2015-01-01

Comparing Electrophysiologic Differences In Linguistic And Tonal Auditory Oddball Tasks In A Normal Population

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by

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THESIS

Presented to the Faculty of the Graduate School of
The University of Texas at El Paso
in Partial Fulfillment
of the Requirements
for the Degree of

MASTER OF SCIENCE

Speech-Language Pathology Program
THE UNIVERSITY OF TEXAS AT EL PASO
August 2015

Abstract

Limited studies using Event Related Potentials (ERP) comparing attentional differences between individuals with and without brain damage have been conducted. In addition, the literature review showed limited studies examining electrophysiologic performances that compare linguistic and tonal auditory oddball tasks. The purpose of this study is to examine the electrophysicologic differences between a linguistic and tonal oddball task in a group of participants with no brain damage. Event related potentials (ERP) were used to examine the neural processes of attention by measuring peak latency and amplitude of the P300 ERP component. Traditional auditory oddball tasks involve participants discriminating between two tones, a target tone and a non-target tone, to examine the processes involved in attention. Adding a linguistic component increases the complexity of the task thus increasing the demands the individuals has to use. This study compared a linguistic discrimination task between two English CV syllables combinations (/tʌ/ and /kʌ/) and a tonal discrimination task between two tones with frequencies of 250 Hz and 325 Hz. Participants for this study were 4 male and 6 female college-aged individuals with no history of brain injury. Participants were evaluated using ERP's that were time-locked with the onset of a linguistic and tonal oddball task. P300 components were analyzed. Since latency of attention varies with the level of difficulty of the discriminating task and linguistic processing is a more complex task than pure tone processing, we hypothesized that there will be a difference in the amplitude and latency of attention between a linguistic and tonal oddball task in a normal population. Results showed no statistically significant differences. This suggests that while the linguistic component increases the complexity and demands of the task, complexity did not affect the attentional process of the participants in this study.

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Chapter 1: Introduction

Deficits in attention may impact and reduce an individual's capacity for new learning. This may have negative consequences on academic performance (Moore, McLaughlin, Pavese, Heidrich, & Posner, 2000). For the purposes of this study attention is defined as the ability for prolonged focus to target stimuli. Traditionally attention has been examined using auditory oddball tasks that require the individual to detect a target sound. However, with the advances in technology, the use of Event Related Potentials (ERP) to study cognitive processes, such as attention, are becoming more and more common.

Recently studies have begun to examine attention in populations with brain damage using a linguistic auditory oddball task. For example, Sanchez (2013) compared a group of participants with concussion to a group of participants with no brain damage attending to a linguistic auditory oddball task that consisted of CV syllables that varied by one distinctive feature. The results of this study, found a statistically significant difference in attentional performance between the two groups. Sanchez (2013) suggests that the addition of a linguistic component to a traditional oddball task increases the complexity of the task and therefore increases the demands and resources the individual has to use to attend to the target stimuli.

Roosemalen (2015) systematically replicated Sanchez (2013) and found no statistically significant differences between the groups. These results contradict the results found in Sanchez (2013) and suggest that the addition of the linguistic component did not impact the attentional performances of participants exposed to a linguistic auditory oddball task.

In an effort to investigate whether the addition of a linguistic component impacts attentional performance we compared attentional performance of individuals using a linguistic and traditional tonal oddball task. The focus of this study was to minimize extraneous variables

and isolate differences in attention between a linguistic and tonal auditory oddball task. By doing so, we can establish a baseline and detect atypical patterns of attention in individuals with brain damage.

1.1ERP

Event related potentials (ERP) measure cortical activity at the level of the cortex in response to external and internal stimuli. ERP's are time locked to specific events within a trial making them the logical choice for investigating cognitive processes such as attention (Patel & Azzam, 2005).

There are several advantages to using ERP. One of the advantages is that you can record electrical activity even when no motor response is required. In addition, ERP is a non-invasive way to measure brain activity during cognitive processing since it measures this activity using a skullcap with electrodes attached. These electrodes will register changes in amplitude and latency whenever a neuron is activated. Furthermore, ERP provides high temporal resolution in the millisecond range time (Bressler & Ding, 2006).

ERPs are measured in amplitude and latency. Amplitude is measured in micro voltages and is defined as the highest peak that occurs within the operational definition of an ERP component. Latency is measured in milliseconds and is defined as the speed or amount of time necessary in the detection and processing of target stimuli (Polich 2010). As found in the literature, amplitude varies with the improbability of the targets and latency varies with the degree of difficulty in discriminating targets (Picton 1992; Horovitz, Skudlarski, & Gore, 2002).

The raw data from the electroencephalogram (EEG) is converted to ERP waveforms that are characterized by a series of positive and negative components. Components span brief

periods of time before or after a measurable event and are characterized by peaks and troughs (Bressler, S. L., & Ding, M. 2006). Components are identified by their time of occurrence and their polarity (negative or positive). For example, the P300 ERP component is a positive going peak that occurs approximately 300 ms after the onset of a stimulus. The P300 ERP component is associated with attention and is the component of interest for this study (Bernstein, 2002; Bressler, & Ding, 2006; García-Larrea, Lukaszewicz, & Mauguiére, 1992; Picton,1992; Horovitz, Skudlarski, & Gore, 2002; Patel & Azzam, 2005; Polich, 1997; Segalowitz, Bernstein, & Lawson, 2001).

1.2 P300

The P300 ERP component has been examined in studies that assess human cognition and information processing, specifically with attentional and memory mechanisms (Polich 1997). P300 ERP component has been specifically linked to the allocation of attention to a stimulus and to selective attention (Bernstein 2001; Sola, Tarancón, Peña-Casanova, Espadaler, Langohr, Poudevida, & Torre, 2008). Research shows that larger amplitudes of the P300 may be interpreted as being indicative of greater amounts of activity occurring at the level of the cortex. A study by Horovitz in 2002 investigating correlations of P300 amplitude during auditory oddball tasks required seven subjects ranging in age from 21-37 years old to discriminate between tones by pressing a button each time they heard a target tone. Results showed that the amplitude of the P300 increased as the probability of oddball target discrimination decreased.

In investigations of the P300 ERP component cortical activity is typically seen across the following midline electrode sites: FCz, Cz, CPz, and Pz because the research literatures shows that these electrode sites display higher levels of activation during attentional tasks (Bernstein, 2002; Bressler & Ding, 2006; García-Larrea, Lukaszewicz, & Mauguiére, 1992; Picton, 1992;

Horovitz, Skudlarski, & Gore, 2002; Patel & Azzam, 2005; Polich, 1997; Segalowitz, Bernstein, & Lawson, 2001). For example, a study by Stekelenburg and Gelder in (2004) used ERP to investigate neural correlations of human perception. In this study amplitude and latency of ERP components where measured while participants were presented with stimuli depicting different human emotions. Researchers noted that the midline electrode sites: FCz, Cz, CPz, and Pz were the areas that reflected maximal positive amplitude.

Two subcomponents of the P300 have been linked to attention. These subcomponents are P300a and P300b. An earlier frontal P300a component can be distinguished from a later parietal P300b component with the P300a occurring at approximately 280-350 ms after the detection of infrequent stimuli and the P300b occurring at approximately 300-600 ms after the detection of infrequent stimuli (Bressler, 2006; Luck, 2005.) P300a has been described as novelty detection with a relatively short peak latency that habituates rapidly. The P300a is thought to derive from stimulus driven frontal attention mechanisms during task processing. In contrast, the P300b component has been described as more task relevant detection deriving from temporalparietal activity associated with attention and memory processing (Polich, 1997).

Research shows that the P300 is smaller and occurs later in individuals with decreased cognitive abilities, such as individuals with traumatic brain injury. A study by Segalowitz, Bernstein, & Lawson, in 2001 examined the performance of 10 college-aged individuals with mild head injury (MHI) and 12 controls during psychometric and electrophysiologic attention tasks. Results showed no statistically significant differences in performance on the psychometric tasks between the two groups. However, during the electrophysiologic attention tasks, the MHI group demonstrated “significantly reduced P300 amplitudes” (Segalowitz et. al 2001). Similarly, in a replication study of Segalowitz et. al (2001), Bernstien (2002) found reduced P300

amplitudes in students with mild head injury. The MHI group demonstrated smaller P300 amplitudes during the tonal discrimination task suggesting decreased P300 amplitudes following damage to the brain (Bernstein, 2002)

1.3 Oddball Paradigm

The oddball paradigm is used to examine "neuronal response to patterns that are required for an adequate behavioral reaction to subjectively relevant changes," (Linden, Prvulovic, Formisano, Völlinger, Zanella, Goebel, & Dierks, 1999). Oddball paradigms require the detection of the occasional target stimuli within a randomized train of frequent non-target stimuli (García-Larrea, Lukaszewicz, & Mauguiére, 1992; Luck, 2005; Linden, Prvulovic, Formisano, Völlinger, Zanella, Goebel, & Dierks, 1999). The oddball paradigm, in conjunction with ERP, has been used extensively by researchers as a means of examining and comparing attentional processes between brain injured populations and non brain injured populations (Bernstein, 2002; Cabeza & Nyberg 2000; García., Lukaszewicz, & Mauguiére, 1992; Maddux, Kerfoot, Chatterjee, & Holland2007; Patel & Azzam, 2005; Sanchez, 2013; Segalowitz, Bernstein, & Lawson, 2001).

A study by Garcia-Larrea, Lukaszewicz, & Mauguiére, (1992) that used oddball tasks and ERP to evaluate attentional effects suggested that responses to oddball paradigms should be routinely studied to improve the diagnostic capabilities of cognitive ERPs, specifically when deciding whether abnormal target P300's are related to "deficits in the mobilization of attentional resources.

1.4 Attention

Attention is a fundamental part of everyday human interaction and a vital component in the organization and control of behavior (Maddux et al., 2007). Attention has been associated

with processes of visual perception, learning, auditory streaming, speech perception, mental imagery and fantasy among other processes (Grossberg, 2010). Attention is central to our ability to communicate with those around us and to process sensory information in our environment. In terms of communication, attention is a cognitive procedure that allows individuals to process, understand, and respond to important language, social cues, and social interactions (Manasco, 2013). Deficits in attention may result in individuals missing relevant information and may lead to difficulties learning, as well as communicating wants, needs, and ideas.

