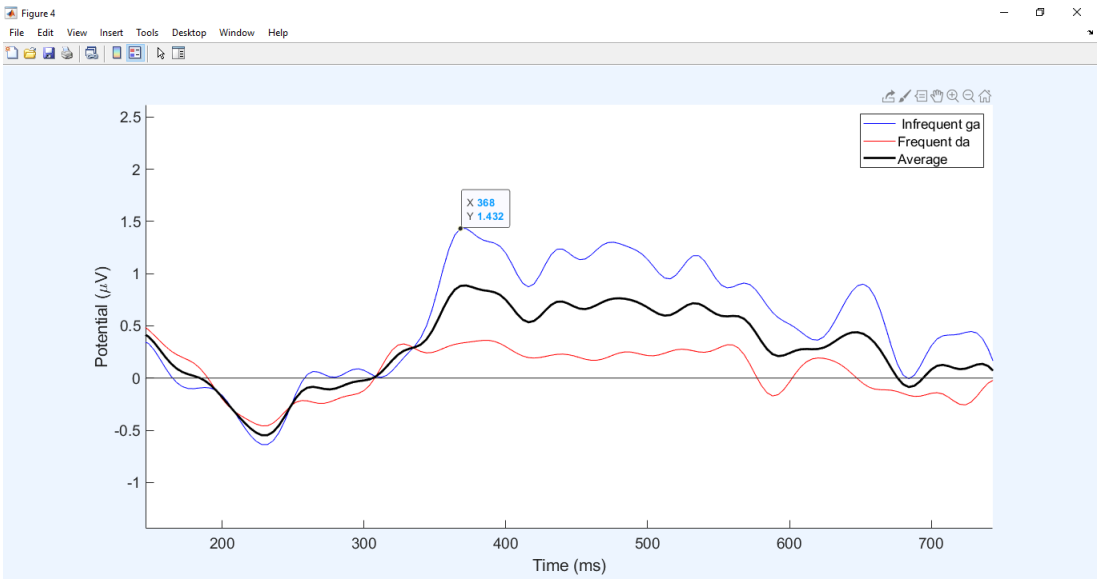


Figure 3.18

The Event Related Potential P300 Obtained After the Analysis



CHAPTER IV

Results

The primary aim of the study was to profile the neurophysiological assessment (P300) in individuals with aphasia and neuro-typicals. Profiling was to identify the waveforms in the particular electrode sites and the brain activation in them. The study comprised a clinical group consisting 4 individuals with aphasia as participants and a control group with 4 neuro-typical individuals. This electrophysiological study did not include any statistical analysis.

The waveform representing P300 in both clinical and control group was studied further by dividing the brain into five regions: frontal (F), left temporal (LT), central (C), right temporal (RT), and posterior (P) by grouping the electrodes at different brain areas (Appendix: A) and the amplitude and the latency were noted.

The results are organized under the following headings:

- Representation of waveform and topography in the clinical group
- Representation of waveform and topography of aphasics in comparison with age-matched individuals
- Representation of waveform and topography in the control group

4.1. Representation of Waveform and Topography in the Clinical Group

In the present study, out of the four participants in the clinical group who participated in the study, the P300 potential was present only in Participant A.

The Participant B, Participant C, and Participant D did not exhibit the P300 potential. The results of the P300 assessment of Participants A in terms of latency and amplitude in described in the following sections. The latency measured was 460 ms in the frontal, central, posterior, left and right electrode regions of the scalp, whereas it was 472 ms in the midline electrode region. The average latency measured was 460 ms among all the electrode sites. The values of latency measures can be related to the findings of Pararini et al. (2018), where it varied from 320 ms to 484 ms in healthy elderly subjects. Similarly, the amplitude measured in the frontal scalp, central, midline, posterior, left and right regions was 0.723 μV, 0.369 μV, 0.459 μV, 0.549 μV, 0.464 μV and 0.331 μV respectively. The average amplitude measured was 0.512 μV among all the scalp electrode sites in Participant A. The value can also be correlated to the study of Pavarini et al. (2018), which shows the variation of amplitude from 2.2 μV to 18.5 μV in the healthy elderly subjects.

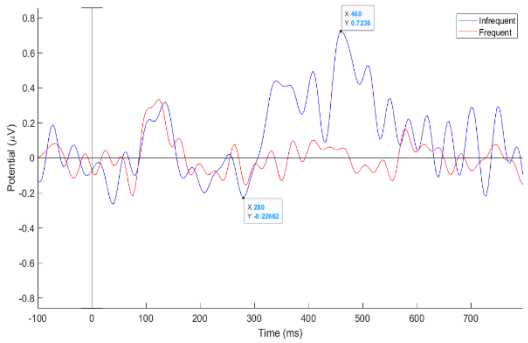
4.1.1 Participant A

The graphical waveform representation of Participant A consists of two waveforms—an infrequent stimulus waveform color-coded with blue and a frequent stimulus waveform color-coded with red. The amplitude and latency measures are represented in Y-axis and X-axis, respectively. The amplitude and latency measures of P300 assessment for different electrode sites are shown in Figures 4.1 and 4.2, the waveform representation and the summary of all the electrode sites are graphically depicted below in Figure 4.3 and 4.4.

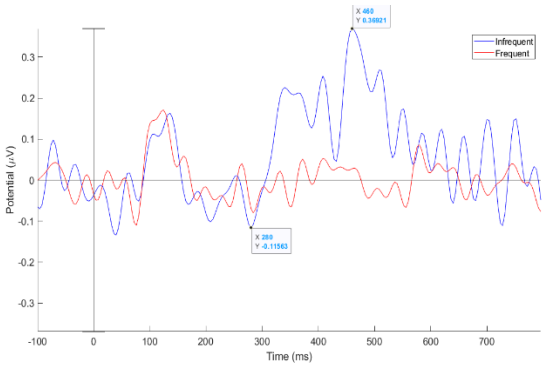
Figure 4.1

Waveforms of P300 in Different Electrode Sites of Participant A

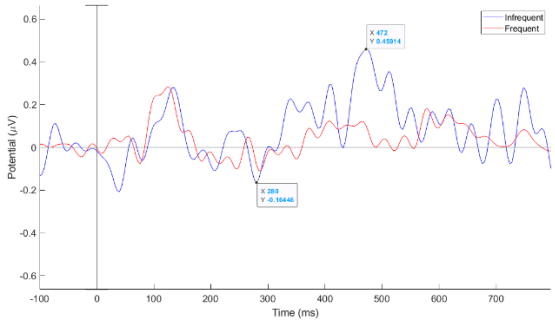
Frontal



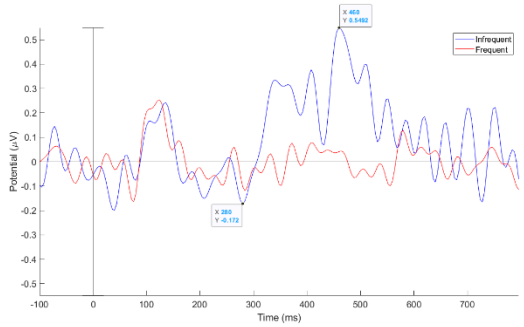
Central



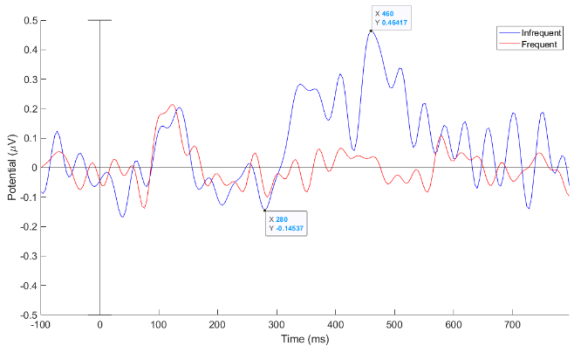
Midline



Posterior



Left



Right

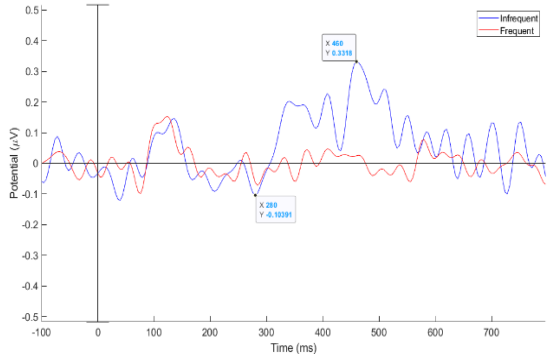
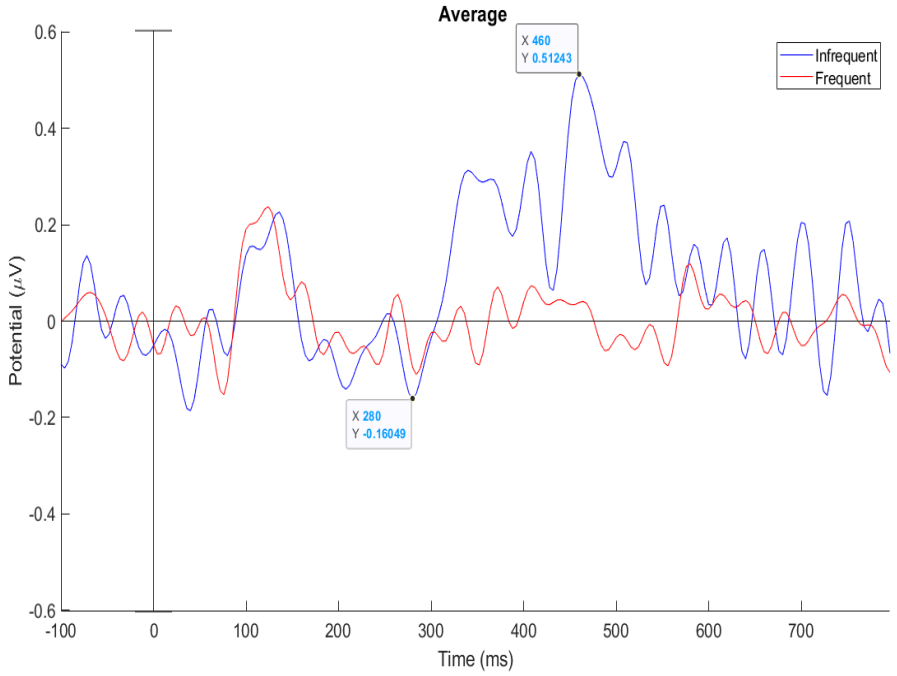


Figure 4.2

Waveforms Showing the Average Responses for the Speech Stimuli at FCz



The amplitude and latency measures of P300 in Participant A along with the average are compared among the scalp electrode regions, and the same is graphically represented in Figure 4.3 and 4.4, respectively. It is observed that the frontal region had the highest amplitude, followed by posterior region, average electrode, left region, midline region, central and right electrode region. With reference to latency, the midline region had prolonged latency, followed by other all electrode regions, which had similar latency values irrespective of different regions.

