2015-01-01

Processing of Language Switches in Bilingual Individuals with Aphasia: An Event-Related Potential Comparison

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PROCESSING OF LANGUAGE SWITCHES IN BILINGUAL INDIVIDUALS WITH APHASIA: AN EVENT-RELATED POTENTIAL COMPARISON

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2015
PROCESSING OF LANGUAGE SWITCHES IN BILINGUAL INDIVIDUALS
WITH APHASIA: AN EVENT-RELATED
POTENTIAL COMPARISON

by

LIZETTE RODARTE, B.S.

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

Program of Speech-Language Pathology
THE UNIVERSITY OF TEXAS AT EL PASO
May 2015
Abstract

Switching between languages, or code-switching, is a common phenomenon in bilingual individuals. In proficient bilinguals, these switches are done with ease and are used for many purposes. Contrary to popular belief, these switches are rule-governed and follow grammatical structure. Bilingual individuals diagnosed with aphasia present with difficulty processing languages and these language switches. With the increase in bilingual individuals, it is likely that the speech-language pathology community will see an increase of bilingual individuals with aphasia on their caseload. For this reason, the purpose of this study is to increase our understanding of the neural processes involved in processing of language switches and how grammatical structure plays a role in this population.

Event related potentials (ERPs) were used to compare a group of five bilingual individuals with aphasia and eight individuals with no history of brain damage during an auditory task consisting of language switches under four different conditions. The participants were presented with a total of 80 sentences, each containing a language switch from either English (E) to Spanish (S), or Spanish to English. The language switches were made to either adhere to, or violate grammatical rules. N400 and P600 peak amplitude and latency were compared between the two groups for each type of switch. Cortical activation maps between the two groups were also compared. It was hypothesized that there would be no differences between the two groups during any of the switches.

Though there were no statistically significant effects on peak amplitude and latency between the two groups and type of switch, based on the results of the grand averaged waveforms and cortical activation maps, the study found there were differences in the processing of the language switches associated with the groups and type of language. While both groups followed patterns reported by previous research, resulting in a large N400 during grammatical switches and large P600 during ungrammatical switches, the presence of these peaks does not indicate appropriate processing. Cortical activation highly differed between the two groups.
Further research is therefore needed to expand on these results and test for comprehension of the language switches in bilingual individuals with aphasia.
# Table of Contents

Abstract......................................................................................................................... iv

Table of Contents ........................................................................................................ vi

List of Tables ................................................................................................................. viii

List of Figures ................................................................................................................ ix

Chapter 1: Introduction ................................................................................................. 1
  1.1 Background ............................................................................................................ 1
  1.2 Statement of Purpose ........................................................................................... 3
  1.3 Research Question ............................................................................................... 3
  1.4 Rationale ............................................................................................................... 4

Chapter 2: Literature Review ....................................................................................... 5
  2.1 Bilinguals and Bilingualism ................................................................................. 5
  2.2 Bilingualism and Code-Switching .................................................................... 8
  2.3 Aphasia ................................................................................................................. 9
  2.4 Bilinguals and Aphasia ....................................................................................... 11
  2.5 Aphasia and Language Switches ...................................................................... 12
  2.6 ERP ...................................................................................................................... 13
  2.7 ERP and Language Switches .......................................................................... 14
  2.8 ERP and Aphasia ............................................................................................... 15
  2.9 Summary ............................................................................................................. 17

Chapter 3: Methods ..................................................................................................... 19
  3.1 Participants ......................................................................................................... 19
  3.2 Experimental Design ......................................................................................... 21
  3.3 Experimental Task ............................................................................................. 21
  3.4 Procedure ............................................................................................................ 23
  3.5 Data Collection and Analysis .......................................................................... 24
  3.6 Statistical Analysis and Visual Inspection ....................................................... 25

Chapter 4: Results ....................................................................................................... 27
  4.1 Statistical Analysis ............................................................................................. 27
4.2 Grand Average Waveforms ................................................................. 30
4.3 Cortical Activation Maps ................................................................. 33

Chapter 5: Discussion .................................................................................. 40
  5.1 Interpretation of the Results ................................................................. 40
  5.2 Clinical Implications ........................................................................ 43
  5.3 Limitations ....................................................................................... 44
  5.4 Future Research .............................................................................. 44
  5.5 Conclusion ...................................................................................... 45

References ................................................................................................ 46