Individuals are presented with an onslaught of stimulus at all times and different types of attention serve different purposes in the processing of incoming sensory input. Selective attention, for example, is the ability to concentrate on some stimuli while ignoring others (Berger 2003). Alternating attention is the ability to alternate one's attention back and forth from one stimulus to another, allowing individuals to process information from multiple stimuli. Divided attention is the ability to attend to one stimulus while simultaneously attending to another stimulus. Divided attention is useful in multitasking. Selective attention is a crucial element for learning and reading, as it allows individuals to listen and pick out important information while ignoring distractions (Manasco, 2013). Deficits in any component of attention may result in individuals missing relevant information from their environment and may lead to difficulties high order language, communication, and learning.

Grossberg (2010) suggests that attention helps to stabilize cortical development and learning. One important feature of learning is the ability to read. Reading is a complex cognitive activity that involves word recognition and comprehension. Attention problems have often been associated with reading disabilities because reading requires considerable attentional resources to think, evaluate, judge, imagine; reason and problem solve (Kahmi & Catts, 2012). Studies show

that even relatively small decrements in an individual's attention ability may significantly reduce the capacity for new learning and may affect academic performance (Moore, McLaughlin, Pavese, Heidrich, & Posner, 2000).

In efforts to investigate and better understand the mechanisms of cognitive processing researchers have begun to rely more on more on electrophysiological responses as measures of attention. Further understanding of the substructure of attention may have applications in clinical settings as a prognostic and diagnostic tool.

Chapter 2: Methods

2.1 Design

The current study uses Event Related Potentials (ERP) to examine electrophysiologic differences in a group of participants with no brain damage exposed to a linguistic and tonal auditory oddball task. Specifically, this study seeks to investigate whether a statistically significant difference in the peak latency and amplitude of the P300 ERP component exists between the linguistic and tonal auditory oddball task in a group of college-aged participants with no history of brain damage. Therefore, this is a within subjects study. The independent variables are the linguistic and tonal auditory oddball tasks. The dependent variables are the peak latency and amplitude of the P300a and P300b ERP components.

2.2 Research Question

The purpose of the current study is to examine electrophysiologic differences between a linguistic and tonal auditory oddball task in a group of participants with no history of brain damage. The participants were asked to sit and listen to two different versions of an auditory oddball tasks, linguistic and tonal. The linguistic oddball task consists of two CV syllable combinations /tʌ/ and /kʌ/ while the tonal oddball task consist of two tones occurring at 250 Hz and 375 Hz. Participants include a group of college-aged individuals with no history of brain damage recruited from the University of Texas at El Paso. Electrical activity was recorded from 64 electrodes attached to a skullcap while the participants listened to the two different tasks. The following research questions were addressed:

1. Are there statistically significant differences in electrophysiologic measures between a linguistic and tonal auditory oddball task in a group of college-aged participants with no history of brain damage?
2. Are there cortical activation differences between a linguistic and tonal auditory oddball task in a group of college-aged participants with no history of brain damage?

The hypothesis for this study is:

There will be a statistically significant difference in peak latency and amplitude of the P300a and b ERP components between a tonal and linguistic oddball discrimination tasks in a group of college-aged individuals with no history of brain damage.

2.3 Participants

Ten healthy college-aged individuals with no history of brain damage were included in this study. Participants were recruited from the University of Texas at El Paso via face-to-face meetings. Participants consisted of six females and four males ranging in age from 20-28 years with a mean age of 24.6 years (Refer to Table 2.1 for participant characteristics). All participants reported no history of brain damage on the self-report medical questionnaire.

Participant inclusion criteria included:

- No documented history of brain damage as reported on the self report medical questionnaire
- No documented history of learning disabilities or attentional deficits as reported n the self report medical questionnaire
- Between the ages of 18-30 years
- Normal or corrected to normal hearing as determined by audiometric screening

Any history of brain damage, learning disabilities, attentional deficits, or uncorrected hearing excluded participants from this study.

Table 2.1: Participant Characteristics.

Participant	**Age**	**Gender**
1	22	F
2	23	F
3	24	F
4	28	M
5	22	M
6	27	F
7	25	M
9	28	M
10	27	F
11	20	F
Mean Age	24.6	

Participants were provided with an explanation regarding the purpose and procedures of the study. In addition, participants were informed of their right not to participate or to withdraw from the study at any time during the study. All participants were given the opportunity to ask questions and once all questions were answered to the participant's satisfaction the participant was asked to sign a written informed consent under the provision of the University of Texas at El Paso (UTEP) Institutional Review Board.

2.4 Stimuli

The linguistic oddball task consists of two English CV syllables combinations (/tʌ/ and /kʌ/) spoken in a male voice and presented one at a time at 80 dB binaurally at a frequency of 1000 Hz via speakers. All stimuli had a duration of 50 milliseconds and a rise and fall time of 10 milliseconds along with an interstimulus interval (ISI) of 1000 milliseconds (Sanchez, 2013).

The /tʌ/ and /kʌ/ speech sounds were chosen due to their similar phonetic features. Both sounds are voiceless, stop-plosive consonants. The sounds differ in placement of articulation with /tʌ/ having an alveolar placement and /kʌ/ having a velar placement. Two blocks of 200 stimuli were presented to the participant. The first part of the task included 160 non-target tones /tʌ/ and 40 target tone /kʌ/ presented in random sequence. This paradigm of 80-20 percent was used to control for the frequency of stimuli presented and to ensure that habituation will only occur for non-target stimuli. Additionally, a second block was presented and inverted in order to control for any electrophysiological differences associated to detection of different phonetic components of the CV sounds (Sanchez, 2013). This task was the same task used in Sanchez (2013).

The pure tone oddball task consisted of two tones with frequencies of 250 Hz and 325 Hz. These frequencies were chosen based on previous studies that used auditory oddball tasks. The tones were presented binaurally one at a time at 80dB via speakers. Two blocks of 200 tones were presented with 160 of them being non-target tones and 40 being target tones. Tones were presented in random sequence to control for the frequency of stimuli presented with the second block inverted similar to the linguistic task.

2.5 Electrophysiologic Procedures

Participants completed the following tasks:

1. Self- report medical questionnaire
2. Hearing screening completed at 500, 1000, 2000, and 4000 HZ at 25 dB HL.
3. Experimental tasks (linguistic and tonal auditory oddball tasks)

The principal investigator completed the following tasks:

1. Measured participant’s head including circumference, from inion to nasion, and from tragus to tragus.

2. Fitted participant with the “best fitting” electrode cap based on the head measurements.
3. Filled electrodes with Signa conduction gel in order to decrease impedance.
4. Attached sixty-four electrodes to the electrode cap. The electrodes were systematically and symmetrically distributed across the frontal, parietal, temporal, and occipital areas of the scalp in the traditional 10-20 International System (Handy, 2005).
5. Placed four additional electrodes on the lower outer canthi and the orbital ridge of the right eye and the right and left temple in order to track vertical and horizontal eye movements. All electrodes were referenced to the mastoids.

Once all electrodes were secured and filled with conduction gel, participants were led to a 6 X 6 soundproof room and seated comfortably in front of a computer screen. In order to minimize distractions, the participant was asked to visually fixate on a white square in the middle of a black screen that appeared on the computer monitor at the beginning of each experimental task. The participant was then instructed to listen attentively to the auditory stimuli that were presented via speakers at a distance of 34 cm from the participant. Additionally, the participant was instructed to place his/her hands on lap and to avoid any extraneous movements. No motor response was required from the participant. The electrophysiological procedure was the same for both the linguistic and tonal oddball task for all participants. Participant completed each experimental task on two separate days, ranging from 2-7 days apart to avoid fatigue. Superlab Presentation Software (Superlab Pro, Cedrus Corp) was used to develop and present the linguistic and tonal auditory oddball tasks to ensure uniformity in auditory presentation.

2.6 Data Collection

Electrical activity was recorded via 64 electrodes placed on the scalp according to the International 10-20 System. (See figure 2.2) All electrodes were referenced to the mastoids. Two reference electrodes were placed on the left and right mastoids and vertical and horizontal eye movement were tracked via placement of four additional electrodes on the lower outer canthi, the orbital ridge of the right eye, and the right and left temple (Handy, 2005; Jasper, 1958; Rugg& Coles 1997). The custom software program ActiveTwo from Bio Semi was used to record electrical signals from the 64 electrodes placed on the scalp. The electrodes transmitted electrical signals at a sampling rate of 2048 Hz. The bandpass was set at 0.1 Hz for the low cut off with a 12 dB slope and a high cut off at 30 Hz. A notch filter was used to filter any noise coming from electrical power line. The notch filter was set at 60 Hz.