Figure 4.3

Amplitude Measures of P300 in Participant A

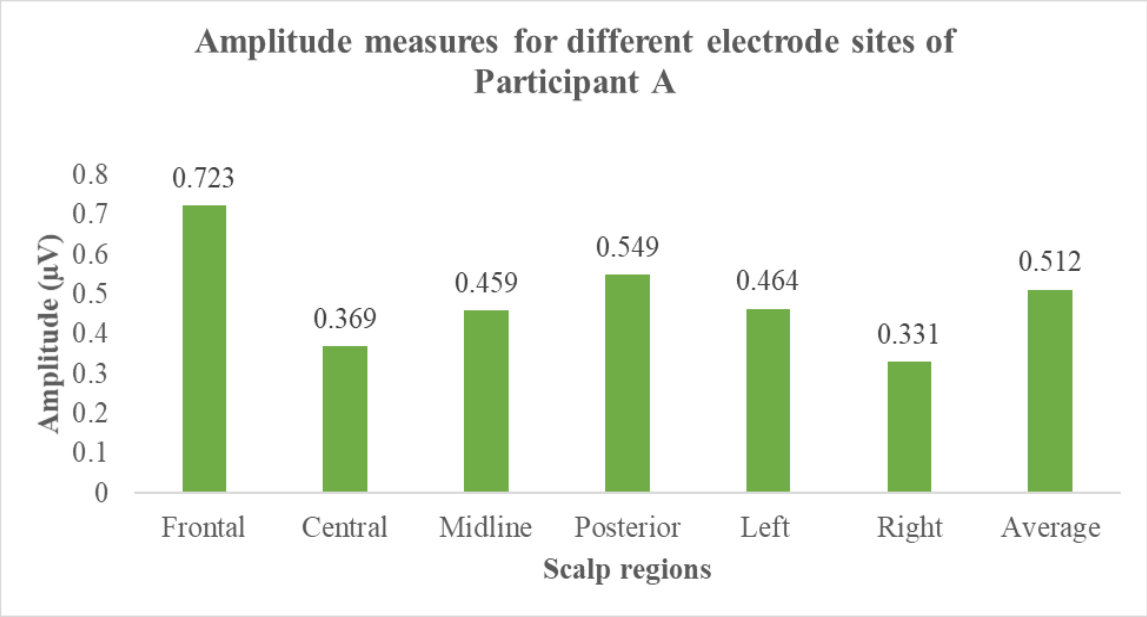
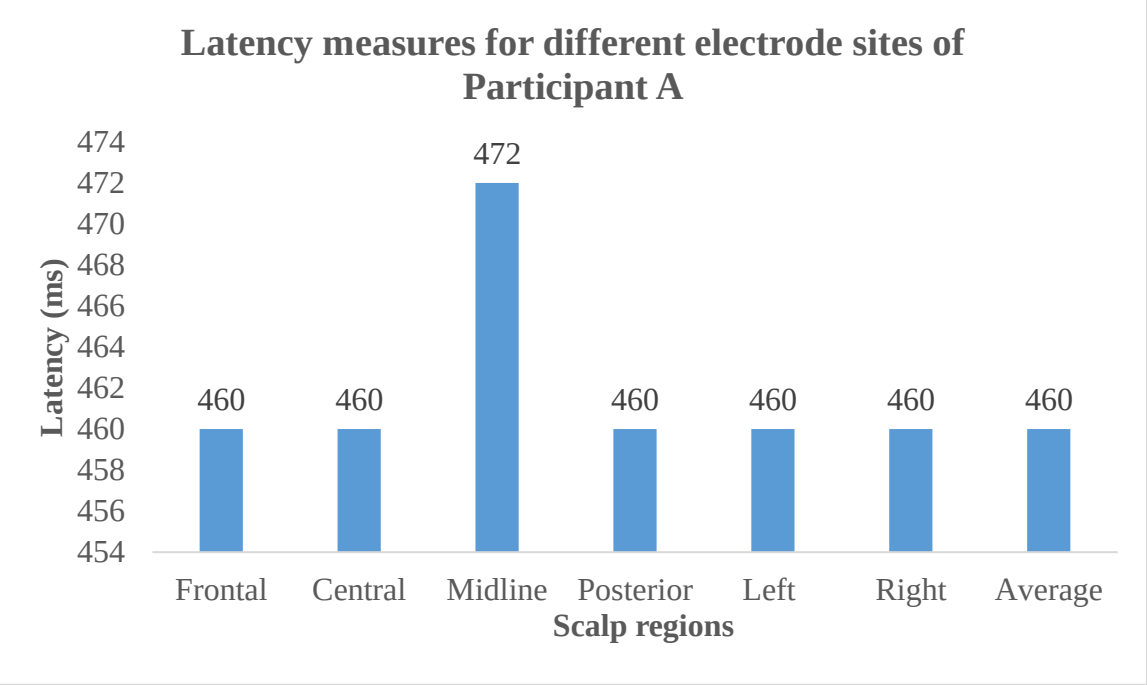


Figure 4.4

Latency Measures of P300 in Participant A

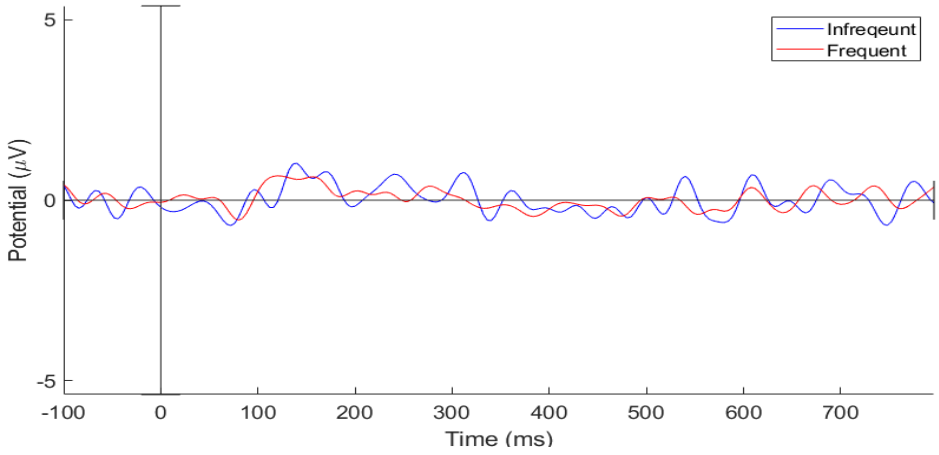


The P300 potential was not found in participants B, C, and D, the waveform without P300 peak amplitude and latency is shown in Figure 4.5, 4.6, and 4.7.

4.1.2 Participant B

Figure 4.5

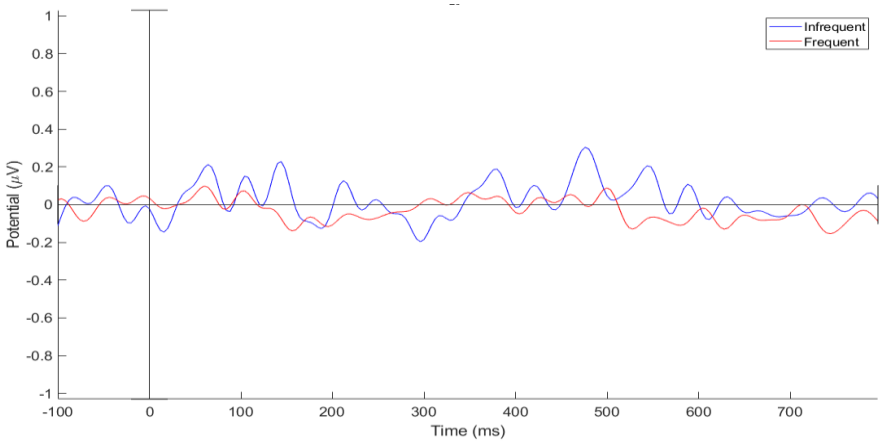
Waveforms Showing the Average Responses for Participants B



4.1.3 Participant C

Figure 4.6

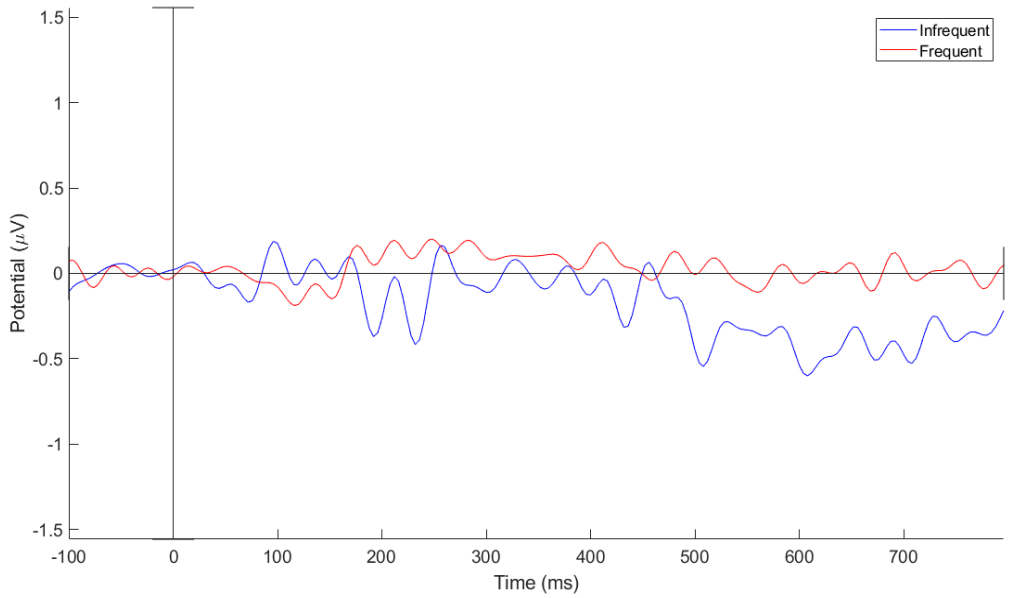
W*aveforms Showing the Average Responses for Participants C*



4.1.4 Participant D

Figure 4.7

Waveforms Showing the Average Responses for Participants D

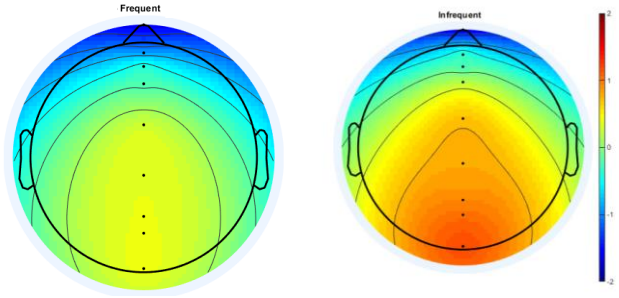


The comparison of brain activation for frequent and infrequent stimuli at the peak latency is represented topographically for Participant A, B, C, D of the clinical group. Where the darker shades for the infrequent one show the brain activity to the infrequent stimuli, from the topographical representation it was seen that the brain region which was strongly activated was the posterior brain region/sites for Participants A. For Participant B, C, and D, the P300 potential was absent, and the topographical representation showed no activation towards the infrequent stimulus. The same is shown in Figure 4.8.

Figure 4.8

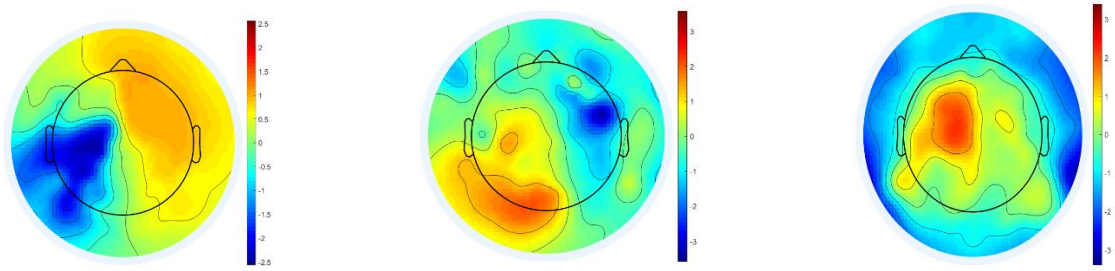
Topographic Representation in the Clinical Group (Aphasic Participants)

Participant A



(a) Frequent stimuli (b) Infrequent Stimuli

Participant B **Participant C** **Participant D**



(b) Infrequent Stimuli (b) Infrequent Stimuli (b) Infrequent Stimuli

4.2 Representation of Waveform and Topography of Aphasics in Comparison with Age-Matched Individuals

In this sub-section, the neuro-typical Participant 1 and the aphasic Participant A are compared in terms of latency and amplitude measures in the different scalp regions. In the frontal region, the latency for Participant 1 was 288 ms, whereas the amplitude is 1.591μV, and for Participant A, the latency was 460

ms, and the amplitude was 0.723μV. The latency was 300ms, and amplitude was 2.249μV for Participant 1 and latency 460ms and amplitude 0.369μV for Participant A in the central region. In the posterior region, for Participant 1, latency was 300ms and amplitude 2.636μV, whereas, for Participant A, latency was 460ms and amplitude 0.549μV. The latency and amplitude in the midline regions for Participant 1 are 300ms and 1.289μV, respectively, and for Participant A are 472ms and 0.459μV, respectively. For Participant A, in the right region, the latency was 460ms, and the amplitude was 0.331μV. For the left region of Participant A, the latency was 460ms, and the amplitude was 0.464μV. The average values of latency and amplitude of Participant 1 were 300ms and 2.093μV, respectively. For Participant A, the average value of latency was 460ms, and the amplitude was 0.512 μV.

The waveform representation P300 of Participant A of the clinical group (P300 - present) and Participant 1 of neuro-typical (P300- absent) consists of two waveforms—an infrequent stimulus waveform color-coded with blue and a frequent stimulus waveform color-coded with red. The amplitude and latency measures are represented in Y-axis and X-axis respectively for different electrode regions in Figure 4.9 (frontal electrode site), 4.10 (central electrode site), 4.11 (posterior electrode site), 4.12 (midline electrode site), 4.13 (right electrode site), 4.14 (left electrode site) and 4.15 (average electrode site).

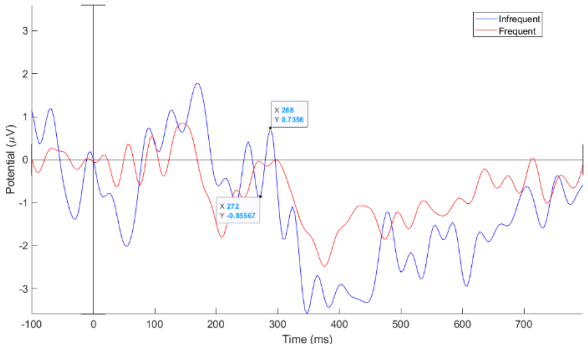
The summary of all the electrode regions showing the differences in terms of latency and amplitude values between Participant A of clinical and Participant 1 of the neuro-typical group is graphically depicted in Figure 4.16 and 4.17.