Appendix .................................................................................................... 49
  Appendix A – Consent From ................................................................. 49
  Appendix B – Self-Report Medical History Questionnaire ................. 52
  Appendix C – Self-Report Bilingual Proficiency Questionnaire .......... 55
  Appendix D – Annett Hand Preference Questionnaire ....................... 58
  Appendix E – Stimuli ............................................................................ 59

Vita ............................................................................................................. 63
List of Tables

Table 3.1 Participants: No Brain Damage .......................................................... 20
Table 3.2 Participants: Aphasia ................................................................. 20
Table 3.3 Likert Rating of Speech Accentedness .......................................... 23
Table 4.1 Overall Statistical Results from Mixed Design ANOVA ................. 27
Table 4.2 Means and Standard Deviations for N400 .................................. 29
Table 4.3 Means and Standard Deviations for P600 .................................. 30
List of Figures

Figure 2.1 Representation of the Revised Hierarchical Model ..................................................7
Figure 3.1 Arrangement of 64 Electrodes ..................................................................................25
Figure 4.1 Grand Averaged Waveforms ..................................................................................32
Figure 4.2 Cortical Activation Maps of Cz N400 During L1-L2 Switches .........................36
Figure 4.3 Cortical Activation Maps of Cz N400 During L2-L1 Switches .........................37
Figure 4.4 Cortical Activation Maps at Cz P600 During L1-L2 Switches .......................38
Figure 4.5 Cortical Activation Maps at Cz P600 During L2-L1 Switches .......................39
Chapter 1: Introduction

Currently, over 60 million people in the United States report speaking a language other than English at home. That means about 21% of the population considers themselves bilingual, and this number is only projected to increase in the next 10 years (US Census Bureau, 2013). It is common for bilingual individuals to switch between their languages during a conversation. These switches occur for different reasons, such as to replace a word the speaker cannot recall, to show emphasis, or for formulaic phrases (Anderson & Toribio, 2007). Bilingual individuals perceive and produce these language switches with minimal difficulty (Abutalebi et al., 2007).

Aphasia is an acquired language disorder that affects language processing. Currently, there are about 100,000 new cases of aphasia every year. With the increase of bilingual individuals, it is expected that the number of cases of aphasia in bilingual individuals will also rise (Paradis, 2001). In order for the healthcare profession to better serve this population, it is important that we understand how these individuals affected by aphasia are processing language in all aspects. This study aims to add to the literature and provide an analysis of processing of language switches by bilingual individuals with aphasia.

The chapter will begin with background information and content used to structure this research. The statement of purpose, research questions, and rationale will then follow the background.

1.1 Background

Language switches, or code switching\(^1\), are very common in border communities, such as El Paso, where more than half of the population is bilingual (Moreno et al., 2002). Contrary to popular belief, these language switches are systematic and rule governed. A switch is considered grammatical when it is made following the syntactic rules of the language. On the other hand, a switch is considered ungrammatical when the syntactic rules of the language are violated.

\(^1\) For the purpose of this study, code switching and language switching are used interchangeably.
Proficient bilinguals can determine when the switch is made appropriately and when it is not (Anderson & Toribio, 2007). The speaker makes these switches with an intent to convey the same message as if only one language was used, almost like the use of synonyms. However, to the listener, these switches are unexpected and can increase difficulty in processing of the message (Moreno et al., 2002).

Research on language processing in bilingual individuals shows that there are several factors that play a role in how easily the language switch is processed. The main factor in this is proficiency. Research shows that the more proficient the bilingual is, the less reaction time is required to process the language and switches (Kotz & Elston-Guttler, 2003, Ansaldo et al, 2008).

Aphasia is a neurogenic communication disorder that typically occurs after a stroke to the left hemisphere. Aphasia manifests in many different forms with different symptoms, with one of the symptoms being difficulty in processing the message conveyed by the speaker. When bilingualism is thrown into the mix, aphasia can be a very complicated disorder to treat and deal with. Recovery patterns for bilinguals with aphasia show that aphasia is highly variable on a case-by-case basis. In some instances, the more dominant language is recovered first, while in others both languages recover simultaneously, or yet in other cases, one language can be completely lost (Ansaldo et al., 2008). Furthermore, bilinguals with aphasia demonstrate what is known as pathological language mixing. Bilinguals with aphasia experiencing pathological mixing are known to switch between languages when speaking with a monolingual individual or during inappropriate communicative situations (Grosjean, 1985; Ansaldo et al., 2008). This suggests that bilingual individuals with aphasia experience many more linguistic deficits than their monolingual counterparts. Therefore, therapy for these individuals cannot be approached in the same manner.
1.2 Statement of Purpose

The purpose of this study is to compare processing of language switches in bilingual individuals with aphasia and bilingual individuals with no history of brain damage. Research shows that bilingual individuals process information slower than monolinguals, but little is known about how bilingual individuals with aphasia process language switches, and how syntax affects that processing. This study uses ERP to compare processing of both grammatical and ungrammatical language switches in bilingual individuals with aphasia and bilingual individuals with no history of brain damage. An auditory task was presented to a group of bilingual individuals with no history of brain damage and a group of bilingual individuals with aphasia. The task consisted of 80 sentences containing either a grammatical or ungrammatical switch from English to Spanish as well as Spanish to English. ERP components were analyzed and compared.