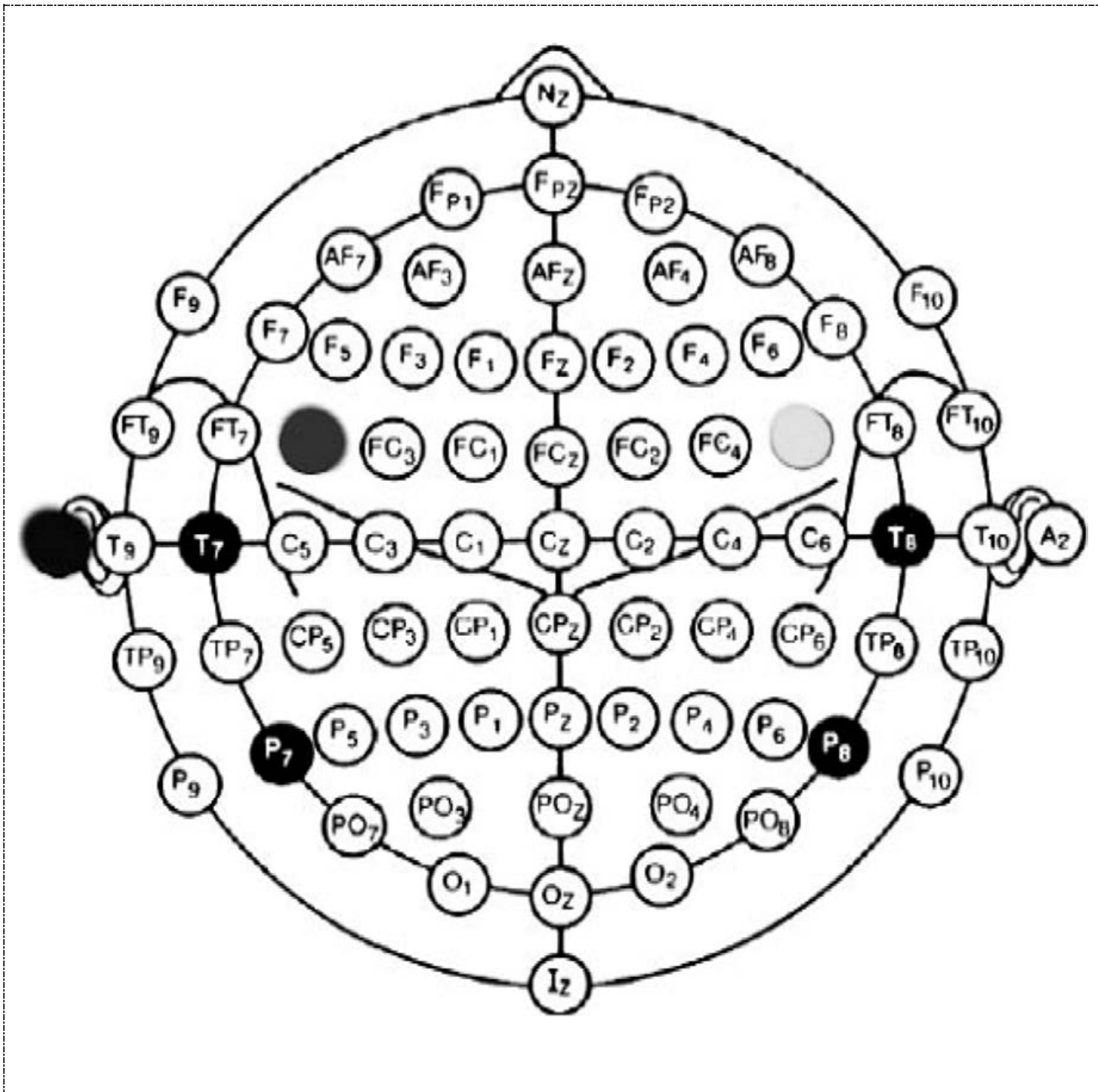


Illustration 2.1: Illustration of electrode scalp placement in accordance with the International 10-20 system.

EEG data was filtered and analyzed offline at a sampling rate of 512 Hz using the Brain Vision Analyzer from Cortech Solutions (2008). Artifacts from the ERP wave such as noise, eye blinks, movements and electrical activity not associated with the signal of interest were eliminated using the filtering feature from Brain Vision Analyzer (2008).

Once data was filtered, the ERP waveform was segmented into temporal blocks called epochs. Temporal blocks, or epochs, are time-locked windows that capture the events within a trial. The event markers, also known as triggers, were placed at certain points within the trial to create time locked windows These time locked windows were then used for individual trial analysis and averaging.

2.7 Data Analysis

Analysis was completed offline. Raw EEG data was analyzed in order to obtain ERP waveforms. Peak latency and amplitude of the P300a and P300b ERP component were measured at highest positive peak that occurred within the operational definition of the P300a and P300b ERP components for each participant. The P300a ERP component was defined as occurring between 280-350 ms after the onset of the target stimuli. The P300b ERP component was defined as occurring between 300-600 ms after the onset of the target stimuli. Latency is measured in milliseconds (ms) and amplitude is measured in microvolts (mv).

Spatial analysis was in the form of topographic (surface) maps that allow for localization of the ERP signal source relative to the electrode placement on the scalp. The topographic maps were generated at FCz, Cz, CPz, and Pz electrode sites. These electrode sites were chosen based on the ERP literature that reports these sites demonstrates maximum amplitude of the P300 ERP components. Topographic maps were generated using grand averages and compared across participants for both tasks.

Electrophysiologic measures were subjected to statistical analysis using SPSS version 22. Paired samples t-tests were used to compare P300a and P300b peak latency and amplitude across the following four electrode sites: FCz, Cz, CPz, and Pz for both the linguistic and tonal auditory oddball tasks. In order to examine the joint and interactive effects of task and electrode site,

repeated measures of analysis of variance (ANOVAS) of P300a and P300b peak latency and amplitude were used. Cortical activation maps were derived using Brain Vision Analyzer of the grand averaged P300a and P300b.

Chapter 3: Results

3.1 Introduction

Peak latency and amplitude of P300a and P300b ERP components were measured for each participant for the linguistic and tonal auditory oddball task. Peak latency and amplitude were subjected to statistical analysis using ANOVAs and paired samples t-tests.

3.2 Statistical Analysis

Paired samples t-tests were used to compare differences in peak latency and amplitude of the P300a and b ERP components at FCz, Cz, CPz, and Pz electrode sites. No statistically significant differences were found in peak latency or peak amplitude between the two experimental tasks at any of the electrode sites. Figure 3.2 shows the results of the paired samples t-test for peak latency of the P300a and P300b ERP components during the linguistic and the tonal auditory oddball tasks at FCz, Cz, CPz, and Pz electrode sites. Figure 3.2 shows the results of the paired samples t-test for peak amplitude of the P300a and P300b ERP components during the linguistic and the tonal auditory oddball tasks at FCz, Cz, CPz, and Pz electrode sites.

Electrode Site	Linguistic task mean (SD)	Tonal task mean (SD)	t	p
FCz_P300a_ms	296.5 (33.23)	311.80 (17.23)	-4.00	0.16
FCz_P300b_ms	497.17 (48.35)	462.67 (83.27)	0.90	0.41
Cz_P300a_ms	315 (30.05)	318.00 (16.75)	-0.72	0.55
Cz_P300b_ms	526.33 (48.07)	477.83 (108.34)	0.81	0.45
CPz_P300a_ms	312.33 (28.29)	311.80 (20.36)	-3.03	0.09
CPz_P300b_ms	508.5(64.67)	465.33 (79.07)	0.79	0.47
Pz_P300a_ms	300 (16.25)	302.40 (16.43)	-0.58	0.59
Pz_P300b_ms	487.17 (54.59)	504.67 (62.67)	-0.43	0.68

Figure 3.1: Peak latency differences by experimental task

Site	Linguistic task mean (SD)	Tonal task mean (SD)	t	p
FCz_P300a_µV	3.84 (2.68)	2.95 (1.47)	0.13	0.92
FCz_P300b_µV	2.40 (1.63)	3.11 (2.32)	-0.78	0.47
Cz_P300a_µV	2.80 (1.65)	2.54 (0.87)	0.30	0.79
Cz_P300b_µV	3.54 (2.35)	2.59 (1.19)	0.86	0.43
CPz_P300a_µV	5.13 (2.36)	3.49 (1.19)	0.70	0.56
CPz_P300b_µV	3.18 (2.39)	3.22 (1.90)	-0.04	0.97
Pz_P300a_µV	2.32 (2.21)	3.57 (1.90)	-2.89	0.05
Pz_P300b_µV	3.54 (2.40)	3.16 (1.66)	0.36	0.74

Figure 3.2: Peak amplitude differences by experimental task.

A 2 x 4 factorial ANOVA was used to test joint and interactive effects of task across four electrode sites. No statistically significant interactions were found. Figure 3.1 and 3.2 show the results of the ANOVAS main effects and interactions.

P300a	P300b
Task *F(1,1) = 1.71, p=0.41*	Task *F(1,5) = 0.38, p=0.57*
Site *F(3,3) = 0.74, p=0.60*	Site *F(3,15) = 0.49 p=0.70*
Task*Site *F(3,3) = 0.95, p=.0.52*	Task*Site *F(3,15) = 1.52, p=0.25*

Figure 3.3: ANOVA Main effects and interactions (Latency).

P300a	P300b
Task *F(1,1) = 0.17, p=0.75*	Task *F(1,5) = 0.03, p=0.88*
Site *F(3,3) = 0.47, p=0.72*	Site *F(3,15) = 0.29 p=0.83*
Task*Site *F(3,3) = 0.38, p=.0.78*	Task*Site *F(3,15) = 0.98, p=0.*

Figure 3.4: ANOVA Main effects and interactions (Amplitude).

3.3 Grand Averaged Waveforms

Grand averaged waveforms showing the peak latency and amplitude of the P300a and P300b ERP components at electrode sites CPz, Cz, Pz, and FCz are shown in figures 3.5-3.8. These electrode sites were selected for analysis as the literature reports that they provide an accurate reflection of the maximum amplitude of the P300a and b ERP components in an auditory oddball task. (Polich 2010.) Peak latency and amplitude were measured at the highest

positive peak that occurred within the operational definition of the P300a and P300b ERP components. The P300a ERP component was defined as occurring between 280-350 ms after the onset of the target stimuli. The P300b ERP component was defined as occurring between 300-600 ms after the onset of the target stimuli.

Visual inspection of the grand averaged waveforms was completed for the CPz, Cz, Pz, and FCz electrode sites. Figure 3.5 shows grand averaged waveforms at electrode site FCz. Figure 3.6 shows grand averaged waveforms at electrode site Cz. Figure 3.7 shows grand averaged waveforms at electrode site CPz. Figure 3.8 shows grand averaged waveforms at electrode site Pz.