Figure 4.9

Waveforms Showing the Responses at Frontal Region Sites for Participant A and Participant 1

Frontal electrode sites

PARTICIPANT A (Aphasia)



PARTICIPANT 1 (Neuro-typical)

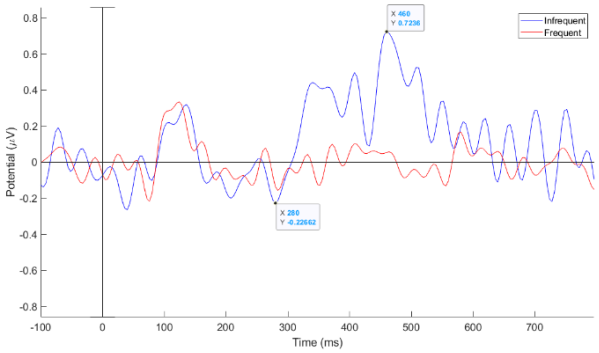
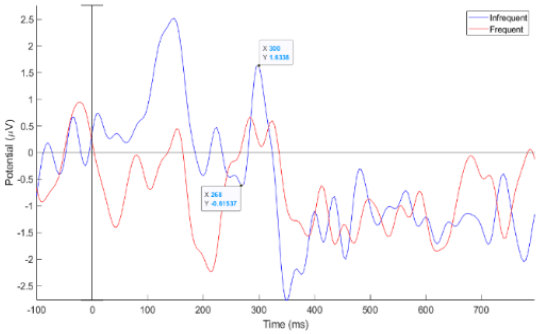


Figure 4.10

Waveforms Showing the Responses at Central Region Sites for Participant A and Participant 1

Central electrode sites

PARTICIPANT A (Aphasia)



PARTICIPANT 1 (Neuro-typical)

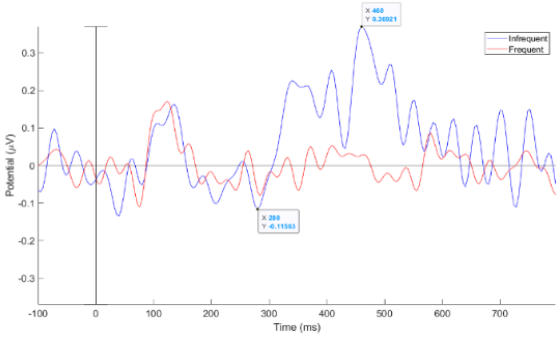


Figure 4.11

Waveforms Showing the Responses at the Posterior Region Site for Participant A & Participant 1

Posterior electrode sites

PARTICIPANT A (Aphasia) PARTICIPANT 1 (Neuro-typical)

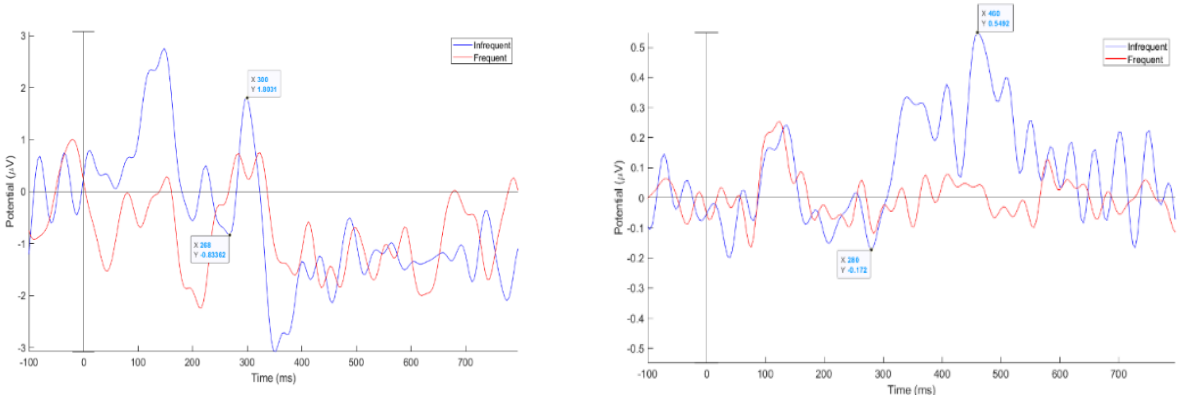


Figure 4.12

Waveforms Showing Responses at Midline Electrodes Sites for Participant A & Participant 1

Midline electrode sites

PARTICIPANT A (Aphasia) PARTICIPANT 1 (Neuro-typical)

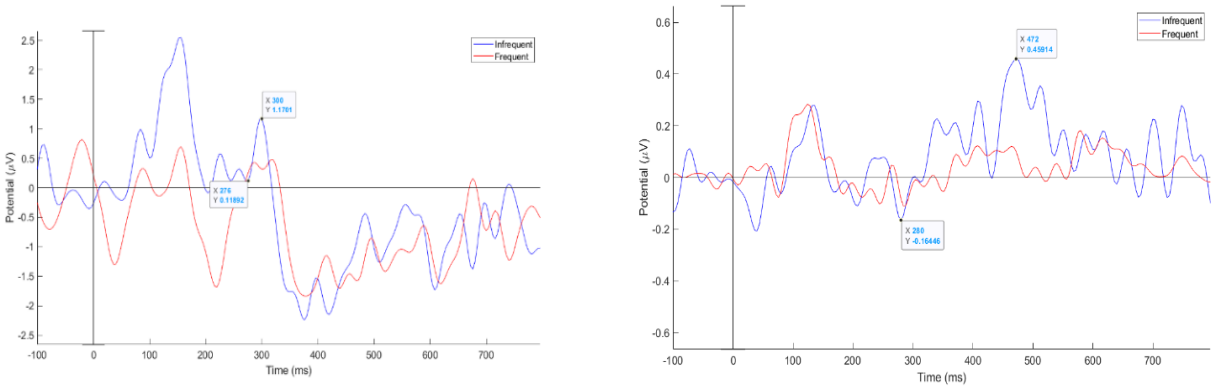
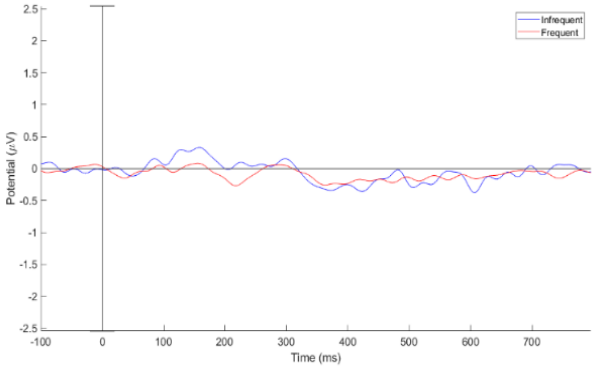


Figure 4.13

Waveforms Showing the Responses of the Right Region Site for Participant A & Participant 1

Right Electrode sites

PARTICIPANT A (Aphasia)



PARTICIPANT 1 (Neuro-typical)

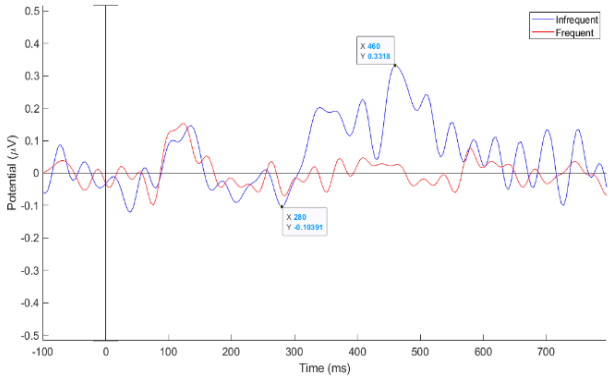
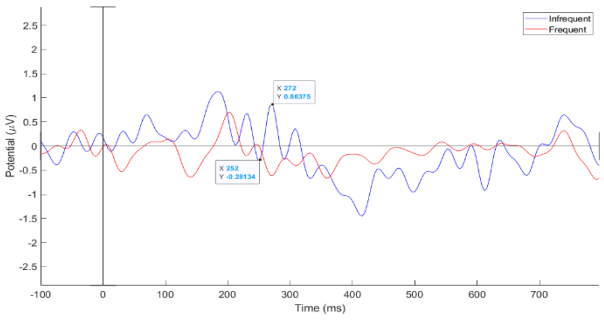


Figure 4.14

Waveforms Showing the Responses of the Left Region Site for Participant A & Participant 1

Left Electrode sites

PARTICIPANT A (Aphasia)



PARTICIPANT 1 (Neuro-typical)

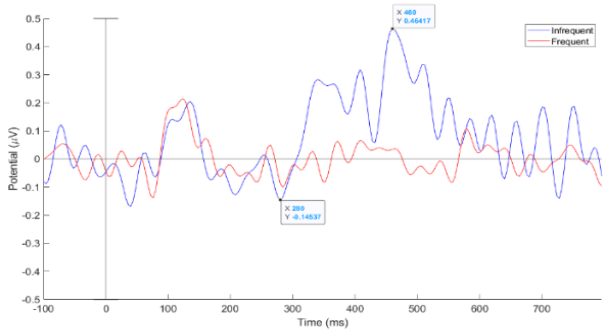


Figure 4.15

Waveforms Showing the Responses from the Average Electrodes of Participant A & Participant 1

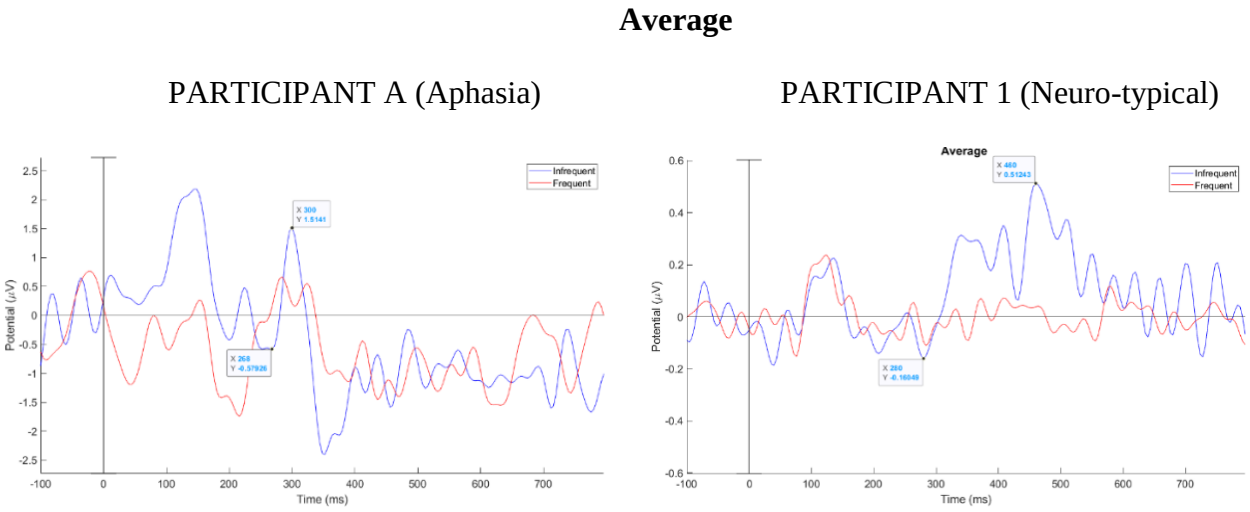


Figure: 4.16

Comparison of Latency at Different Electrode Sites for Individuals with Aphasia and Age Match Neuro-typical