1.2.1 Significance of the Study

Understanding how bilingual individuals with aphasia process language switches, as compared to their non-brain damaged counterparts, is of major significance to the communication disorders field and the healthcare field in general. By better understanding how language switches are processed, speech-language pathologists can better meet the needs of their patients.

1.3 Research Question

The following research questions will be addressed:

1. What are the peak latency and amplitude differences of the N400 and P600 ERP components between individuals with aphasia and individuals with no history of brain damage while listening to grammatical and ungrammatical language switches?

HO: There will be no statistically significant differences of the N400 and P600 peak amplitude and latency between the experimental and control group when
listening to grammatical and ungrammatical language switches.

2. What are the cortical activation map differences between individuals with no history of brain damage and individuals with aphasia when listening to grammatical and ungrammatical language switches presented orally?

HO: There will be no statistically significant differences in the cortical activation maps between the control group and the experimental group when listening to grammatical and ungrammatical language switches.

1.4 Rationale

In the near future, it is very probable that the majority of cases of aphasia will be in bilingual individuals. Since the number of individuals that speak more than one language has increased in the past few year, and the number of individuals that survive a stroke with resulting aphasia has also increased, speech language pathologists will undoubtedly see an increase in the number of bilingual individuals with aphasia on their caseloads. Therefore, therapeutic management strategies need to be created in order to accommodate such a fast growing population. Because language switching is a common occurrence in bilinguals, especially in communities with a high bilingual population, an understanding of how these switches are processed is essential.
Chapter 2: Literature Review

The purpose of this study is to compare how bilingual individuals with aphasia process both grammatical and ungrammatical code-switches, and how they compare to individuals with no history of brain damage. Before one can understand how and why there might be differences between the two groups, there needs to be an understanding of how language is processed in bilinguals. There also needs to be an understanding of how aphasia can have an impact in processing. The following chapter will review the literature as it relates to the following topics: 1) Bilinguals and Bilingualism, 2) Bilingualism and Code-Switching, 3) Aphasia, 4) Bilingualism and Aphasia, 5) Aphasia and Language Switches, 6) ERP, 7) ERP and Aphasia, 8) ERP and Language Switches.

2.1 Bilinguals and Bilingualism

A person is considered bilingual when they are able to communicate in at least two languages. According to the 2011 U.S. Census Language Use Survey, over 60 million individuals over the age of 5 are now considered to be bilingual, with over 37 million of those being Spanish/English bilinguals (U.S. Census Bureau, 2013). According to Francois Grosjean (1994), a bilingual is defined as someone that uses more than one language, or dialect, in everyday life, regardless of fluency and modality (spoken, written, or read). This represents the idea that the bilingual individual is not the combination of two or more monolinguals equally proficient in each language, but an individual that has his or her own distinct communicative abilities.

Bilinguals are then separated into two different groups; simultaneous or native bilinguals, and successive or late bilinguals. A simultaneous bilingual learns their native language (L1) and their second language (L2) during infancy or early childhood. A successive bilingual learns L1 and L2 at different times (Ansaldo et al., 2008). Language dominance is then determined later in life. Because a bilingual is a native bilingual does not mean that they have equal proficiency in both languages. It is rare that equal fluency is achieved in both languages, mostly because the
need of each language is different. The level of fluency is determined by the specific need of that language or language skill (Grosjean, 1994).

2.1.1 Bilinguals and Language Processing

Many theories are postulated about the way bilingual individuals process language. It is common knowledge that like their monolingual counterparts, the left hemisphere is dominant in language production and processing (Grosjean, 1994). In more recent neurolinguistic studies, it has been accepted that the bilingual individual has his own linguistic configuration (Grosjean, 1989). Originally it was believed that bilinguals stored all language in the same area, but this was disproven, as injury to the area did not result in a loss of all languages. It is now believed that some language areas are shared, while others remain separate, as no activation differences have been found during certain tasks (Lorenzen & Murray, 2008). It has been suggested that processing and activation is linked to proficiency of the bilingual in each language (Ansaldo et al., 2008). As many studies have suggested, neurological mapping of the bilingual brain is still considered terra incognita.