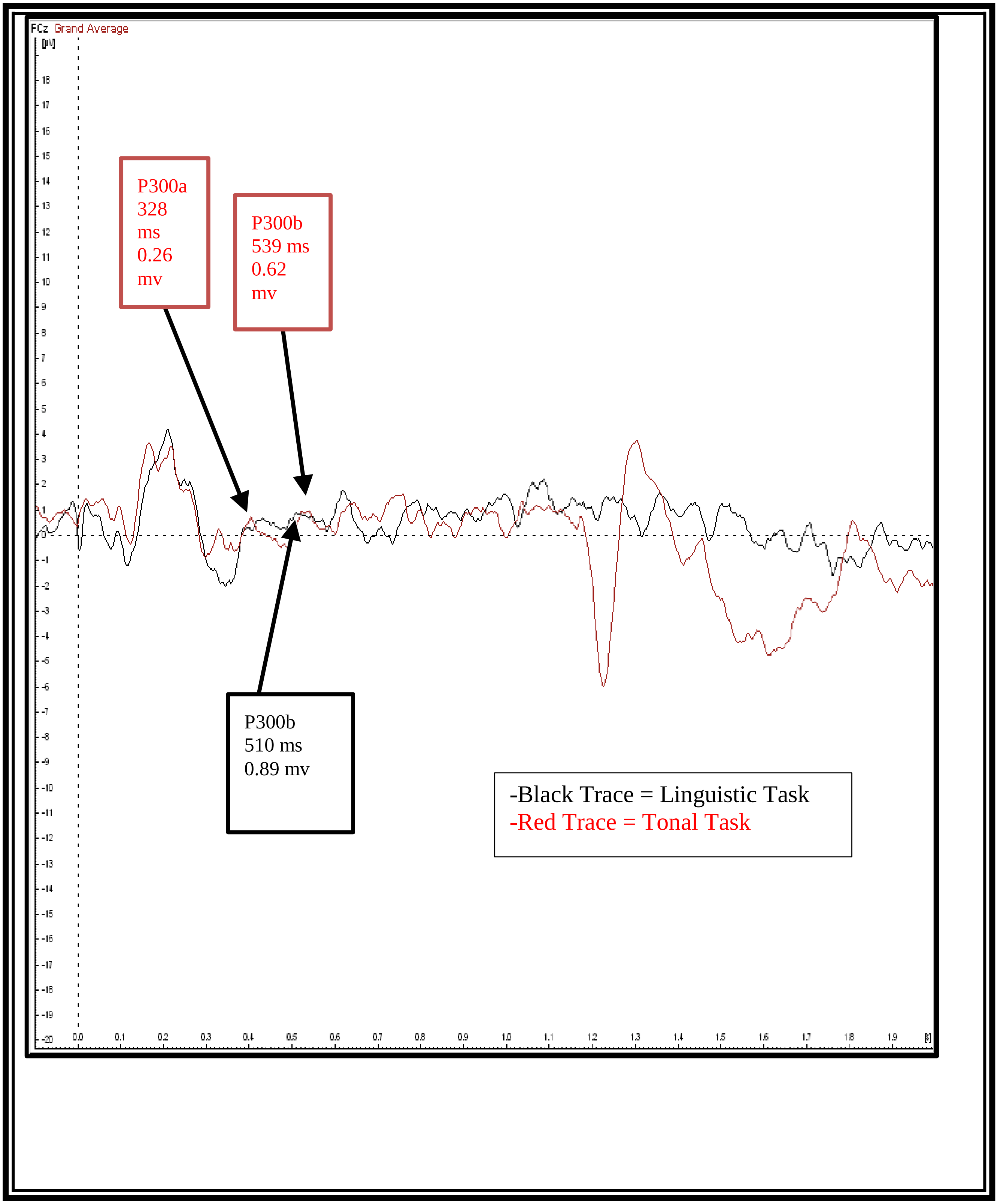


Figure 3.5: Grand Averaged P300a and b ERP components at electrode site FCz

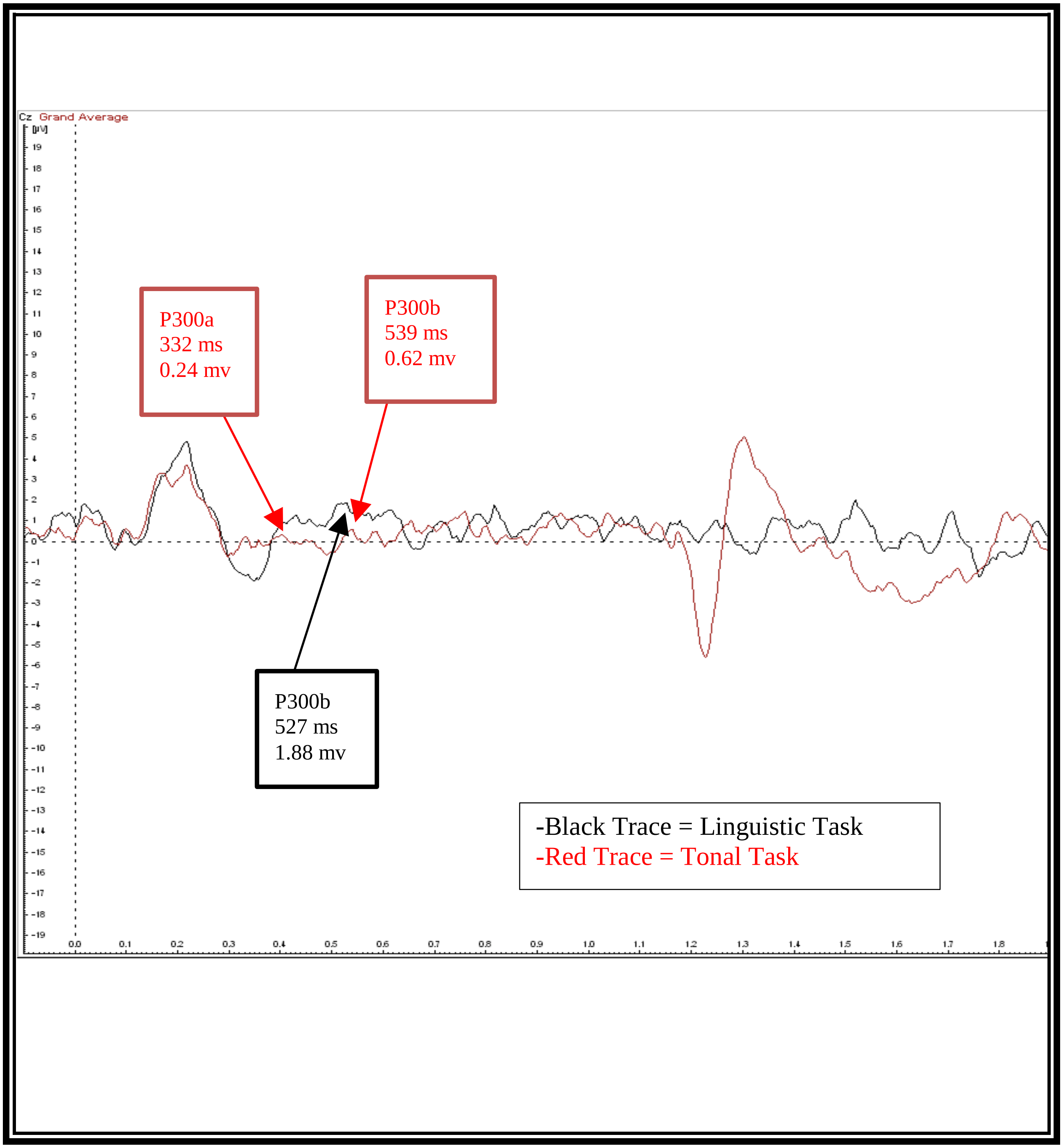


Figure 3.6: Grand Averaged P300a and b ERP components at electrode site Cz.

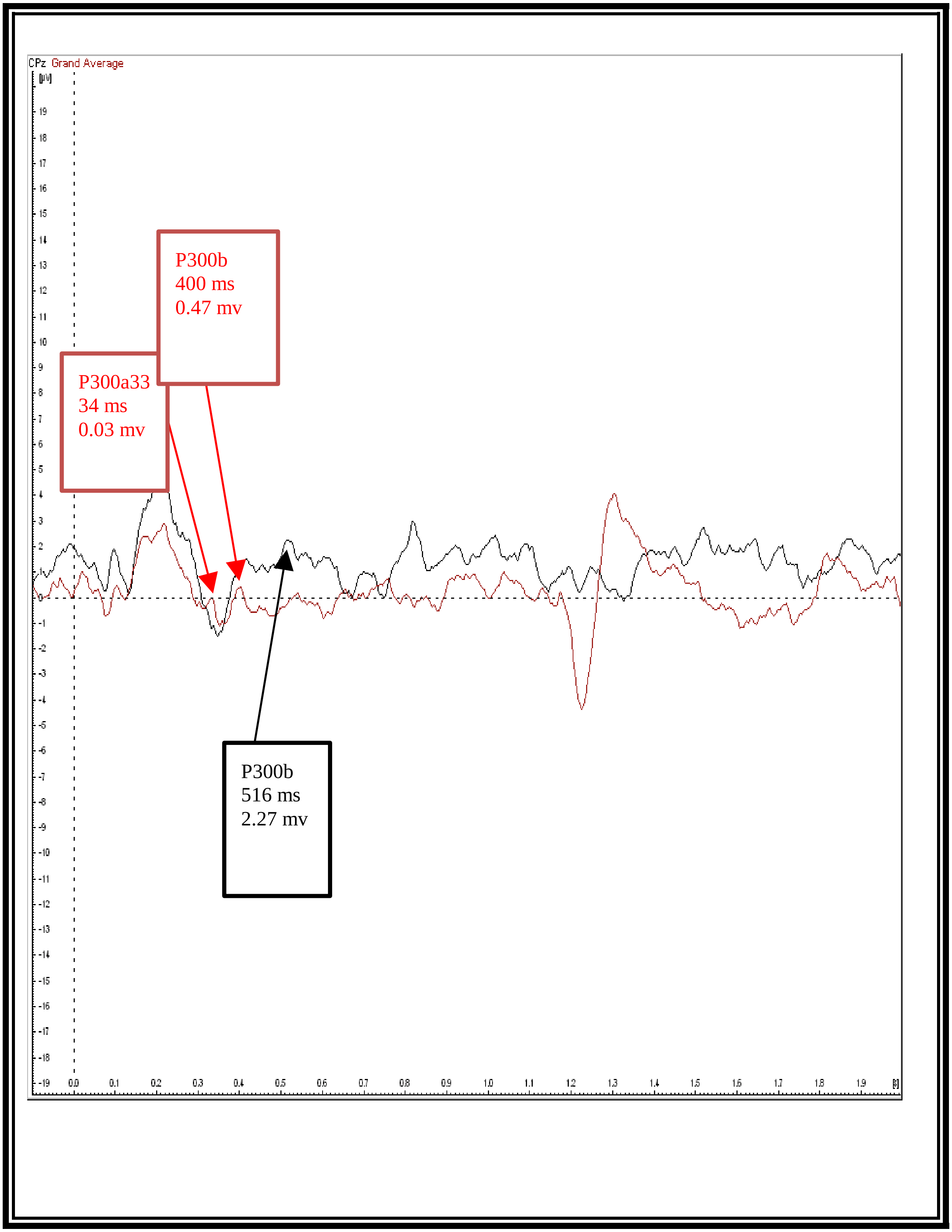


Figure 3.7: Grand Average P300a and b ERP components at electrode site CPz.