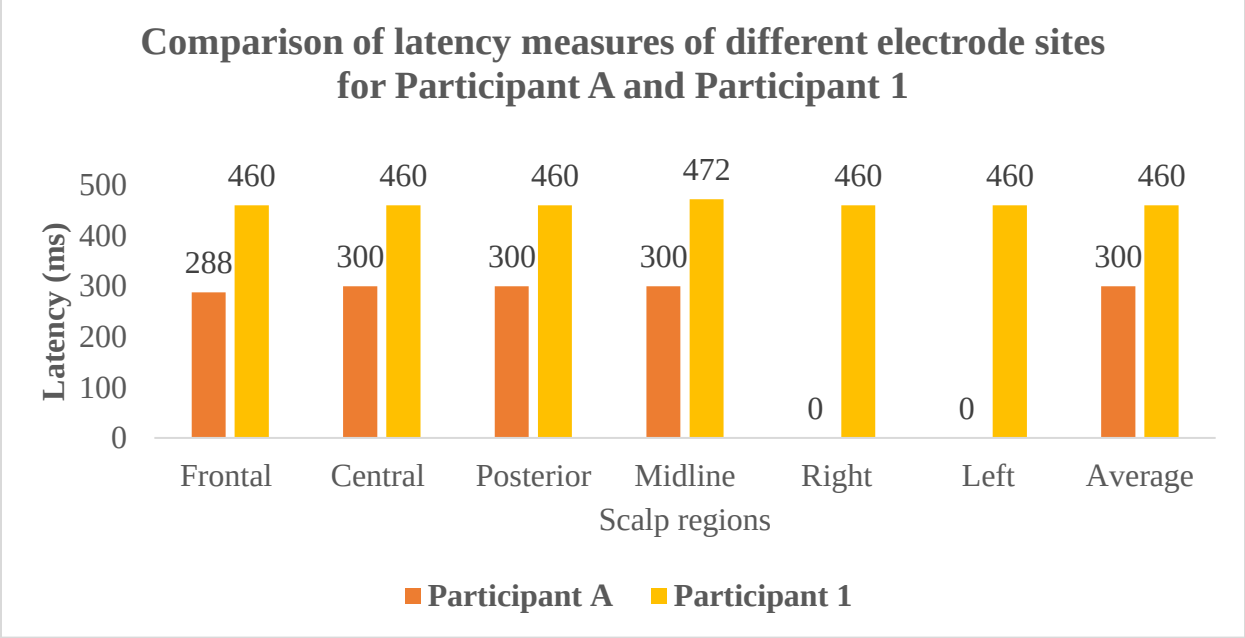
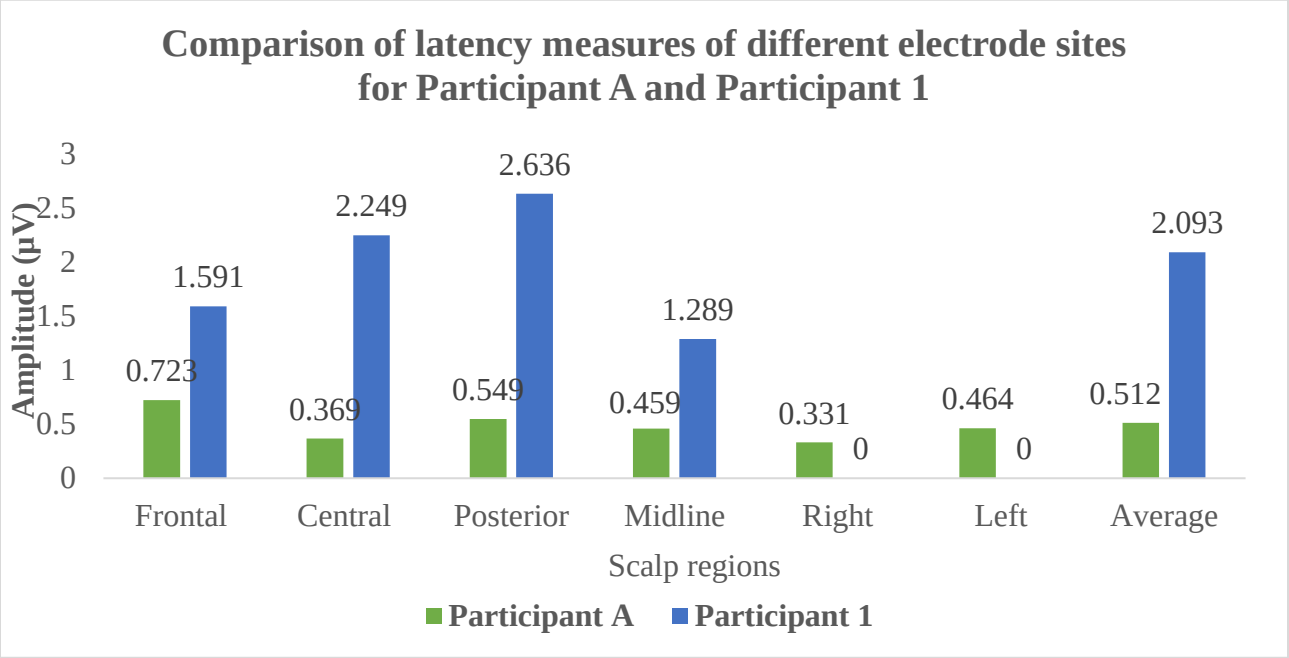


Figure: 4.17

Comparison of Amplitude at Different Electrode Sites for Individuals with Aphasia and Age Match Neuro-typical



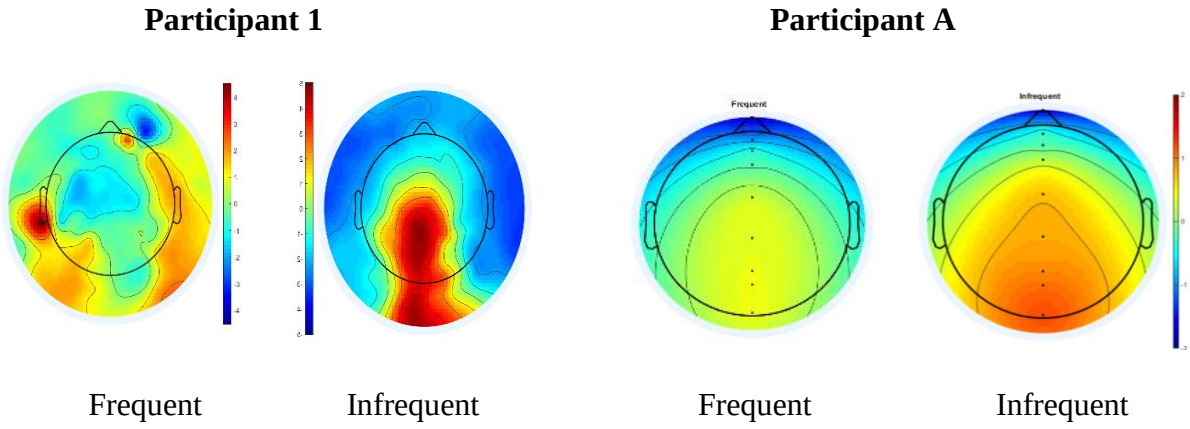
From the above Figure 4.16 and 4.17, it clearly depicted that the prolongation of latency and reduction of amplitude across distinct scalp regions in aphasic individuals when compared with the age-matched neuro-typical individual.

The comparison of brain activation for frequent and infrequent stimuli at the peak latency is represented topographically for Participant 1 of control group was compared with Participant A of the clinical group. Where the higher activation for the infrequent one show the brain activity to the infrequent stimuli, from the topographical representation it was seen that the brain region which was strongly activated was the posterior brain region/sites and more centralized

significantly for both Participants 1 than Participant A. For Participant A and Participant 1, the P300 potential was present, and the topographical representation showed activation towards the frequent stimulus also with more activated electrode sites in Participant 1 compared to Participant A. The same is shown in Figure 4.18.

Figure 4.18

Comparison of Scalp Topography of Participant A with Participant 1



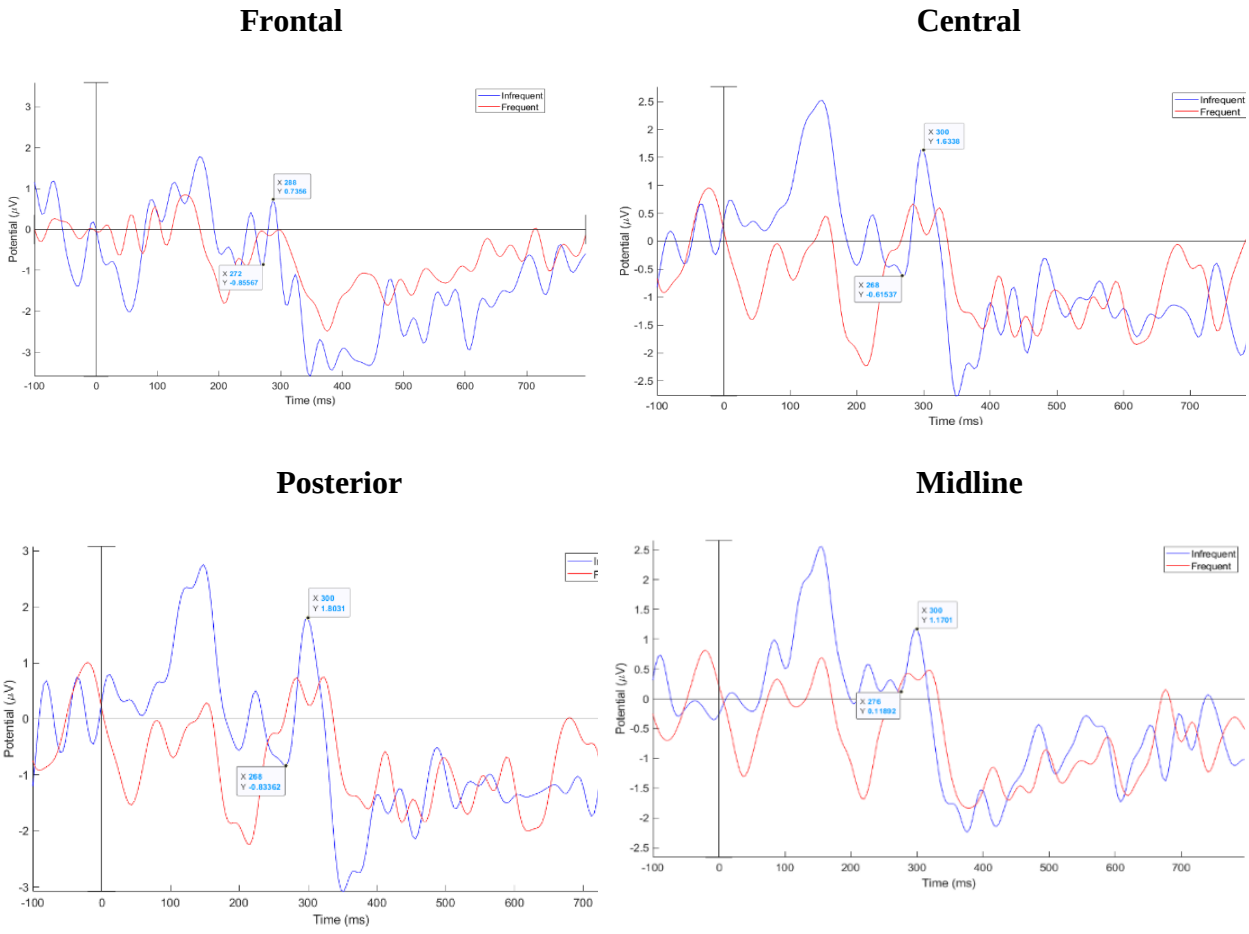
4.3 Representation of Waveform and Topography in Neuro-typical Individuals (NTI)

The latency and amplitude measure in the different scalp regions, along with the average for Participant 1, is shown in Figure 4.19. Here, the latencies for frontal, central, posterior, and midline regions are 288ms, 300ms, 300ms, and 300ms. The amplitude for the same Participant 1 in frontal, central, posterior and midline regions is 1.591 µV, 2.249 µV, 2.636 µV, and 1.289 µV respectively. The

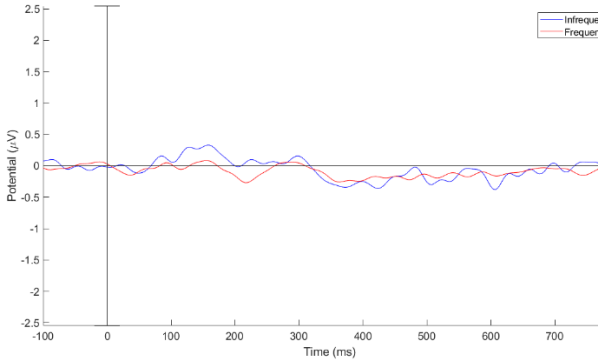
average electrode latency is 300 ms, and the amplitude is 2.09 μV. The P300 response was not seen in the right and the left region for Participant 1.

Figure 4.19

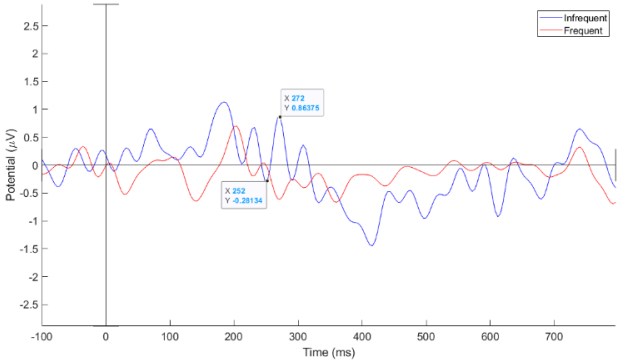
Waveforms Showing the Responses at Different Scalp Regions for Participant 1 (NTI)



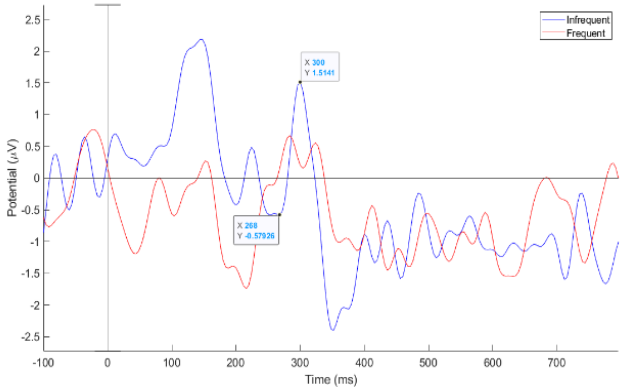
Right



Left



Average

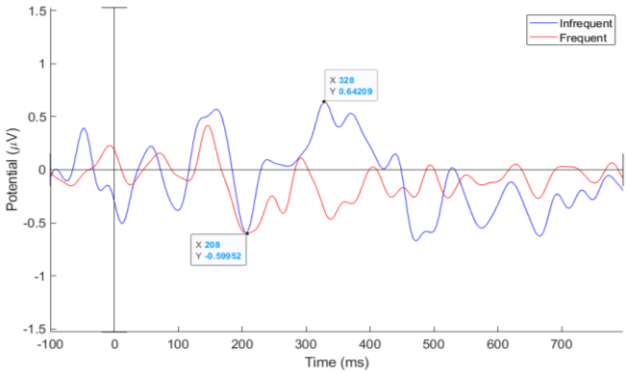


The latency and amplitude measure in the different scalp regions, along with the average for Participant 2, is shown in Figure 4.20. Here, the latencies for frontal is 328ms and 1.241 μV, for the central region it was 328ms and 1.515 μV, for the posterior region it was 328ms and 1.335 μV, for the midline region it was 328ms and 0.792 μV, for the right it was 364ms and 0.388 μV, and for the left, it was 328ms and 0.787 μV in their respective orders as seen in the review, whereas the average electrode site latency and amplitude were 328ms and 1.208 μV respectively. The same is shown in Figure 4.20.