Psycholinguistic studies also show many different models of how bilinguals access and control their languages. The more dominant of the models is the Revised Hierarchal Model (RHM). This model is based on the idea that each bilingual has two separate lexical, or word form, inventories with one shared semantic, or concept, inventory. Each lexical inventory has access to the semantic inventory, as well as to the other lexical inventory, but these links are strengthened by fluency and use of the language. When a bilingual individual is first learning L2, they link the word with the corresponding word in L1 and access word meaning through L1. As the individual becomes more fluent in L2, the connection to the L1 lexical inventory can be bypassed and L2 can link directly to the semantic inventory (Figure 2.1) (Lorenzen & Murray, 2008; Kotz & Elston-Guttler, 2004, Peña et al, 2012). When the individual learns languages at the same time, it is possible that L2 develops the links to the semantic inventory just as strongly
Figure 2.1 Representation of the Revised Hierarchical Model

a) When a bilingual individual is learning L2, their lexical inventory for L2 is linked to the lexical inventory of L1 and can only access the semantic inventory through this connection. b) As the individual increases fluency of L2, the semantic inventory can be accessed through both the L1 and L2 lexical inventories.

As L1. This is also changed as language dominance changes. If L1 is not used as frequently as L2, it is possible the link between the L1 lexical inventory and semantic inventory deteriorates and the link between the L2 lexical inventory and semantic inventory is strengthened (Kotz & Elston-Guttler, 2004). In general the RHM states that for less proficient bilinguals, L2 needs to be translated into L1 in order to be conceptually processed. A study by Kotz and Elston-Guttler (2004) demonstrated that less proficient bilinguals have less automated semantic processing than early bilinguals and native bilinguals. This decrease in autonomous processing can result in slower reaction times, though more evidence is needed to support this idea.

Not only do bilingual individuals have to deal with different linguistic units, but they also have to be able to control their languages. The bilingual individual has no way to turn off their bilingualism and process language in a monolingual mode, therefore there will always be interference between the two languages (Desmet & Duyck, 2007). Though it is not entirely
understood how bilinguals control the interference, studies show that it causes delays in processing, known as the “language-switching cost” (Abutalebi et al, 2007). In studies that use various priming tasks, the results show that picture naming in L1 has reduced latencies, but once L2 is introduced, naming in L1 increases in latencies, suggesting that L1 has been inhibited in order to access L2. This inhibition needs to be bypassed in order for the individual to access L1 again, contributing to the increase in processing times.

2.2 Bilingualism and Code-Switching

In communities where the majority of habitants are bilingual, such as El Paso, it is not uncommon to hear bilingual speakers code-switch mid-conversation (Moreno et al., 2002). Code-switching, also known as language switching, is the insertion of words or phrases from one language into sentences or discourse in the other language (Paradis, 2012). This phenomenon allows for swapping of languages within conversations, and can occur for a variety of reasons, including the inability to recall a word in a language, to show emphasis, for formulaic speech, and even to promote in-group inclusion (Proverbio et al., 2004; Moreno et al., 2002; Paradis 2012). These language switches tend to be viewed negatively by some and are associated with linguistic incompetence. However, according to Paradis (2012), language switching is not done without following proper syntactical and semantic structure. In other words, it is rule-governed and sophisticated form of speaking. These code switches are not randomly inserted, they occur when there is equality between the two grammar structures, and it takes a proficient bilingual to make these switches correctly (Paradis, 2012). A typical strategy in code switching is to make the switch between nouns and auxiliary verbs and keep the auxiliary and main verbs in the same language. Take for example the two sentences provided by Paradis (2012):

Ex: a) “The students habian visto la pelicula italiana

Ex: b) The students had visto la pelicula italiana” (p.83)

In example a, the language switch is made between the noun and auxiliary verb, making it an appropriate, or grammatical, change. In example b, the switch is made between the auxiliary and
main verb, making it sound awkward and ungrammatical. Though they might not know why, proficient bilinguals are able to reject these “illegal” ungrammatical language switches by relying on subconscious grammatical knowledge of both languages (Anderson & Toribio, 2007). According to a study conducted by Toribio, proficient bilinguals rejected language switches in an invented narrative read aloud task; the participants claimed the switches appeared “forced” and even made recommendations to make the switches more appropriate (2007).