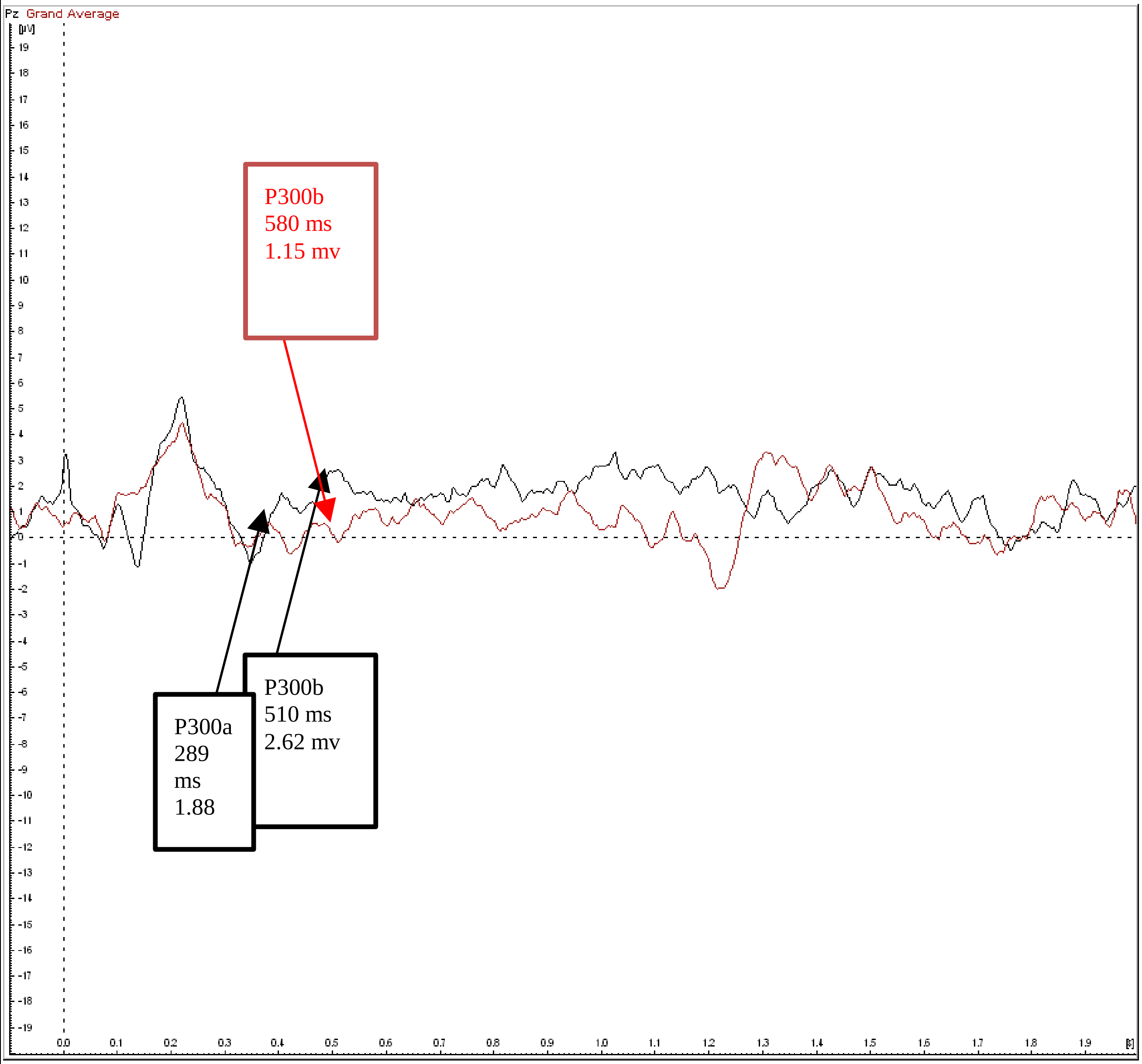


Figure 3.8: Grand Average P300a and b ERP components at electrode site Pz.

	FCz		Cz		CPz		Pz	
	Linguistic Task							
	Amplitude (ms)	Latency (µ)	Amplitude (ms)	Latency (µ)	Amplitude (ms)	Latency (µ)	Amplitude (ms)	Latency (µ)
P300a	n/a	n/a	n/a	n/a	n/a	n/a	289.00	1.88
P300b	510.00	0.89	527.00	1.88	516.00	2.27	510.00	2.62
	Tonal Task							
P300a	328	0.262	332.00	0.24	334.00	0.03	n/a	n/a
P300b	539	0.617	539.00	0.62	400.00	0.47	580.00	1.15

Grand Averages of Peak Latency and Amplitude of P300a and b

Figure 3.9: ERP grand averages for linguistic and tonal tasks at CPz, Cz, Pz, and FCz sites.

Upon visual inspection of the ERP waveforms no differences were found in latency and amplitude at any of the electrode sites except for Pz. The Pz electrode site is located in the parietal area, where electrophysiological activity is more prominent during attentional tasks.

3.4 Spatial Analysis

Cortical activation maps were generated through spatial analysis in the form of topographic maps. Topographic mapping was used because it localizes the ERP signal source relative to electrode placement on the scalp. Electrode sites FCz, Cz, CPz, and Pz were used to derive the cortical activation maps as these electrode sites are reported by the literature as reflecting attentional processes.

Figures 3.10-3.18 shows the cortical activation maps at each electrode site for both tasks with the exception of P300a at FCz, Cz, and CPz during the linguistic oddball and P300a at Pz

during the tonal oddball tasks. Topographic maps are color coded as follows: blue indicates no cortical activity, green indicates neutral cortical activity, yellow indicates moderate cortical activation and red indicates high level of cortical activation. Upon visual inspection of cortical activation maps there are large areas of activity during the linguistic oddball tasks compared to the tonal oddball task. Sanchez (2013) examined the P300a and b ERP components between individuals with concussions and individuals with no brain damage attending to a linguistic auditory oddball task. The results showed a statistically significant difference between the two groups. Sanchez (2013) suggests that this was a result of the increased complexity due to the addition of the linguistic variable. The cortical activations maps for the current study suggest that the addition of the linguistic variable does increase the demands placed on the attentional process. However, the results of the current study found no statistically significant differences between a linguistic and tonal auditory oddball task. This suggests that while the complexity is increased in a linguistic oddball task, it is not statistically significant.

P300a at FCz

Linguistic Oddball Task

Tonal Oddball Task

Cortical activation map could not be derived for FCz during the linguistic oddball task because no P300a was visible upon visual inspection

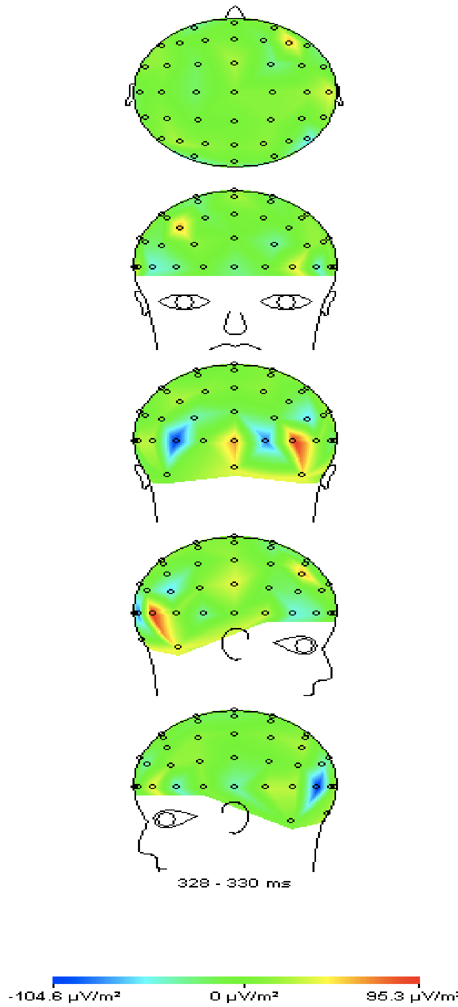


Figure 3.10: P300a ERP component at FCz cortical activation maps.

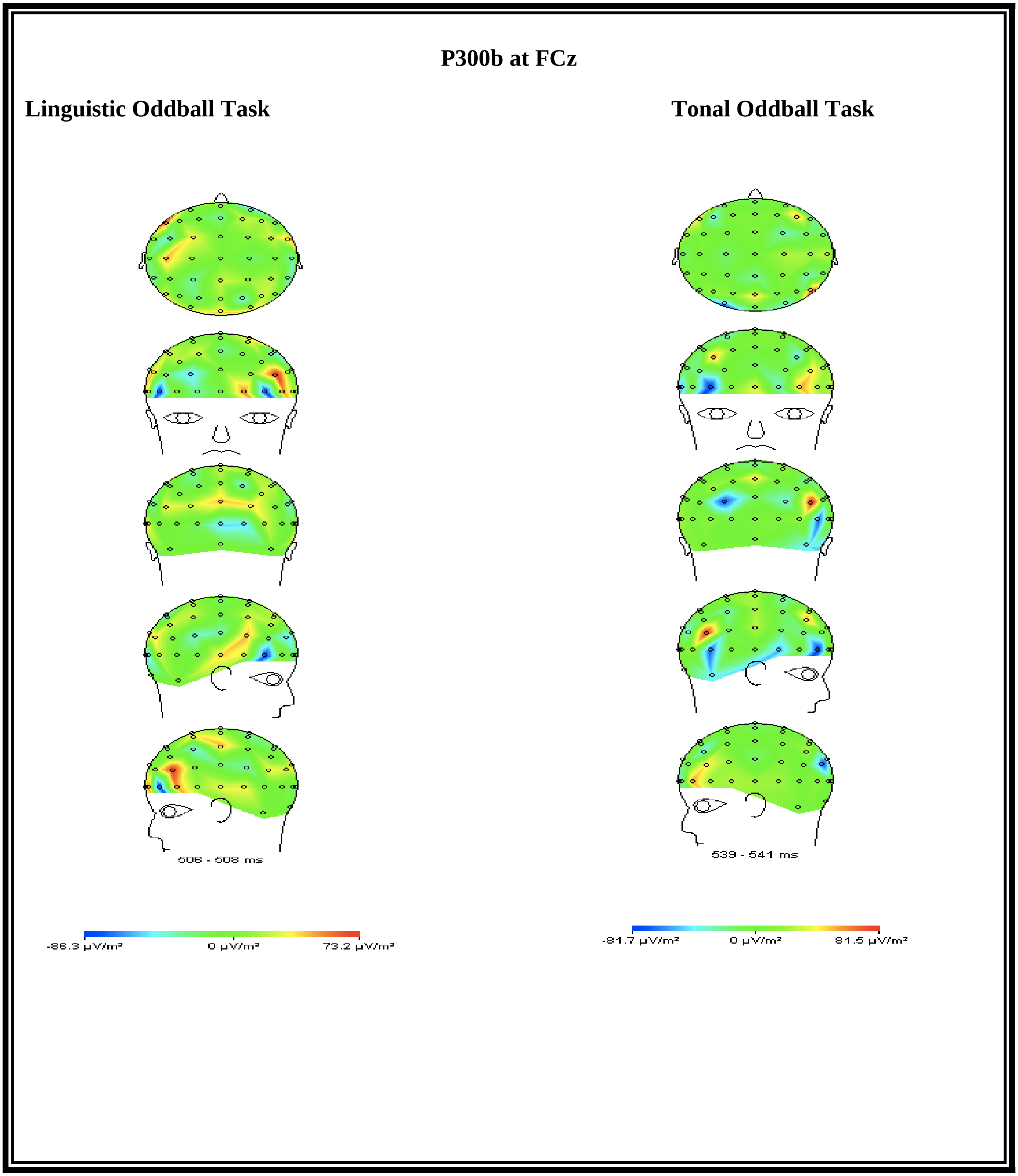


Figure 3.11: P300b ERP component at FCz cortical activation maps.