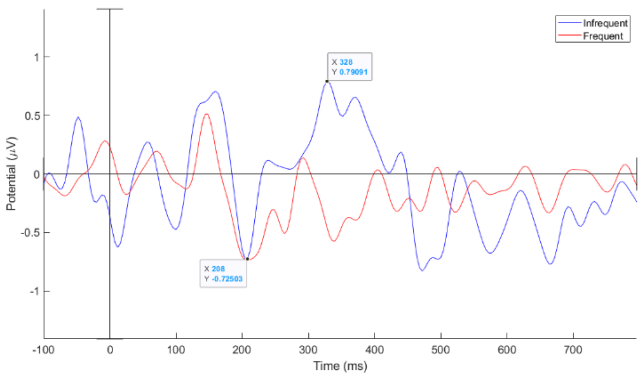
Figure 4.20

Waveforms Showing the Responses at Different Scalp Regions for Participant 2 (NTI)

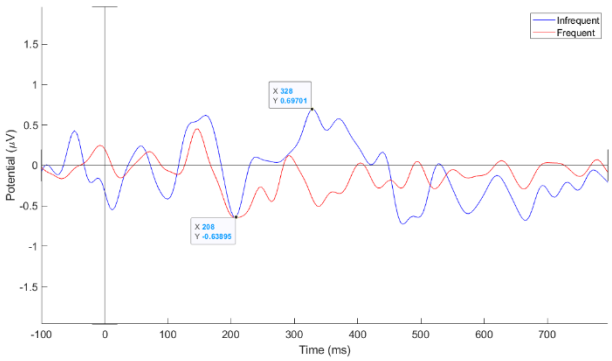
Frontal



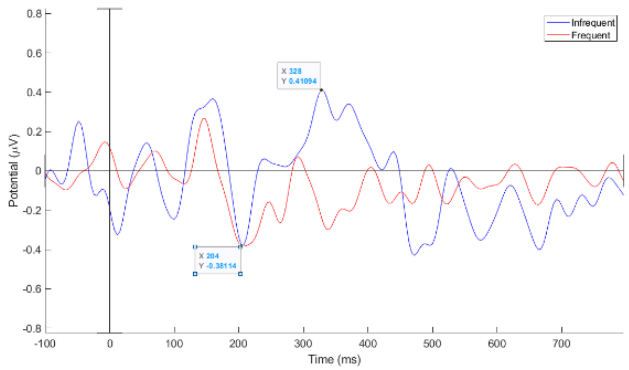
Central



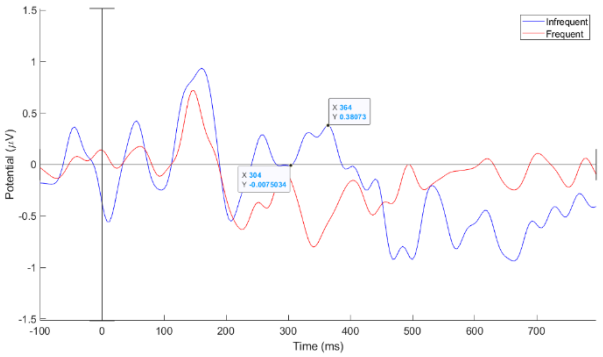
Posterior



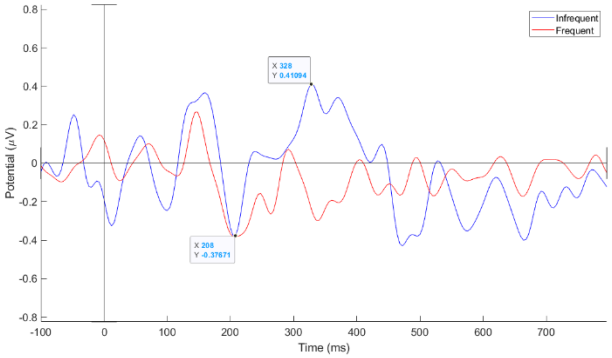
Midline



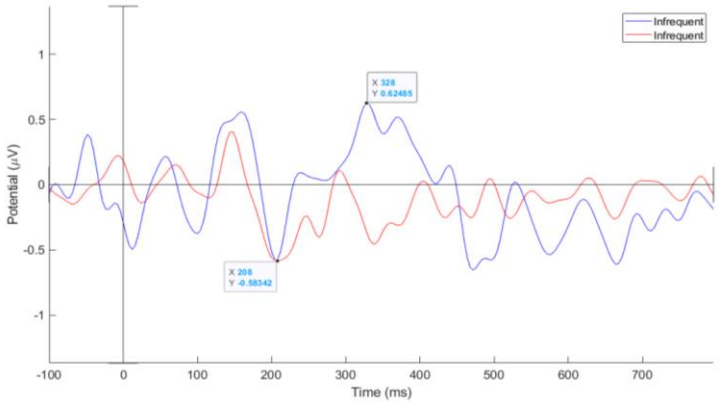
Right



Left



Average



The latency and amplitude measure in the different scalp regions, along with the average for Participant 3, is shown in Figure 4.21. , Here the latency values in the frontal, central, posterior, midline and left regions are 280ms, 272ms, 276ms, 276ms, and 264ms, respectively, with the average 276ms. The values of amplitude for frontal, central, posterior midline, and left regions are 0.584 μV, 1.361 μV, 1.536 μV, 1.152 μV, and 0.211 μV respectively with the average 1.545 μV. The same is shown in Figure 4.21.

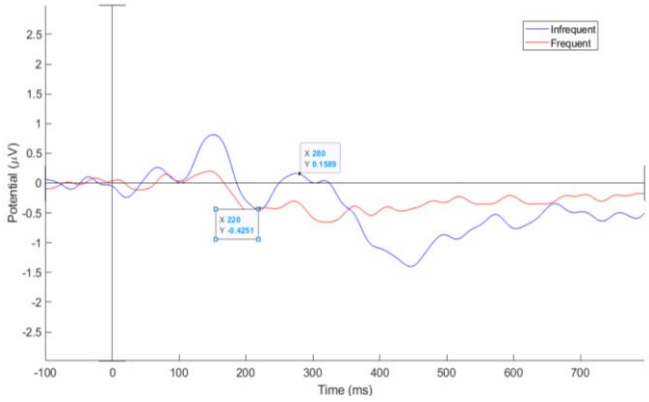
For Participant 4, in the frontal region, the value of latency was 328ms, and the amplitude was 1.472 μV; in the central region, the latency and amplitude are 328ms and 2.463 μV, respectively. For the posterior region, the latency and amplitude values are 328ms and 1.578 μV; for midline, the latency and amplitude values are 328ms and 1.436 μV; for the right region, the latency and amplitude are 328ms and 0.774 μV, and for the left region, the latency and amplitude are 328ms and 0.993 μV respectively. The average for Participant 4 in terms of

latency and amplitude was 328ms and 2.227 µV, respectively. The same is shown in Figure 4.22.

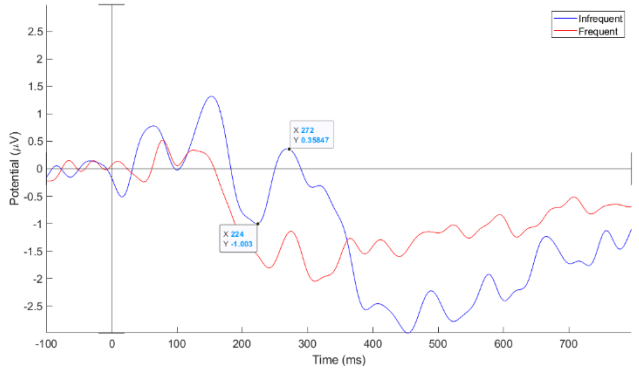
Figure 4.21

Waveforms Showing the Responses at Different Scalp Regions for Participant 3 (NTI)

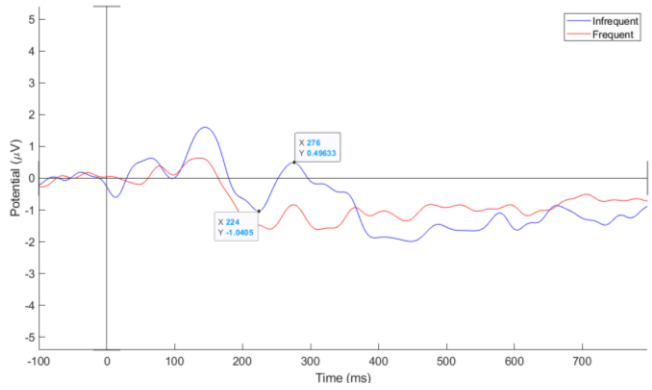
Frontal



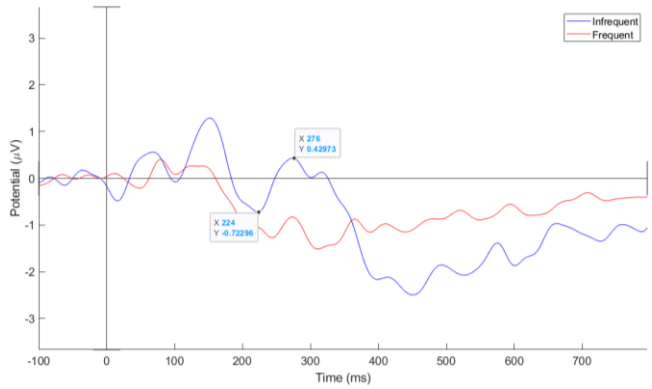
Central



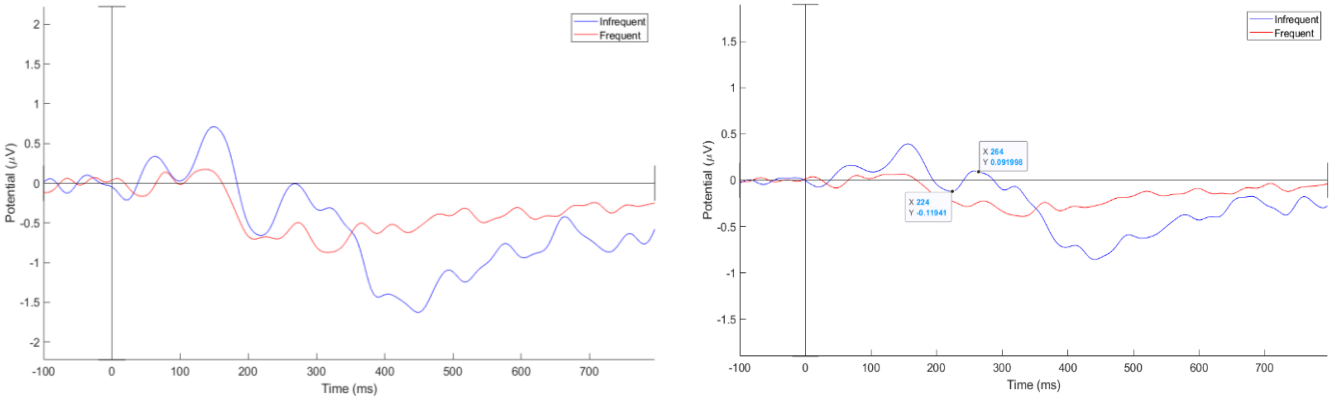
Posterior



Midline



Right **Left**



Average

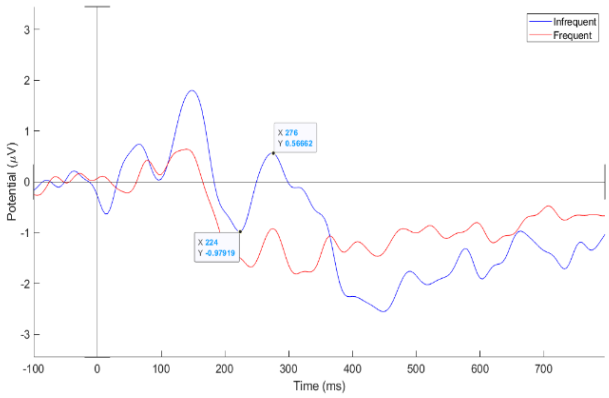
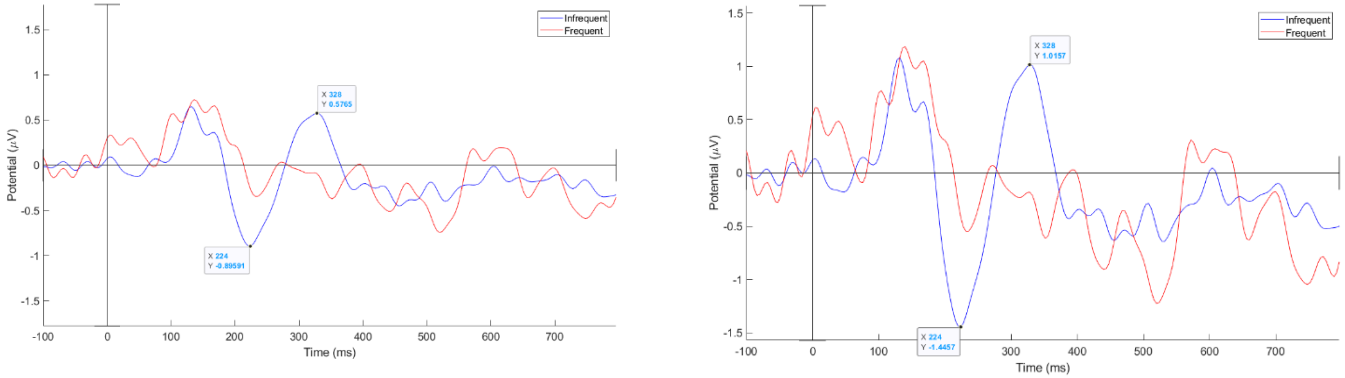