We now know that proficient bilinguals can distinguish grammatical and ungrammatical switches, but need to have a better understanding of how the difference in syntax impacts processing. In a study that examined a group of Italian-French bilinguals, Abutalebi, et al. (2007) found that ungrammatical language switches were processed differently than grammatical language switches. While the grammatical switches were simply processed semantically, requiring less effort, ungrammatical switches were processed more syntactically, suggesting an increase in processing demands. Further studies on language switches also show that even when the switch is an expected word, but different than the base language, an increase in semantic processing is observed. When the switch is unexpected, and different than the base language, increased processing times are also seen. The results of these studies suggest that proficiency is a key factor in processing times (Moreno et al., 2002).

2.3 Aphasia

Aphasia is characterized as an acquired language disorder that affects the production and/or comprehension of all modalities of language, including speech, reading, writing, and auditory comprehension (Darley, 1982). While most aphasias are caused by damage to the left hemisphere of the brain, or the hemisphere that contains the language zones, those with right hemisphere damage can demonstrate acquired language disorders that can be characterized as aphasia (Ansaldo et al., 2008). The most common cause of aphasia is a cerebral vascular accident (CVA), more commonly referred to as a stroke. According to the Center for Disease Control (CDC), almost 800,000 people in the United States will suffer a stroke every year,
resulting in over 100,000 new cases of aphasia (CDC, 2014; National Aphasia Association, 2007). With the rise in bilingualism, it is currently expected that out of all the new cases, approximately 45,000 of them will occur in multilingual individuals (Paradis, 2001).

There are three main categories of aphasia: fluent, non-fluent, and mixed aphasia. Fluent aphasia is characterized by fluent, but possibly nonsensical speech. Meaning the individual is able to fluently produce speech, but may not be conveying a meaningful message. Those with fluent aphasia also tend to have receptive language deficits. Non-fluent aphasia is characterized by non-fluent, halting, and effortful speech. Receptive language tends to remain intact for those with non-fluent aphasias. Mixed aphasia is a result of a combination of both fluent and non-fluent aphasia (Manasco, 2014). The type of aphasia an individual acquires is dependent on the location of the lesion and damaged cerebral region. Fluent aphasias are a result of damage to Wernicke’s area, an area in the temporal lobe associated with interpretation and derivation of meaning. Non-fluent aphasias are associated with damage to Broca’s area, located in the inferior posterior frontal lobe and associated with assembly of words to convey a message (Manasco, 2014).

Two common symptoms of aphasia are verbal comprehension deficits and agrammatism. It is not uncommon for a person that suffers from aphasia to have difficulty processing verbal language, especially when it is lengthy and detail heavy, as this requires more neural processing (Manasco, 2014). Agrammatism, or the lack of proper grammar, is also seen in individuals with aphasia. Studies show that some individuals with aphasia have difficulty processing sentences that do not follow traditional Subject + Verb + Object (SVO) structure, such as passive sentences (Thompson et al., 2003). It has been suggested that these deficits are not due to semantic and syntactic storage deficits, but rather deficits in accessing the information in real-time (Swaab et al., 1997).
2.4 Bilinguals and Aphasia

Recovery of language in bilingual aphasia is currently a critical issue in the field. Since the number of individuals that speak more than one language in the world is increasing, it is highly likely that cases of bilingual aphasia will soon account for the majority of aphasia diagnostics (Ansaldo et al., 2008). However, because the bilingual brain is still very much an uncharted territory, little is known about how and why languages are recovered after injury (Edmonds & Kiran, 2006). Some thought that if languages all came from the same shared areas, then injury would result in all languages having parallel or similar deficits. However, this is not the case (Paradis, 1977).

Two major hypothesis of language recovery in bilingual aphasia were found to have no greater than chance accuracy (Gitterman et al., 2012). Ribot proposed the first theory in 1881, claiming that the first language learned would recover first. In 1895, Pitres argued that the language used most around the time of damage would be the language recovered first (Gitterman et al., 2012). Recently however, it was reported that many different recovery patterns are observed. For example, Paradis (1977) reports the following six patterns: Parallel, differential, selective, blended, antagonistic, and successive. Parallel recovery refers to both languages improving at the same rate. Differential recovery occurs when one language recovers better than the other. Selective language recovery is seen when only one language recovers, blended recovery is language mixing, successive recovery occurs when one language recovers before the other, and antagonistic recovery is when one language improves while the other regresses (Lorenzen & Murray, 2008; Paradis, 1977).