P300a at CPz

Linguistic Oddball Task

Tonal Oddball Task

Cortical activation map could not be derived for CPz during the linguistic oddball task because no P300a was visible upon visual inspection

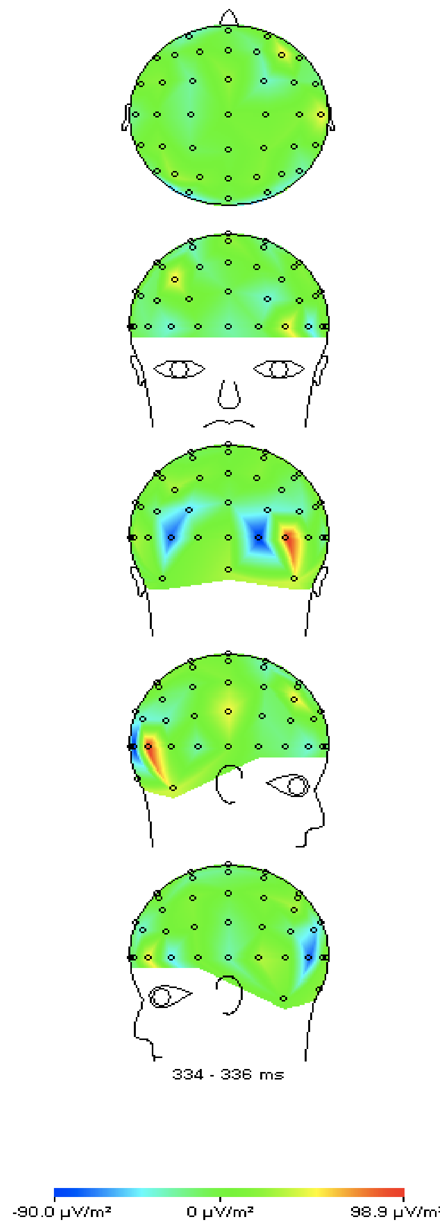


Figure 3.12: P300a ERP component at CPz cortical activation maps.

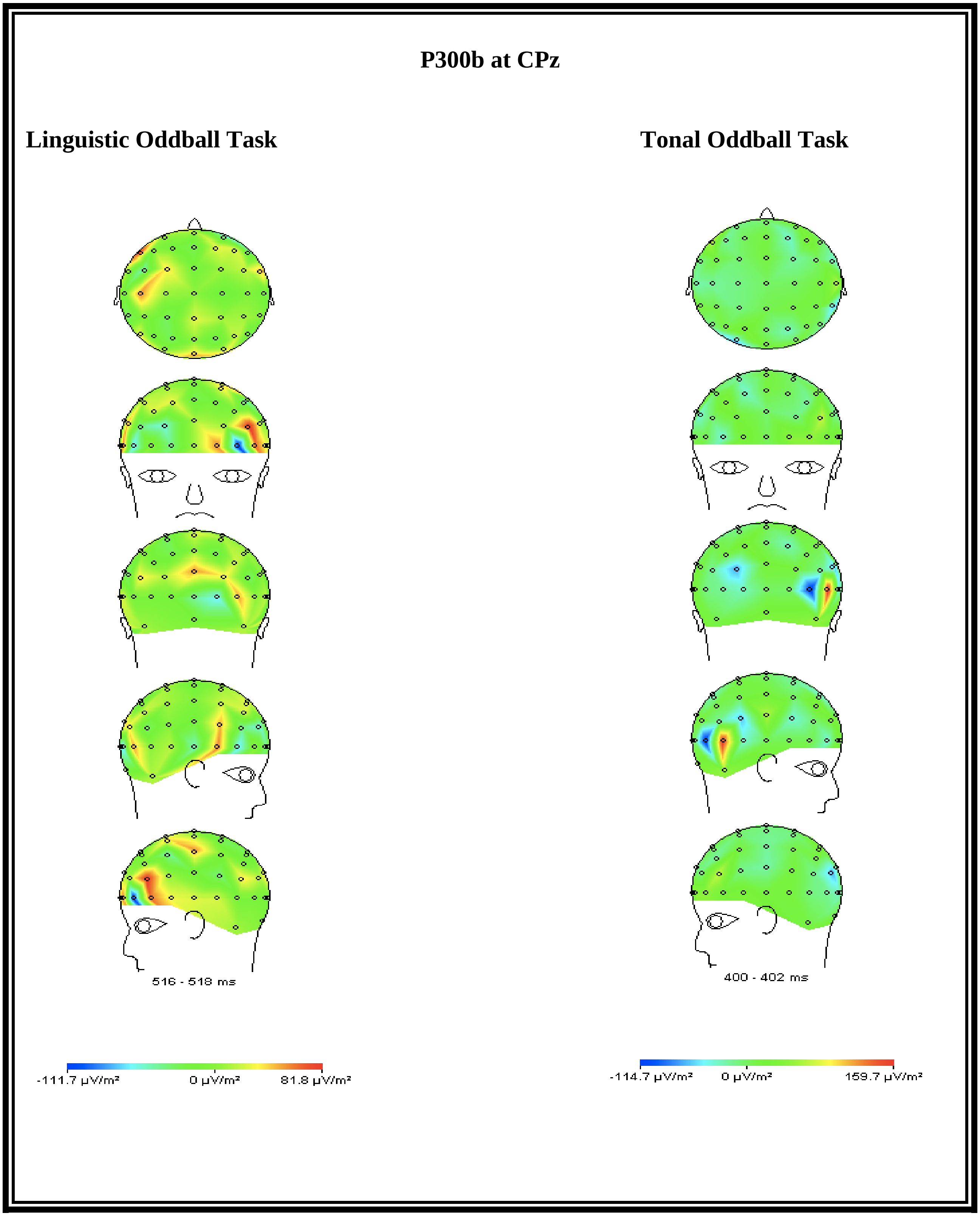


Figure 3.13: P300b ERP component at CPz cortical activation maps.

P300 at Cz

Linguistic Oddball Task

Cortical activation map could not be derived for Cz during the linguistic oddball task because no P300a was visible upon visual inspection.

Tonal Oddball Task

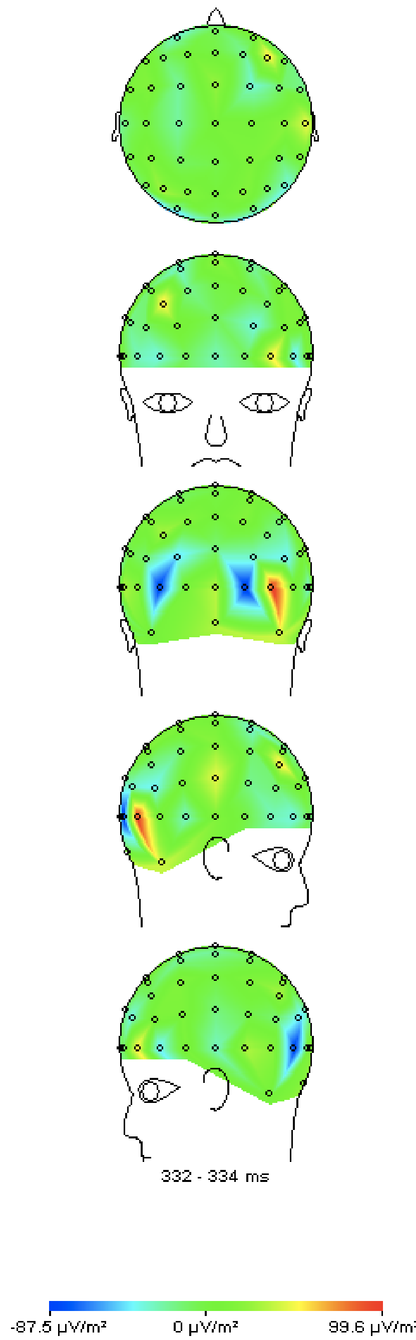


Figure 3.14: P300a ERP component at Cz cortical activation maps.