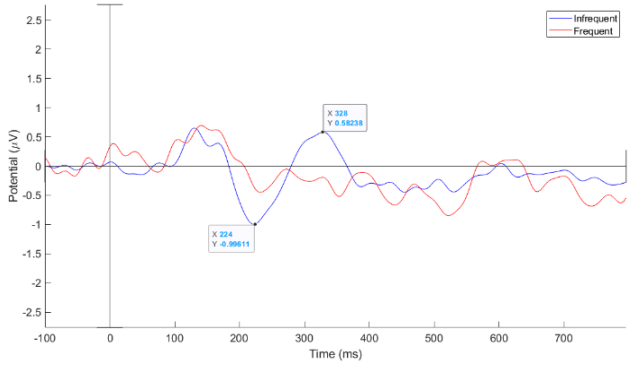
Figure 4.22

Waveforms Showing the Responses at Different Scalp Regions for Participant 4 (NTI)

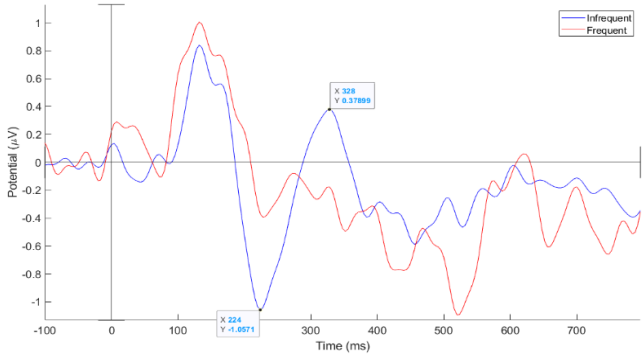
Frontal **Central**



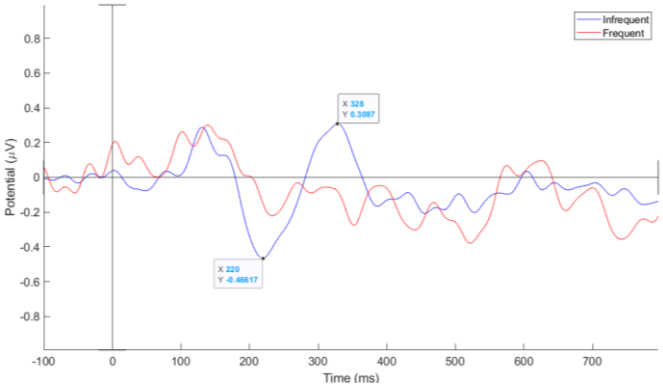
Posterior



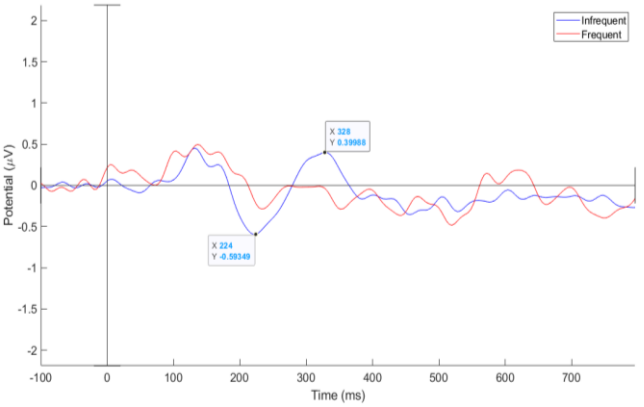
Midline



Right



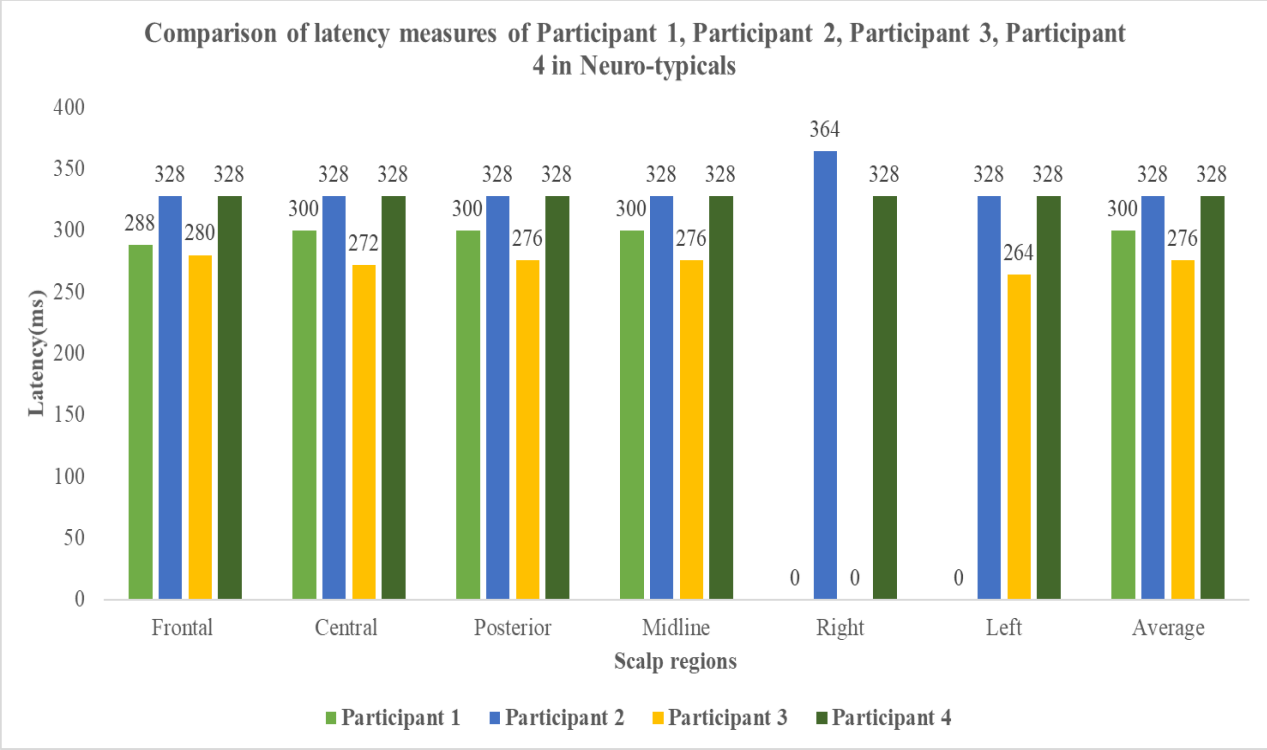
Left



To summarize, the latency and amplitude value of each electrode site for participants 1, 2, 3, 4 of neuro-typical individuals are graphically represented in Figure 4.23. The most active electrode region is found to be the posterior, frontal, central, midline, average, and left regions—the least active region right electrode site.

Figure: 4.23

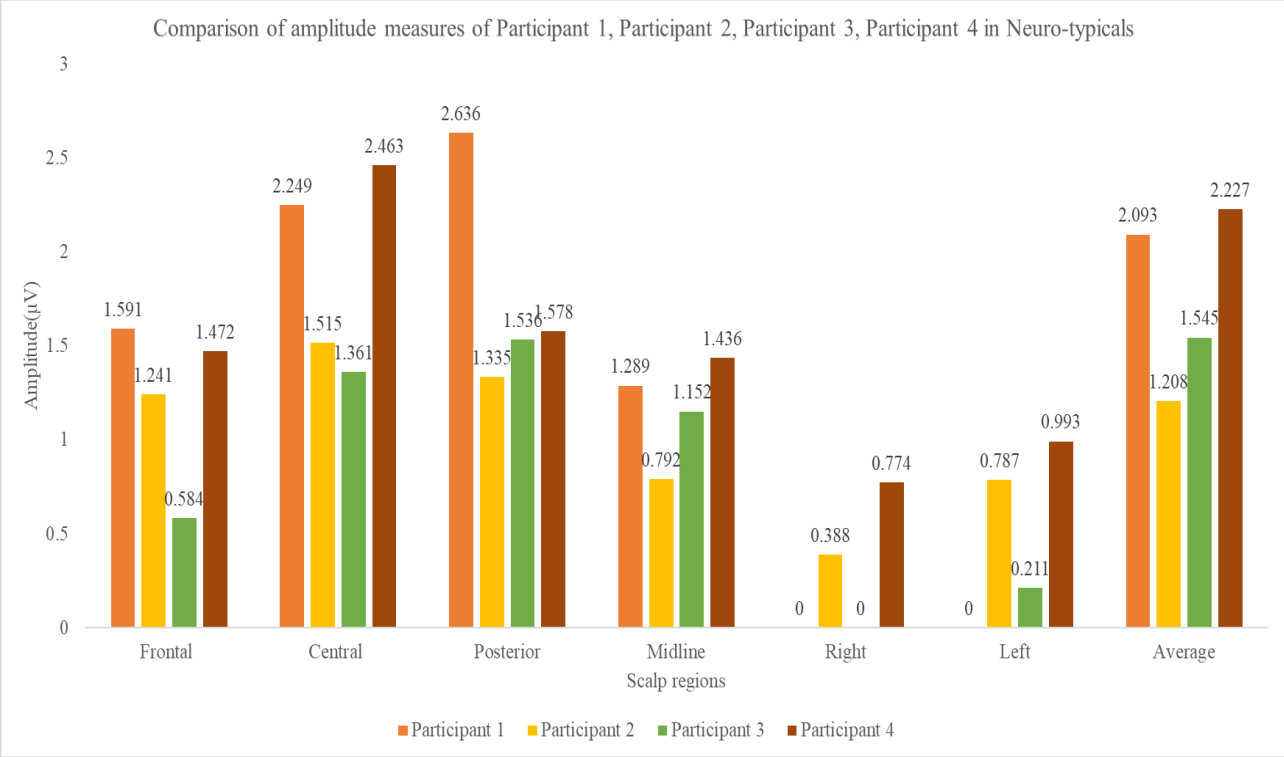
Comparison of Latency Measures in Participants of Neuro-typical Individual



With reference to amplitude, the significant amplitude values were seen in electrode sites like posterior, central, midline, average, and frontal. There was no significant amplitude seen for some Participants in electrode regions like right and left. The same is shown graphically in Figure 4.24 with reference to each electrode site for participants 1, 2, 3, 4 of neuro-typical individuals.

Figure: 4.24

Comparison of Amplitude Measures in Age Match Neuro-typical Individual

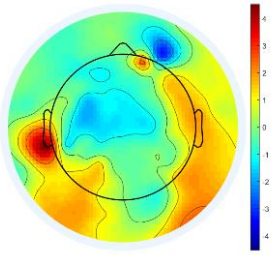


The comparison of brain activation for frequent and infrequent stimuli at the peak latency is represented topographically for participants 1, 2, 3, 4 of the control group (NTI). Where the darker shades for the infrequent one show the brain activity to the infrequent stimuli, from the topographical representation, it was seen that the brain region, which was strongly activated, was the posterior brain region/sites for Participants 1, 2, 3, and 4.

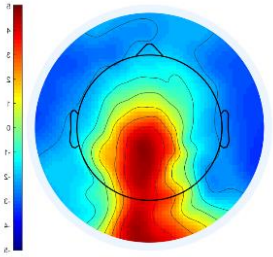
Figure 4.25

Topographic Representation in the Control Group (NTI participants)

Participant 1

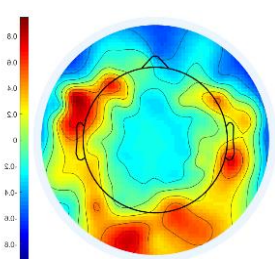


(a). Frequent Stimuli

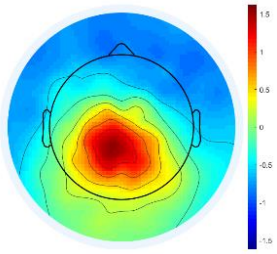


(b) Infrequent Stimuli

Participant 2

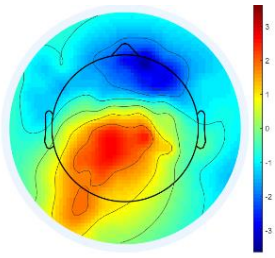


(a). Frequent Stimuli

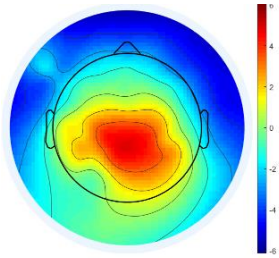


(b) Infrequent Stimuli

Participant 3

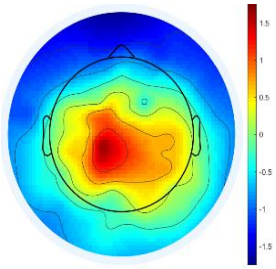


(a). Frequent Stimuli

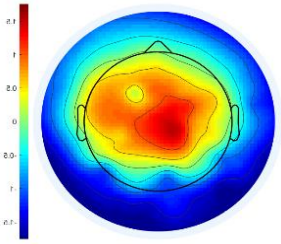


(b) Infrequent Stimuli

Participant 4



(a). Frequent Stimuli



(b) Infrequent Stimuli

CHAPTER V

Discussion

P300 is considered to be one of the endogenous potentials that are recorded with an oddball paradigm stimulus to generate responses to the infrequent stimulus from the cortical areas of the brain. In the present study, which was aimed to investigate the comparison between the aphasics and the neuro-typical individual for their amplitude, latency, and topographical representation, thus profiles the neuro-physiological assessment in the clinical population with adult language disorder, example- persons with aphasia. Further, for the ease in understanding, the discussion would be subcategorized into the following:

- P300 potential in individuals with aphasia (IWA-clinical group) in comparison with neuro-typical (NTI-control group) with respect to latency and amplitude.
- Topography in aphasics and neuro-typical (NTI).