Traditionally, therapy has been given in one of the two languages, however, by only treating one language, the bilingual individual with aphasia is being limited in their communicative ability (Ansaldo et al., 2008). Because of this, the ideal therapy would involve both languages and have cross-linguistic generalization. In a study conducted by Edmonds and Kiran (2007), the basis of the RHM was used for recovery purposes. The RHM states that when L2 is weaker, concepts are accessed through the L1 lexical inventory, and vice versa if L1 is
weaker. The authors of the study took 3 bilingual individuals with aphasia and applied treatment based on the RHM principle. Participants were treated in their pre-morbid least proficient language. All 3 participants demonstrated cross-linguistic generalization to the stronger language, even though it was not directly treated. Though this study by Edmonds and Kiran (2007) shows promise, it is important to note that the participants were not balanced bilinguals, meaning there was a language more dominant than the other. Further studies need to be conducted to determine whether this same approach can also be applied when an individual is a balanced bilingual.

2.5 Aphasia and Language Switches

For bilingual individuals with no history of brain damage, controlling their two languages from interfering with one another is done with ease. The individual is aware of when it is appropriate to switch between languages according to the communicative situation. The same cannot be said about bilingual individuals with brain damage. Bilinguals with aphasia switch between languages at inappropriate contexts. This phenomenon is known as pathological language switching or mixing (Ansaldo et al., 2008). In bilinguals with aphasia, language switching occurs spontaneously, even during a conversation with a monolingual and after the individual is asked to stick to one language. This causes visible frustration in an individual, as they are failing to control the interference between the two languages. This pathological mixing may indicate deficits in cognitive control, and can handicap communicative abilities (Ansaldo et al., 2008; Kohnert 2004). Though an individual may be displaying pathological mixing, this does not indicate that comprehension is affected. In a study reported by Fabbro in 2000, an Italian-Friulian bilingual demonstrated comprehension in both languages, but had no control over switching between the two languages (Green & Abutalebi, 2008).

Though language mixing is seen in individuals with aphasia, it cannot be used to indicate a linguistic deficit. According to Grosjean (1985), there are many factors that need to be taken into account about the testing situation before making the assumption that the individuals
switching is indicative of a linguistic deficit. For example, if the individual was aware that the examiner is bilingual, they are more likely to code-switch often. The individual’s premorbid language use is also of importance, as their performance post-injury may be similar, if not the same, as that of prior to injury. He also argued that excessive language mixing by an individual with aphasia is simply a strategy used to compensate for their communication deficits (Grosjean, 1985). This claim is further supported by a study conducted by Muñoz et al. (1999). The study compared patterns of code-switching between four bilinguals with no history of brain damage to four bilinguals with aphasia. The study found that a communication difficulty due to inappropriate switching with a monolingual and the use of ungrammatical switches was only found in the bilinguals with aphasia. Furthermore, it was determined that bilinguals with aphasia had a greater frequency of code-switching than their neurologically intact individuals, and had different types of switches. Therefore making the type of switch more important to look at than the frequency of switches.

2.6 ERP

The study of neurophysiology via measuring of electrical activity has been around for several decades. Electroencephalography (EEG) was first established in the early 1930s and is used to measure electrical activity in the brain of an individual. This was accomplished by attaching a skullcap with electrodes to the skull, along with electrodes to the face. Electrical activity can then be detected and recorded. However, this raw EEG data cannot do much other than determine whether a person is awake or asleep. In order to connect brain activity with a certain sensory, motor, or cognitive task, a more detailed and specific analysis is required. This is where we introduce event-related potentials, or ERP (Luck, 2005). ERP are time-locked measures of electrical activity at the cortical level that are taken through the several electrodes attached to the skullcap. By time-locking the ERP, we are able to link electrical activity in response to both internal and/or external stimuli (Handy, 2005; Luck 2005). ERP are composed of very small voltages and must be filtered and averaged in order to arrive at the relevant
components (Luck, 2005). The waveform of an ERP contains voltage deflections that are negative and positive. These negative and positive voltage deflections are related to the component of interest. These components consist of negative and positive peaks that are labeled N (negative) and P (positive). These peaks are measured in milliseconds (ms) for latency of response and microvoltage (mv) for amplitude (Luck, 2005).

Certain ERP components are associated with cognitive responses such as language and attention. The language components are the N400 and the P600. The N400 is a negative going peak occurring at approximately 400ms post onset of stimuli and is usually seen in in electrodes over the central and parietal areas. The N400 ERP component is associated with semantic processing and unexpected words (Luck, 2005). The N400 tends to be generated in the left temporal lobe, which corresponds to the language centers. The P600 is a positive occurring peak occurring approximately 600ms post onset of stimulus. This component has been linked to syntactic violations.