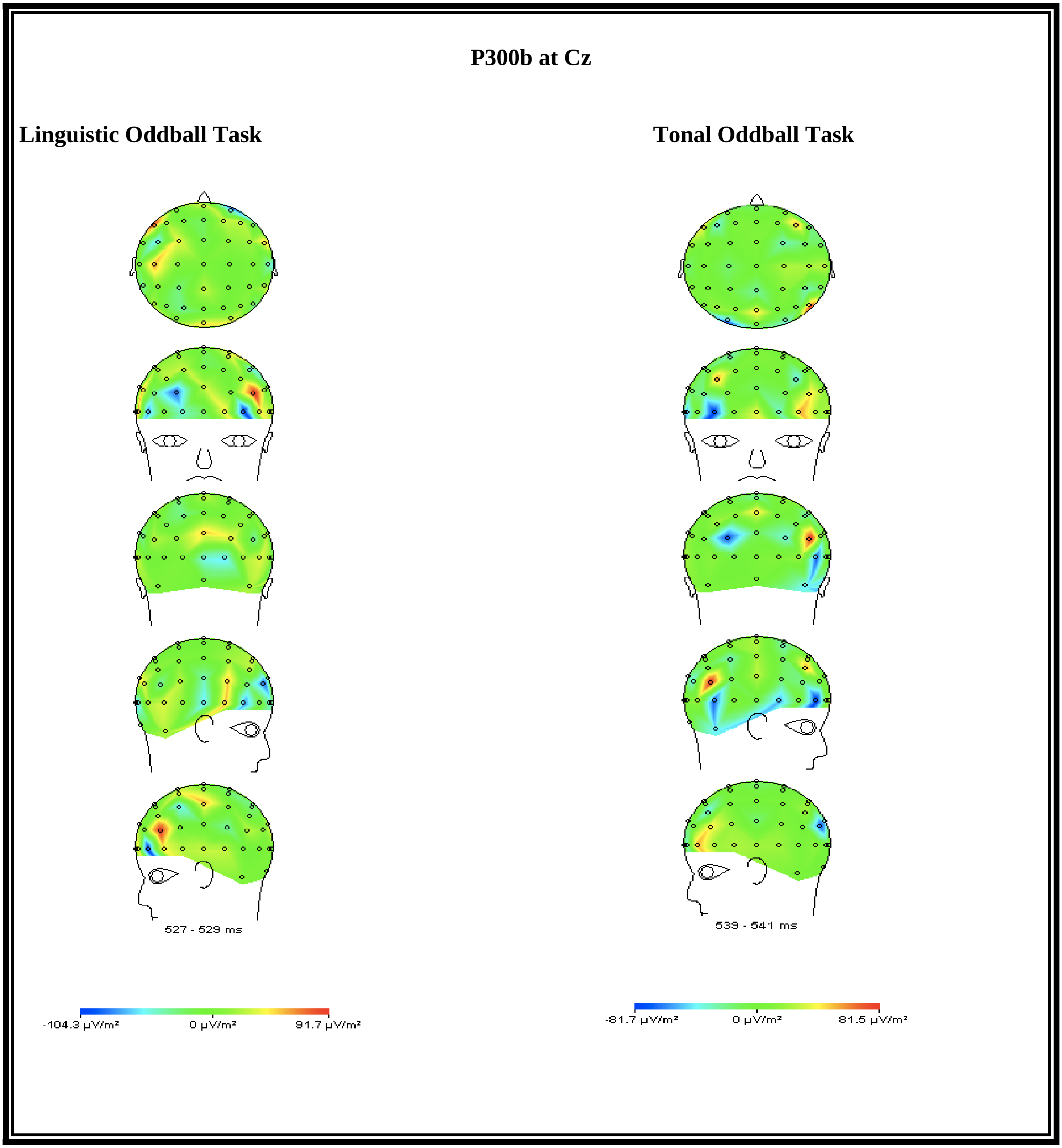
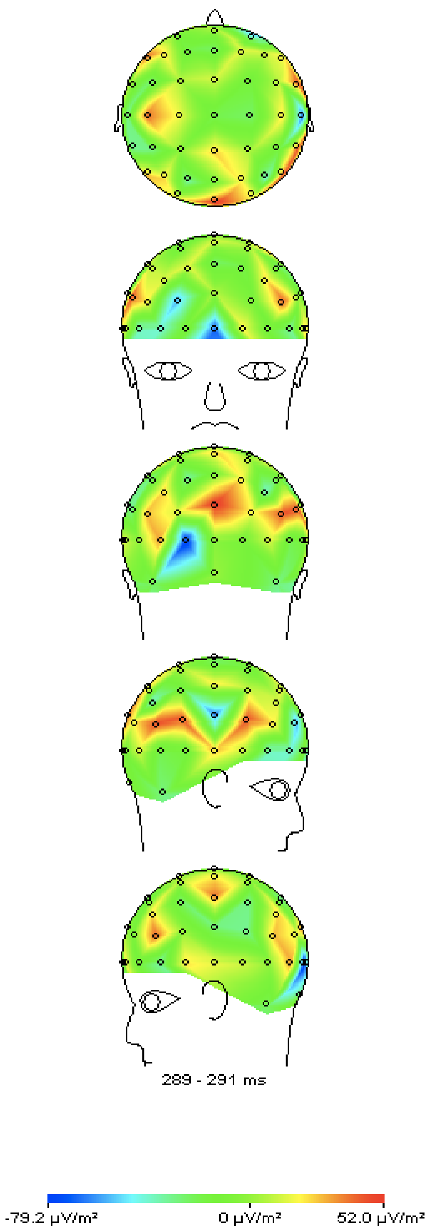


Figure 3.15: P300a ERP component at Cz cortical activation maps.

P300a at Pz

Linguistic Oddball Task

Tonal Oddball Task



Cortical activation map could not be derived for Pz during the tonal oddball task because no P300a was visible upon visual inspection

. Figure 3.16: P300a ERP component at Pz cortical activation maps.

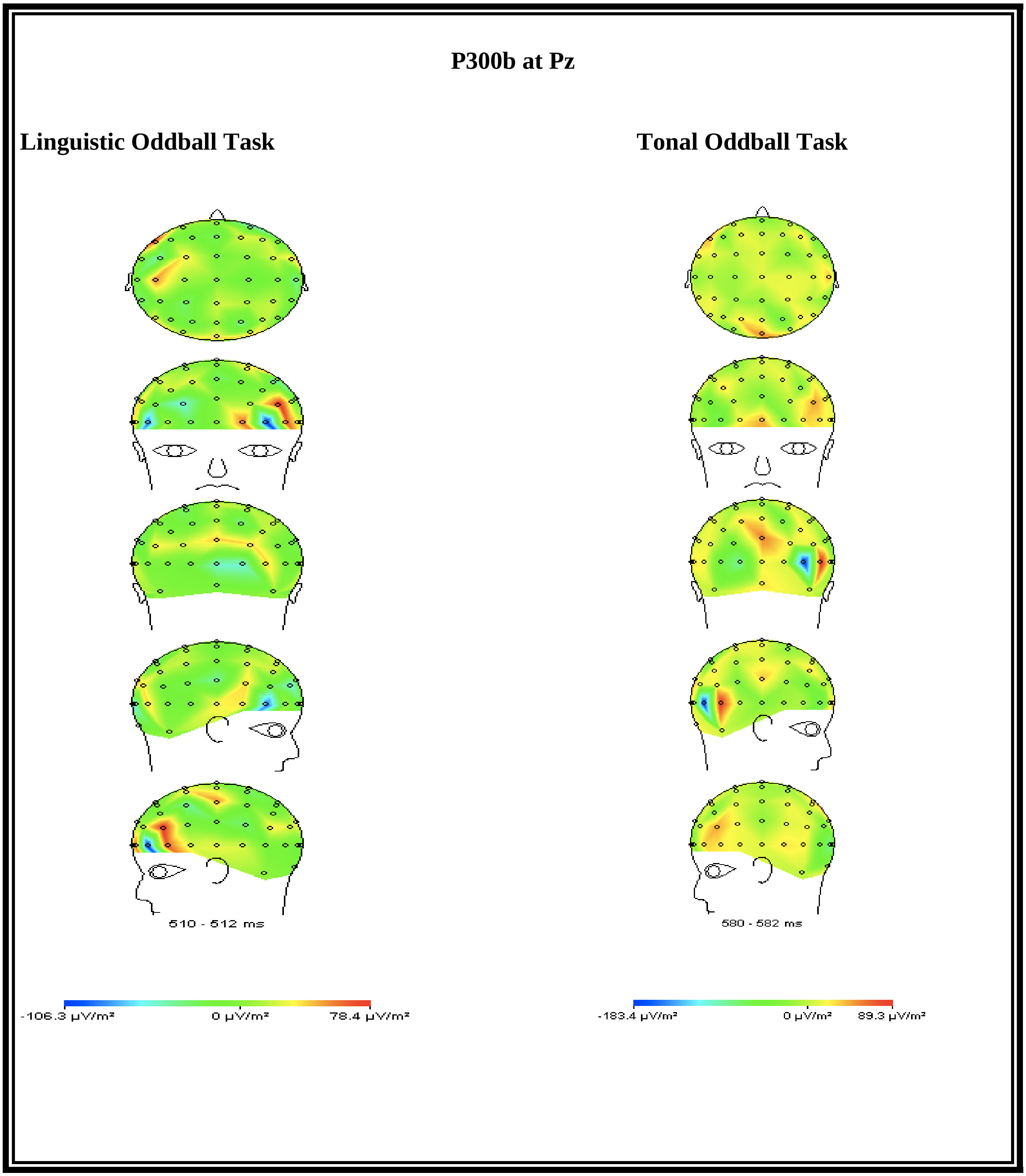


Figure 3.17: P300b ERP component at Pz cortical activation maps.

Ch. 4 Discussion

4.1 Interpretation of Results

The purpose of this study was to examine electrophysiologic differences between a linguistic and tonal auditory oddball task in a group of participants with no history of brain damage. Participants were instructed to sit and listen to two different versions of an auditory oddball tasks, linguistic and tonal. The linguistic oddball task consists of two CV syllable combinations /tʌ/ and /kʌ/ while the tonal oddball task consists of two tones occurring at 250 Hz and 375 Hz. The ERP components of interest for this study are the P300a and P300b because these components are associated with attentional processes. Electrophysiologic activity was recorded using electrodes attached to the skullcap. Peak amplitude and latency of the P300a and b ERP components were subjected to statistical analysis. Visual inspection of ERP waveforms and cortical activation maps were used to compare the performance of a group of college aged participants on a linguistic and tonal auditory oddball tasks.

Sanchez (2013) examined attentional differences in two groups of individuals. In this study electrophysiological differences between a group of participants with concussion and a group of participants with no brain damage were examined. Participants were instructed to attend to a linguistic auditory oddball task that consisted of CV syllables that varied by one distinctive feature. Results found a statistically significant difference in attentional performance between the two groups. Sanchez (2013) suggests that the addition of a linguistic component to a traditional oddball task increased the complexity of the task and therefore increased the demands and resources the individual uses.

However, Roosemalen (2015) found no statistically significant difference in a systematic replication of Sanchez (2013). In an effort to examine whether a linguistic auditory oddball task increased the attentional demands of participants, we examined the neural processes of attention in a group of college aged participants with no history of brain damage using a tonal and linguistic auditory oddball task. The results of this study show no statistically significant differences in the performance of these individuals between the two tasks. This suggests that the addition of the linguistic component does not significantly impact attentional demands in this group of individuals with no brain damage. While statistically significant differences were not l found, cortical activation maps of the P300 derived from the linguistic task show increased levels of activation in the frontal and parietal electrodes. This suggests that the addition of a linguistic component may increase the demands required though not statistically significant.