5.1 P300 Potential in Individuals with Aphasia in Comparison with Neuro-typical with Respect to Latency and Amplitude

In the present study, it was found that among the participants in the clinical group (IWA), Participant A had P300 responses with prolonged latencies and reduced amplitude compared to the participants in control group (NTI), Participant 1. The other three Participants (B, C, and D) of clinical group did not show prominent P300 responses compared to control group. The possible

explanation would be the alterations of the P300 observed in the neuro-physiological assessment which is caused due to (1). The disruption of neural circuits generating or augmenting evoked potentials localized primarily in the temporoparietal cortical areas, and which might have resulted from stroke-related changes in the various neurotransmitters. To support the present findings of prolonged P300 responses of Participant A, Korpelainen et al. (2000) compared the P300 response of 38 aphasic patients with 29 healthy control subjects. The aphasic participants had an acute brain infarction, and P300 was recorded using an oddball auditory paradigm among these 38 brain infarct patients who reported mild neurological deficits at 3 and 12 months' post-stroke period. The results indicated a slight prolongation of the latency of the P300 in patients with brain infarction. It was noted that the infarction did not influence the amplitude of the P300 or its distribution on the scalp.

The second contributing reason could be the neurological injury that may also be aggravated by changes in behaviors during P300 recording such as fatigue because aphasic individuals tend to have fatigue in situations where concentrated attention is required (Alvarenga, Lamônica, Costa Filho, Banhara, Oliveira, & Campo, 2005). Such rationale may be provided for three individuals in the present study who showed the absence of P300 in the clinical group as P300 is related to cognitive processes such as attention skills, auditory discrimination, and memory. So, the authors have concluded that in the presence of brain injury, such cognitive skills described may be compromised, which could explain the increase in latency and decrease in the amplitude for Participant A of clinical group or absence of

P300 in individuals with aphasia, the Participant B, C, D. Thus, these findings can be contributed for the good cognitive processes in some individuals with aphasia and neuro-typical to show the presence of P300. Another factor that must have helped for the presence of the potential can be the attentional allocation to the stimuli. The event-related potential P300 is a potential that is related to the attention and the memory processes (Grover, Chetri, Sood, Das & Nehra, 2012) and it requires active attention from the participant (Polich & Pitzer, 1999). The participant paying attention to the stimulus will increase the chances of the potential being present.

The other contributing reasons would be the concerned site of the lesion among the participants who had a diffuse lesion in the brain which is stated as in Participant A: hypodensities in the left peri-rolandic cortex and temporo occipital cortex- subacute infarcts. Participant B: Hyperacute infarct involving frontal operculum and posterior frontal regions. Participant C: Left fronto-parieto-temporal lobe chronic infarct with gliosis, Participant D: Mild interval decrease in the size and mass effect of subacute infarct of the left MCA territory involving the left gangliocapsular region, insular cortex, perito-temporal lobe. When P300 recording was carried out, and the results revealed, three of the four participants (B, C, D) had absence of P300 responses. The possible reason could be that in Participant C and D, who had no P300 responses, had typical diffuse parietal lesion as observed in the neuroimaging findings, where the parietal area and its associated areas were one of the generator sites of P300; whereas, Participant A had acute onset of aphasia, neuroimaging findings reveal hypodensities in the left

peri-rolandic cortex and temporo occipital cortex- subacute infarcts. This shows no involvement of the parietal lobe and its associated areas leading to aphasia, thereby not affecting the P300 generator sites, which could have resulted in obtaining the P300.

To support this findings of lesion affecting P300, Linden (2005) aimed to identify the brain generators for the P300 responses and found that consistent pattern of generators has emerged in response to the oddball paradigm, with respect to the target-related responses. The generators found were the parietal cortex and the cingulate gyrus. The inferior parietal and prefrontal regions are activated with respect to novelty stimulus-related activations. In Participant B, C, D the neuro-imaging findings reveal hyperacute infarct involving frontal operculum and posterior frontal regions, which did not support the findings of Linden (2005) since the lesion was more prominent in the frontal, parietal, temporal and combined regions of all these lobes that is MCA infarct.

Stenklev and Laukli (2004) gave a possible explanation that the participant's age could also be a factor to result in prolonged latency and reduced amplitude. The study further states that the presence of P300 is reported only in 52 percent of subjects over the age of 60. This can be correlated to the present study as the Participant B belonged to the age group of 60-70 years. In addition to the age factor, Participant B had neurological insult in the brain's frontal region.

According to, Milner (2014); Shahin, Alain, and Picton (2006), the neurological lesions in frontal areas after stroke revealed P300 findings with diminished amplitude and latency prolongation. Moreover, it has also been noted

the absence of response in some cases with neurological insult, which explains the absence of P300 in Participant B, C, and D.

The possibility of P300 in individuals with aphasia is characterized by the individual variables like type of aphasia, undergoing rehabilitation, neuronal toxicity, and age. The factor age is discussed in the previous section according to Alvarenga, Lamônica, Costa Filho, Banhara, Oliveira, and Campo, (2005). The latency and amplitude of the P300 component in the aphasic individuals were observed and compared with the control group, suggesting increased latency and decrease in the amplitude of this P300 component. However, the authors stated that the control group, which was age, and gender-matched, showed shorter latency than the group of aphasic individuals. Thus, these facts suggest that neurological injury can justify the increase in P300 latency, which can also be aggravated by behavior changes like fatigue during P300 recording as discussed in the previous sections. Aphasic individuals tend to be fatigue in situations that require concentrated attention. Light drowsiness during the recording also affects the P300 response (Koshino et al., 1993). Such reasoning could be given to three individuals who showed the absence of P300 in the clinical group since P300 is related to cognitive processes reflected in its components and sub-components of attention skills, auditory discrimination, and memory. So, the authors have concluded that in the presence of brain injury, such cognitive skills described may be compromised, which could explain the increase in latency and decrease in the amplitude or absence of P300 in individuals with aphasia. The participants (B, C,

and D) of the present study who had an absence of P300 responses can be attributed to these justifications.

In the present study, Participant A had the presence of P300 with prolonged latency and reduced amplitude. This can be justified by the explanation in the study by Becker and Reinvang (2007) that, severe and moderate aphasic patients have their ability to detect rare target syllables among many standard syllables. It was investigated, and the electrophysiological processes involved were studied. Given the promising task performance (discrimination task) of the aphasics, they observed some critical variations in their electrophysiological processing measurements. Nonetheless, in the aphasic groups, the P3 component was not significantly varied, suggesting no severe impairments in the target recognition, thus relates to the fact that the aphasic patients were able to identify the target syllables behaviorally. The possible explanation provided that the aphasic participants were able to execute the existing tasks simultaneously successfully. The electrophysiological variables were significantly attenuated in the stimulus discrimination in some aphasic subjects. This was not based on linguistic analysis but mainly the acoustic features. This strategy is appropriate in a task with a minimal set of stimuli and no demands for semantic interpretation but is not efficient in a task of naturalistic comprehension as in the present study. Where the syllables used in the present study as stimulus were just for identification as frequent and infrequent, without any association of linguistic expression or comprehension. Thus, the acoustic variable of discrimination ability has played a major rule to elicit P300 response. This study investigated the speech

sound processing during a syllable detection task in aphasia recording event-related potentials. The aphasic subjects were able to perform the task almost without mistakes, and the processes associated with the identification of the target (P3) were not significantly reduced. However, electrophysiological components indicating primary stimulus analysis (N1) and associated stimulus categorization and discrimination (N2) indicated reduced processing, which implied weakness in more complex and naturalistic comprehension tasks. As one of the subjects (Participant A) had the presence of P300 with prolonged latency and reduced amplitude could be due to his good auditory discrimination ability.

With reference to stimulus variable, in the present study, it was found that among the participants in the control group where Participant A had P300 responses, whereas the other three participants did not show prominent P300 responses. According to the study by Lew, Slimp, Price, Massagli, & Robinson (1999), the healthy individuals with no medical history of neurological complaints had robust P300 responses for the speech stimulus when compared to tonal stimulus. Nevertheless, in this study, the speech stimulus included was infrequent as ‘mommy’ and frequent stimuli as 1000Hz tone, which formed as an oddball paradigm. In comparison to the present study, there was a gross difference in the stimulus used in their study, which resulted in better speech evoked P300 responses than tone evoked P300 responses as reasoned out. They conducted P300 testing in an intensive care unit, where the patient's response to a tonal stimulus could be fatigued by numerous beeping machines. In such a situation, the brain perceives tones as part of the background, whereas during the speech-

evoked P300 testing, almost all subjects remarked that the word 'mommy' provided mental arousal when they were on the verge of falling asleep. The present study included the speech stimulus (infrequent: /da/ and frequent: /ga/) and had contradicting results, which revealed that only one of the participants had P300 responses. In contrast, the other 3 participants did not have P300 responses; the possible reason could be that P300 latency increases when the discrimination targets are more complicated than the standard because latency is sensitive to the task processing demand. On the other hand, the P300 amplitude is higher in more manageable tasks, and decreases as tasks become more complicated.

Similarly, in the study by Massa, Rabelo, Matas, Schochat, & Samelli (2011) it was found that the P300 latencies for verbal stimuli were significantly higher than those of non-verbal stimuli. The above finding was also supported by Linden (2005) and Polich (2007) that he generators found were the parietal cortex and the cingulate gyrus. The inferior parietal and prefrontal regions are activated with respect to novelty stimulus-related activations. However, amplitudes by speech stimuli were significantly lower when compared to non-verbal stimuli, which could be because the discrimination of verbal stimuli (in this study, syllables /ba/ and /da/) is a more complicated and challenging task compared to discrimination of non-verbal stimuli (Martin, Tremblay, & Korczak, 2008).

Other stimulus variables like the modality of stimulus can also be considered as a contributing variable. In the present study, the unimodal (auditory mode) stimulus was used, which resulted in absent P300 response in three of the participants and present in only one participant. According to the study by (Li,

Wu, & Touge, 2010; Sangal & Sangal, 1996) the auditory-visual mode was compared with auditory mode and visual mode as separate parameters. They found that behavioral identification of the auditory stimulus was improved when integrated with the auditory and visual stimuli in the region of the brain. The absence of P300 in the present study could also be attributed to unimodal stimulation.

5.2 Topography in Aphasics and Neuro-typical Individual (NTI)

With reference to the topographical differences in P300 potential being present in Participant A of clinical group and Participant 1 of control group was in terms of scattered responses in the brain scalp regions of Participant A (IWA) and more centralized activation in Participant 1 (NTI). These responses were seen only for infrequent stimuli in Participant A (IWA) and the topographical representation was seen for infrequent and frequent stimuli in Participant 1(NTI).

The present study with reference to neuro-typicals is in support with the previous studies (Picton & Hillyard, 1974) (Pfefferbaum, Ford, Wenegrat, Roth, & Kopell, 1984) (Sangal & Sangal, 1996) on neurotypical individuals in the age range of 16-25 years, 26-35 years and 35-65years, where they indicated the prolonged latency and reduced amplitude compared to the younger group. Thus the present study confirmed the previously reported increase in latency (both in auditory & visual mode) and a decrease in amplitude with age (both in auditory & visual).

Visual P300 amplitudes were of an overall larger magnitude than auditory P300 amplitudes. There were no other differences in P300 amplitudes or latencies

by gender, modality, or side of the scalp. There were no significant topographical differences in P300 amplitudes or latencies by gender, age-group, modality, or modality or side of the scalp.

Group-averaged auditory and visual P300 waveforms at the group mean P300 latency at Cz, showing a right centroparietal sink surrounded by sources. This suggests a significant right centroparietal P300 generator. Whereas, in the present study the generators were scattered and there was very poor representation in right and left electrode sites for all the participants of control and clinical group except the Participant A (IWA) and Participant 1 (NTI).

The responses of Participant A (IWA) and Participant 1 (NTI) showing more central and midline electrode site activation can be supported by Katayamaa and Polich (1999). The target stimulus in each modality elicited a P300 component that was most significant over the parietal and mid-line electrode sites.

Moreover, a shift in amplitude over midline electrodes (Fz, Cz, Pz.) increased from the frontal (Fz) site along the parietal mid-sagital plane (Pz) (Johnson, 1993). The target P300 for the auditory task was smaller in amplitude and shorter in latency compared to the visual task. Also, it is mentioned (Soltani & Knight, 2000) that the central regions consistently attributed in generating detection-related brain activation that includes the temporal-parietal junction, medial temporal complex, and the lateral prefrontal cortex. Such similar results were observed in the current study in both the aphasics (only in Participant A) and neuro-typical individuals (Participant 1, 2, 3 and 4).