2.7 ERP and Language Switches

The use of ERP in neurocognition in bilinguals is fairly recent. Moreno et al. published the first ERP study looking at language switches in English-Spanish bilinguals (2002). The study looked at unexpected lexical switches within the same base language, as well as unexpected code-switches. The unexpected lexical switches generated a larger N400, suggesting semantic processing. The study also found that code-switches were characterized by a large positive peak between 450-800ms post-onset of stimulus (Moreno et al., 2002). This positive peak correlates with the P600 peak that has been associated with unexpected syntactic processing, however, the authors associated this peak with the unexpectedness of the language switch. Peak amplitude and latency was also affected by the proficiency of the participant. Those that were more proficient in Spanish had an earlier peak (reducing latency), and found the switch less difficult to process (decreasing amplitude) (Moreno et al., 2002).
A study by Proverbio et al. (2004) used ERPs to look at processing of code-switches in Italian-English interpreters. In this study language proficiency was not an issue, as interpreters are required to be highly proficient in both languages. The study found there was still an increase in N400 amplitude when switching from L1-L2. This suggests that though proficiency may play a role in N400 amplitude, an increase in amplitude of the N400 ERP component can still be due to the language switch on its own (Proverbio et al., 2004).

The ERP research on language switches in neurocognitive intact bilingual individuals and language switching is very limited, as only a handful of studies have been conducted. Furthermore, the studies that have been conducted have demonstrated much variation in both experimental design and outcomes (Moreno et al., 2008). However, Moreno and colleagues (2008) state that research in this area is promising.

2.8 ERP and Aphasia

In the past, behavioral methodology has been used to measure recovery of aphasia and to predict recovery patterns. However, these methods do not provide correlation between anatomical structures and the functional and temporal processes involved in recovery. In addition, many individuals with aphasia suffer from physical disabilities that greatly limit the efficacy of behavioral assessment instruments (D’Arcy et al., 2003). Advances in neuroimaging technology provide new avenues to explore aphasia. The neuroimaging options most commonly used in aphasia research are Functional Magnetic Resonance Imaging (fMRI), Positron Emission Tomography (PET), and Event Related Potentials (ERP) (Handy, 2005).

ERP is used to examine the functional brain activity reflected in the electrical activity that is produced in the brain in response to spoken messages. The electrical activity is measured through the skull with electrodes that are attached to a skullcap. While fMRI and PET are excellent tools to localize anatomical structures, they do not provide information regarding the functional and temporal processes that occur in response to stimuli. ERP, on the other hand, provides real-time information in the millisecond range, since it is time-locked to a specific
stimulus event. Cost and availability make the use of fMRI and PET prohibitive in clinical and research settings. Additionally, fMRI and PET are considerably more invasive than ERP (Handy, 2005). These characteristics make ERP an excellent tool for the study of aphasia.

Currently, most neuroimaging studies in aphasia use only PET and fMRI. These studies contribute to the information we have about aphasia. These studies have confirmed the involvement of the frontal and temporal regions of the left hemisphere in aphasia, as well as the brain recovery that is associated with the first few months post-stroke. However, these studies have limitations as well. Simply because an area is activated during a task does not indicate that this area is responsible for the processing of the task. Therefore, functional neuroimaging cannot tell us why there is activation of particular areas (Ramage et al., 2008). Moreover, when a person is unable to complete a task, the corresponding damaged neural systems will not be identified because there will be no expression of neural activity associated with the task. One suggestion to improve this limitation is to scan patients early on post-stroke and again after efficacious language therapy has been implemented (Ramage et al., 2008). The first major issue with this solution is the lack of efficacious language therapy research in aphasia literature. The variability from patient to patient has not allowed for clear efficacious treatment that can be generalized. The second issue is the cost, both monetary and temporal, of the imaging tasks.

ERP can add much more to the literature on aphasia research because of the strengths of the technique. One major strength of ERP is that they are time locked to an event. Furthermore, ERP does not require a behavioral response, such as the functional imaging techniques. According to Ramage et al., (2008), the use of ERP can also help determine the entire network of regions that are involved in completion of a task (2008). Because of the ease of accessibility and noninvasive nature of ERP to researchers, in comparison to functional imaging, it would also be more likely to obtain pre/post-therapy information of an individual with aphasia.