4.2 Limitations and Future Direction

Several limitations were noted in the present study. First, sample population was not randomly selected because it was a sample of convenience in an effort to control for extraneous variables such as education, socioeconomic status, language, and age. All participants were recruited from the University of Texas at El Paso.

A second limitation was the time the participant spent completing each experimental task. In ERP research that examines small components, such as the P300a and b, a large number of trials are required in order to obtain a good signal. Large number of trials increases the time the participant sits through the experimental task resulting in participant fatigue.

Finally, the results of the present study cannot be generalized to other populations other than those participants in this study. Therefore, future research should examine neural processes of attention in different populations such as geriatric, pediatric and individuals with history of

brain damage. Additionally, gender differences should be looked at as the current study did not examine these.

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Appendix

A

Informed Consent

University of Texas at El Paso (UTEP) Institutional Review Board
Informed Consent Form for Research Involving Human Subjects

Title of Study: Examining Event Related Potential Differences During Phonetic and Tonal Oddball Tasks in a Non Brain Damaged Population
Principal Investigator: Luisa Esquivel, B.A
Supervisor: Patricia Lara PhD., CCC-SLP

Thesis Members:

UTEP College of Health Sciences: Speech Language Pathology Department

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In this consent form "you" always means the study subject. If you are a legally authorized representative (such as a parent or guardian), please remember that "you" refers to the study subject.

1. **Introduction**
You are being asked to take part voluntarily in the research project described below. Please take your time making a decision and feel free to discuss it with your friends and family. Before agreeing to take part in this research study, it is important that you read the consent form that describes the study. Please ask the study researcher or the study staff to explain any words or information that you do not clearly understand.

2. PURPOSE OF THE STUDY

You have been asked to take part in a research study that uses event related potentials to compare attention and electrophysiological activity in individuals with no history of brain damage during tonal and phonetic oddball auditory discrimination tasks. This study examines amplitude and latency of attention in response to the presentation of a target stimulus within a string of non target stimulus. This study will compare the amplitude and latency of attention between a phonetic and tonal oddball auditory discrimination task.

The rationale:
Acquired brain injuries, like concussion, frequently result in difficulties in cognitive functions like attention. Attention is a necessary component for auditory processing, communication, memory, and learning. Studies of attention norms within non brain damaged individuals are valuable because the information they provide can be used to recognize discrepancies in patterns of attention in populations with brain damage.

Approximately, 20 subjects (10 college level individuals with no history of brain damage, auditory deficits, or attention deficits) will be enrolled in this study. You are being asked to be in the study because you are a college level subject with no history brain damage. If you decide to enroll in this study, your involvement will last about approximately one hour on two different occasions.

3. Procedure

If you agree to take part in this study, you will be provided with an explanation regarding the use of event related potentials. Also during your first visit, you will be asked to fill out the self-report medical questionnaire. The principal investigator will administer a hearing screening and measure your head to find a cap that best fits the circumference of your head. The principal investigator will fit you with the electrode cap, apply the conduction gel and attach the electrodes. You will then be seated in a soundproof room where computer generated auditory stimuli will be presented to you for the experimental task. The experimental task requires that you listen auditory stimuli through speakers.

4. Risks, Discomforts and Benefits

There are no known risks associated with this research. However, you may experience slight fatigue during the testing conditions. If you feel fatigued, you will be given the opportunity to rest.

5. What will happen if I am injured in this study?

The University of Texas at El Paso and its affiliates do not offer to pay for or cover the cost of medical treatment for research related illness or injury. No funds have been set aside to pay or reimburse you in the event of such injury or illness. You will not give up any of your legal rights by signing this consent form. You should report any such injury to the PI, Luisa Esquivel (915) 274-6205, her supervisor Dr. Patricia Lara at (915) 747-7271, and/or to the UTEP Institutional Review Board (IRB) at (915-747-8841) or rb.orsp@utep.edu.

6. Benefits

You will not be paid for participating in this study. There will be no other direct benefits to you for taking part in this study. However, you may benefit from this study by knowing the outcome of your performance using event related potentials. This research may lead to better understanding of what is involved in the processes that mediate auditory comprehension of spoken sentence length messages.

7. Options

You have the option not to take part in this study. There will be no penalties involved if you choose not to take part in this study.

8. Funding

No funding has been provided, as this is a Thesis Project.

9. COSTS

There are no direct costs to you. However, you will be responsible for travel to and from the research site and any other incidental expenses.

10. COMPENSATION

You will not be paid for participating in this study.

11. Refusal or Withdrawal

Taking part in this study is voluntary. You have the right to choose not to take part in this study. If you do not take part in the study, there will be no penalty. If you choose to take part, you have the right to stop at any time. However, we encourage you to talk to a member of the research group so that they know why you are leaving the study. If there are any new findings during the study that may affect whether you want to continue to take part, you will be told about them. The researcher may decide to stop your participation without your permission, if he or she thinks that being in the study may cause you harm, and/or there is not sufficient effort on your part to complete the testing.

12. Contact Information

You may ask any questions you have now. If you have questions later, you may call Luisa Esquivel at (915) 274-6205 or via email at laesquivel@miners.utep.edu or Dr. Patricia Lara at (915) 747-7271, or via email at *plara2@utep.edu*. If you have questions or concerns about your participation as a research participant, please contact the UTEP Institutional Review Board (IRB) at (915-747-8841) or irb.orsp@utep.edu.

13. Confidentiality

Your part in this study is confidential therefore; all information collected in this study will remain confidential. Only the principal investigator (Luisa Esquivel) and her Thesis Advisor (Dr. Patricia Lara) will have access to this information. In addition, none of the information will identify you by name. Instead, identification numbers will be used. All records will be stored in a locked cabinet in the ERP and Aphasia Laboratory at the UTEP Speech Language Pathology Research Facility located at (1101 N. Campbell, El Paso, Tx. 79902). For further protection, only the principal investigator and her thesis advisor will have access to the locked cabinet. Computer information will be stored in the laboratory computers and password secured. Only the principal investigator and her thesis advisor will have access to the password. The results of this research study may be presented at meetings or in publications; however, your identity will not be disclosed in those presentations.

14. Mandatory Reporting

If information is revealed about abuse or neglect to the elderly or disabled, the law requires that this information be reported to the proper authorities.

15. Authorization Statement

I have read each page of this paper about the study (or it was read to me). I know that being in this study is voluntary and I choose to be in this study. I know I can stop being in this study without penalty. I will get a copy of this consent form now and can get information on results of the study later if I wish.

Participant Name: ________________________________ Date: ______________

Participant Signature: ________________________________ Time: ______________

Consent form explained/witnessed by: ____________________________

Signature

Printed name: ________________________________

Date: ______________ Time: ______________

B

Medical Questionnaire

Self-Report Medical History Questionnaire

UTEP

Brain, Voice and Language Laboratory

The following information is required by the Institutional Review Board to screen for possible participation in EEG studies. We must know if you have had any medical problems that might keep you form participating in this research project. It is important that you be as honest as you can. Information provided will be kept confidential.

Participant ID# __________________________Age_________Gender__________

1. **Since birth have you ever had any medical problems? If yes, please explain.**

2. **Since birth have you ever been hospitalized? If yes, please explain.**

3. **Have you ever hit your head and experienced a concussion? If yes, please explain.**

4. **Did you ever have problems where you saw a counselor, psychologist or psychiatrist? If yes, please explain.**

5. **Have you ever suffered from seizures? If yes, please explain.**

6. **Do you use tobacco (smoke, chew)? If yes, please explain.**

7. Have you had any hearing problems? If yes, please explain.

8. Have you had any vision problems? If yes, please explain.

9. What is your current weight and height?

10. Do you currently have or have you ever had any of the following? (circle yes or no) Please explain any yes answers.

Yes	**No**	**strong reaction to cold weather**
Yes	**No**	**circulation problems**
Yes	**No**	**tissue disease**
Yes	**No**	**skin disorders (other than facial acne)**
Yes	**No**	**arthritis**
Yes	**No**	**asthma**
Yes	**No**	**lung problems**
Yes	**No**	**heart problems/disease**
Yes	**No**	**diabetes**
Yes	**No**	**hypoglycemia**
Yes	**No**	**hypertension**
Yes	**No**	**low blood pressure**
Yes	**No**	**hepatitis**
Yes	**No**	**neurological problems**
Yes	**No**	**epilepsy or seizures**
Yes	**No**	**brain disorder**
Yes	**No**	**stroke**

11. Have you ever been diagnosed formally to have had?

Yes	**No**	**learning deficiency or disorder**
Yes	**No**	**reading deficiency or disorder**
Yes	**No**	**attention deficit disorder**
Yes	**No**	**attention deficit hyperactivity disorder**

12. Do you have

Yes	**No**	**claustrophobia (high fear of small closed rooms)**
Yes	**No**	**high fear of needles**

13. List any over the counter prescription medications you are presently taking.

14. Do you have or have you ever had any other medical conditions that you can think of? If yes, please note them below.

Vita

Luisa Esquivel was born and raised in El Paso, Texas. With the support of her mother, Dr. Rebecca Palacios, she completed her Bachelor of Arts degree in Linguistics at the University of Texas at El Paso in 2011. With a degree in Linguistics and a minor in Speech-Language Pathology, she obtained her Speech-Language Pathology Assistant license and began work as an SLPA at a pediatric clinic where she gained invaluable experience. While working at the pediatric clinic she decided to continue her studies and is currently pursuing her Maser of Science degree in Speech-Language Pathology with an expected graduation date of August 2015. Ms. Esquivel, following in her mother's footsteps, took an interest in research while still an undergraduate. She participated in research in both the UTEP Public Health Department and the UTEP Speech-Language Pathology department. Topics of interest included smoking prevalence in low socioeconomic areas, the effects of alcohol abuse in El Paso firefighters, and the effects of electronic reading devices on reading comprehension in children with Autism. During her graduate career she has worked as a research assistant in the Baby Sign Language Lab and as a member of the ERP and Aphasia Lab where she developed her interest in Event Related Potentials (ERP). Her research interest and experience in ERP led her to complete a thesis on the electrophysiological patterns of attention in individuals with no history of brain injury.

Education
B.A., Linguistics, University of Texas at El Paso, Texas, 2011
M.S., Speech Language Pathology, University of Texas at El Paso, Texas, anticipated completion: Summer 2015

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