CHAPTER VI

Summary and Conclusion

The auditory P300 is an evoked potential of positive long latency peak, which helps in the central nervous system's research of the aural cortex. It helps to depict the cortical activity that includes discriminative, integrative and attention abilities, allowing the finest indicator of cortical processing velocity through auditory stimulation. In the P300 studies so far, the consequence of neurological damage and the older population is frequently noted to be abnormal in cognitive impaired patients. Amplitude and latency are measured in the typical and clinical population for the peak and widely researched parameters. Information processing influences the P300 parameters such as latency and amplitude and also influences the cognitive skills such as attention, stimulus assessment, judgement, memory processing, and input auditory stimulus decision making.

Auditory P300 is a positive peak that occurs after stimulus starts at about 300ms. The produced potential is affected by the activation of various neocortical and limbic areas in the brain and has two functionally distinct P300 sub-components: the P3a, which is maximally represented over the front-central areas, and the P3b, which is maximally represented by the posterior scalp places (Squires, Hillyard & Squires, 1975). However, there was a need to assess the activation of the same neocortical and limbic areas in the brain of individuals with aphasia before they initiate speech-language therapy.

The P300 reflects simultaneous activity in several areas of the brain, including temporoparietal, neocortical and higher limbic systems (Halgren, Baudena, & Clarke et al., 1995). P300 amplitude is also the level of attention dedicated to a particular task and linked with superior mental efficiency (Gonsalvez & Polich, 2002). Therefore, P300 amplitude can be considered as a measure of central nervous system activity reflecting incoming data processing when integrated into the depictions of stimulus memory and the context in which the stimulus exists. Consequently, variation in the amplitude of P300 is assumed to represent the degree or quality of the information processing.

Studies suggest that in global aphasia, passive P300 can be used to monitor their recovery. In other words, it is possible to use P300 recording for prognostic purposes in aphasics (Nolfe, Cobianchi, Mossuto-Agatiello & Giaquinto 2006). Therefore, there is a need to imply the neurophysiological assessment (P300) for comparing the neuro-typical individuals with the individuals with aphasia to obtain the neurophysiological data to distinguish between the normal population and the individual with aphasia. Hence, the present study was aimed to conduct a neurophysiological assessment (Event Related Potential-P300) in individuals with aphasia in comparison with the neuro-typical individuals. Hence, the objectives of the present study were (1) To conduct a neurophysiological assessment (Event Related Potential-P300) in individuals with aphasia in comparison with the age matched neuro-typical individuals and (2) To obtain the topographical representation of Event Related Potential (P300)

response of individuals with aphasia in comparison with the neuro-typical individuals.

The clinical group comprised of four individuals with aphasia in the age range of 20-60 years and the control group comprising four age matched neuro-typical individuals selected from Mysore after following general and specific inclusion criteria. The P300 recording was carried out using Net Station 5 Geodesic EEG Software Version 5.4.2 instrument placed in a sound-attenuated and electrically shielded room, where the noise levels are within permissible limits (ANSI S3.1-1999). The speech stimuli used for testing was syllables /da/ and /ga/, where the frequent one was /da/ and the infrequent one (target) was /ga/. The inter stimulus interval was 2000 ms. The ERPs that was used to record was P300, as per the guidelines provided by Duncan et al. (2009). After the ERP recording, the data was further analyzed in the MATLAB software to extract the P300 from the recorded event related potential. Graphical representation of the waveforms and topographical representation of scalp regions are documented.

The results are explained under three headings. Firstly, the representation of waveform and topography in the clinical group (Participant A, B, C, D), the Participant A only showed P300 responses. There was increase amplitude in frontal electrode site followed by posterior electrode site, average, midline, central and left and right electrode regions. With reference to latency, the midline electrode site had highest latency compared to other electrode regions. P300 response was absent for Participant B, C, and D. The topographical representation was scattered for individuals with aphasia.

Secondly, the representation of waveform and topography of aphasic in comparison with age matched neuro-typical. Here the Participant A of clinical group and Participant 1 of control group shown the presence of P300 and other participants of clinical and control group did not show the P300 responses. The Participant A had prolonged latency and reduced amplitude compared to Participant 1.

Thirdly, the representation of waveform and topography in the control group. The topographical representation showed the P300 responses being strongly activated in the posterior sites of brain regions for both groups but the highest activation was reduced in individuals with aphasia when compared to the neuro-typical, indicating the reduced activation of brain region in individuals with aphasia.

The alterations of P300 observed in the neuro-physiological assessment could be explained with reference to some contributing factors. The first factor could be the disruption of neural circuits generating evoked potentials localized primarily in the temporoparietal cortical areas, which might have resulted from stroke-related changes in the various neurotransmitters (Korpelainen et al., 2000).

The second contributing reason could be the neurological injury that may also be aggravated by changes in behaviors during P300 recording such as fatigue because aphasic individuals tend to have fatigue in situations where concentrated attention is required (Alvarenga, Lamônica, Costa Filho, Banhara, Oliveira, & Campo, 2005). So, the authors concluded that in the presence of brain injury,

cognitive skills like attention, auditory discrimination, and memory may be compromised.

The third one could be the site of the lesion among the participants who had a diffuse lesion did not show P300 responses. According to Linden (2005), the generators found were the parietal cortex and the cingulate gyrus. The inferior parietal and prefrontal regions are activated with respect to novelty stimulus-related activations. These regions were affected in the clinical population involved in the present study.

The participant's age could be the fourth factor to result in prolonged latency and reduced amplitude, which is supported by Stenklev and Laukli (2004).

The fifth contributing factor could be, cognitive processes –attention skills, auditory discrimination, and memory. So, the authors have concluded that in the presence of brain injury, such cognitive skills described may be compromised, which could explain the increase in latency and decrease in the amplitude or absence of P300 in individuals with aphasia.

The sixth contributing factor was related to types of tasks during the testing period. As the task performance (discrimination task) of the aphasics were successful, some critical variations in their electrophysiological processing measurement were observed and the electrophysiological variables were significantly attenuated in the stimulus discrimination in some aphasic subjects. This was not based on linguistic analysis but mainly the acoustic features. This

strategy is appropriate in a task with a minimal set of stimuli and no demands for semantic interpretation but is not efficient in a task of naturalistic comprehension as in the present study. Thus, the acoustic variable of discrimination ability has played a major role to elicit P300 response. In contrast, the other 3 participants did not have P300 responses; the possible reason could be that P300 latency increases when the discrimination targets are more complicated than the standard because latency is sensitive to the task processing demand. On the other hand, the P300 amplitude is higher in more manageable tasks, and decreases as tasks become more complicated.

Other stimulus variables like the modality of stimulus can also be considered as a contributing variable. In the present study, the unimodal (auditory mode) stimulus was used, which resulted in absent P300 response in three of the participants and present in only one participant according to Li, Wu, and Touge, (2010) and Sangal and Sangal, (1996).

The topographical differences in P300 potential being present in Participant A of clinical group and Participant 1 of control group was in terms of scattered responses in the brain scalp regions of Participant A (IWA) and more centralized activation in Participant 1 (NTI). These responses were seen only for infrequent stimuli in Participant A (IWA) and the topographical representation was seen for infrequent and frequent stimuli in Participant 1(NTI). The present study with reference to neuro-typicals is in support with the previous studies (Picton & Hillyard, 1974) (Pfefferbaum, Ford, Wenegrat, Roth, & Kopell, 1984) (Sangal & Sangal, 1996). The responses of Participant A (IWA) and Participant 1

(NTI) showing more central and midline electrode site activation was supported by Katayamaa and Polich (1999). Soltani and Knight (2000), mentioned in their study that the central regions consistently attribute in generating detection-related brain activation that include the temporal-parietal junction, medial temporal complex, and the lateral prefrontal cortex. Such similar results were observed in the current study in both the aphasics (only in Participant A) and neuro-typical individuals (Participant 1, 2, 3 and 4).

6.1 Implications

This study helped us to compare and evaluate the effect of aphasia symptoms, their course of speech-language therapy (yet to continue regular speech-language rehabilitation) and the effect of their cognitive skill on P300 assessment. Thus, the P300 recording could be used as a non-invasive neuro-physiological assessment used to monitor or check the prognosis of individuals with aphasia during their course of speech-language therapy and use the same evaluation during the speech-language training which facilitates improvement in attention skill of individuals with aphasia. Therefore, ERP is a useful method, which can be utilized for these non-verbal individuals who cannot provide any motoric responses due to hemiplegia during the assessment of the routine cognitive and attentional allocation skills. It also helps in differentiating individual with aphasia from that of neuro-typicals.

6.2 Future directions

The smaller sample size in both the clinical and the control group is one of the limitations of this study. The unequal distribution of the subjects among the males as well as the other factors like food intake, sleep, alcoholism, behavioural scores and exercise that influences the P300 components were not considered in the study.

The homogeneity among the aphasics of different types in the clinical group was also not considered. It is suggested that further investigations should be carried out to elucidate the true relationship between age, education, gender, behavioural scores and the P300 in larger sample size with equal distribution with respect to the gender in comparison to the age matched neuro-typical individuals.

Finally, the review identified the lack of studies designed to specifically investigate the scalp topography in individual with aphasia. Similar studies can be carried out in future with homogeneity in the group of aphasics of different types and sites of lesion and larger sample size.

This study can also lead to the future direction where the effects of speech and language therapy can be investigated in aphasics by comparing subjects before and after the therapy.

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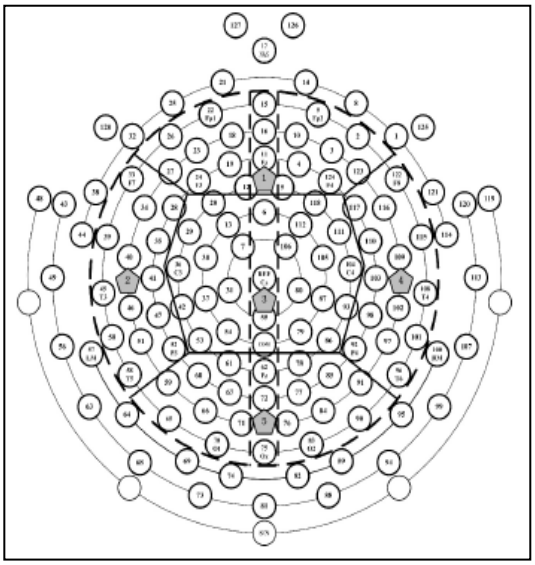
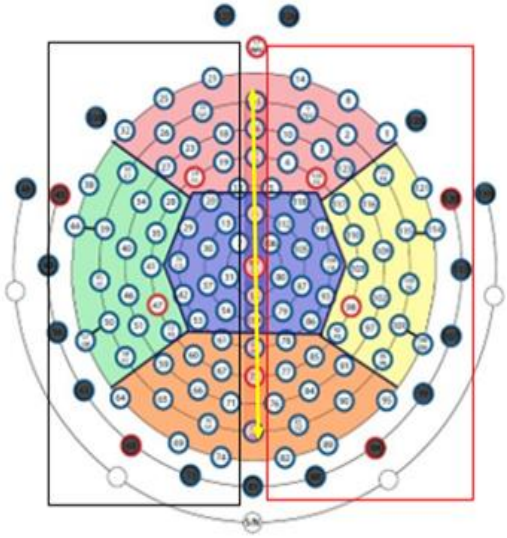
Appendix A

Electrode selection to form specific sites

	
Electrode distribution of 128 channel Geodesic sensor net according to Bian et al., (2014)	*Color coded for the convinience of the ERP analysis*

	Frontal (F)
	Central (C)
	Midline (M)
	Posterior (P)
	Left Hemisphere
	Right Hemisphere
	Left Temporal
	Right Temporal

The interested electrodes were selected to detect EEG power in different regions and inter-/intra regions, the brain was divided into five regions: frontal (F), left temporal (LT), central (C), right temporal (RT), and posterior (P).

Frontal: E32, E25, E21, E14, E18, E1, E26, E22, E15, E9, E2, E27, E23, E18, E16, E10, E3, E123, E24, E19, E11, E4, E124, E12 & E5;

Central: E6, E7, E13, E20, E29, E30, E31, E36, E37, E42, E53, E54, E55, E79, E80, E86, E87, E93, E104, E105, E106, E111, E112 & E118;

Posterior: E61, E62, E78, E60, E67, E72, E77, E85, E59, E66, E71, E76, E84, E91, E65, E70, E75, E83, E90, E64, E69, E74, E82, E89, and E95;

Midline: E17, E15, E11, E6, E55, E62, E72 and E75;

Right: E14, E8, E1, E121, E114, E100, E95, E89, E82, E83, E90, E96, E101, E108, E115, E122, E2, E9, E10, E3, E123, E116, E109, E102, E97, E91, E84, E76, E77, E85, E92, E98, E103, E110, E117, E124, E4, E5, E118, E111, E104, E93, E86, E78, E79, E87, E105, E112, E106, and E80;

Left: E21, E25, E32, E38, E44, E57, E64, E69, E74, E70, E65, E58, E50, E45, E39, E33, E26, E22, E18, E23, E27, E34, E40, E46, E51, E59, E66, E71, E60, E52, E47, E41, E35, E28, E24, E19, E12, E20, E29, E36, E42, E53, E61, E54, E37, E30, E13, E7 and E31;

Average: Grand average from all the electrode sites.