Furthermore, it is important to consider the population that will be the basis of the research. Because the main cause of aphasia is a CVA, it is likely that the participant will also have physical limitations that make fMRI or PET difficult. Similarly, CVAs are more likely to
occur later in life, making the age of the participant an important variable as well. For these reasons, experimental design, as well as the research questions, need to be fully analyzed before deciding on the imaging technique (Handy, 2005).

2.9 Summary

Language switches are a common occurrence in bilingual individuals, and like both base languages, these switches are done following grammatical rules. These language switches can cause a processing delay known as a language-switch cost, as one language needs to be inhibited. This cost is directly associated with proficiency in the languages. The less proficient the individual is in a language, the longer the delay in processing. When syntactical abnormalities are factored in, results of studies show that these switches can increase processing times in individuals with no history of brain damage.

ERP studies looking at language switches in bilingual individuals with no history of brain damage have found a large N400 peak when there is a lexical switch, suggesting an increase in lexical processing. Large late positive peaks, the P600, have also been seen with unexpected syntactic processing, suggesting an increase would be seen with ungrammatical sentences. Furthermore, in a study by Abutalebi et al. (2007), it was reported that in French/Italian bilinguals, grammatical switches resulted in an increased syntactic processing while ungrammatical switches resulted in increased syntactic processing.

Based on the review of the available literature, it is clear that there is limited information about how language switches are processed in bilingual individuals with aphasia, and what role syntax plays in that processing. In the past, ERP studies that look at language switches focused on bilingual individuals with no history of brain damage. Because of what we know about aphasia, and how agrammatism and pathological language mixing can be seen, it is not unexpected that individuals with aphasia produce, and have difficulty processing, ungrammatical language switches.
This study aims to add to the literature and provide a basis for future research to help understand how language switches are processed in bilingual individuals with brain damage. By gaining a better understanding of how this is done, treatment approaches can be developed to help this population improve their communicative function.
Chapter 3: Methods

3.1 Participants

Participants included five English-Spanish bilingual individuals with aphasia and eight English-Spanish bilingual individuals with no history of brain damage. All participants were recruited from the El Paso area, including the Stroke Support Group and the UTEP Speech, Language, and Hearing Clinic. Inclusion criteria for the participants with aphasia was: English-Spanish bilingual, diagnosis of left hemisphere stroke, diagnosis of aphasia, assessment using the Western Aphasia Battery – Revised (WAB-R, Kertesz, 2006) for confirmation of aphasia type and severity, normal or corrected-to-normal vision, and normal or corrected-to-normal hearing. Inclusion criteria for individuals with no history of brain damage was: English-Spanish bilingual, no documented history of brain damage, normal or corrected-to-normal vision, and normal or corrected-to-normal hearing. Individuals were considered bilingual if they were proficient in spoken English and Spanish as determined by a language proficiency questionnaire. Participants with aphasia were assigned to the experimental group. Participants with no history of brain damage were assigned to the control group.

The control group consisted of eight English-Spanish bilingual individuals ranging in age from 45 to 71 years with a mean age of 58.3 years. There were five males and four females included in the control group. Table 3.1 shows the control group characteristics. All participants in the control group reported equal to close to equal proficiency in both languages, making them balanced bilinguals.
The experimental group consisted of five participants, two males and three females, previously diagnosed with aphasia by a physician and/or speech-language pathologist. Participants ranged in age from 37 years to 63 years, with a mean age of 52.4 years. All five participants were diagnosed with a fluent aphasia. Severity levels, as measured by the Western Aphasia Battery – Revised (Kertesz, 2006), ranged from mild to severe. Time post-onset of injury ranged from 1 year to 12 years. All participants reported being balanced bilinguals before their stroke. However, post-stroke, four reported being Spanish dominant, and one reported being English Dominant. Table 3.2 shows the characteristics of the participants in the experimental group.

### Table 3.2 Participants: Aphasia

<table>
<thead>
<tr>
<th>PARTICIPANT</th>
<th>AGE</th>
<th>GENDER</th>
<th>BILINGUAL PROFICIENCY</th>
<th>APHASIA TYPE</th>
<th>SEVERITY</th>
<th>TIME POST-ONSET</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-01</td>
<td>49</td>
<td>M</td>
<td>Spanish Dominant</td>
<td>Fluent</td>
<td>Severe</td>
<td>1yr</td>
</tr>
<tr>
<td>A-02</td>
<td>63</td>
<td>M</td>
<td>Spanish Dominant</td>
<td>Fluent</td>
<td>Moderate</td>
<td>4.5yrs</td>
</tr>
<tr>
<td>A-03</td>
<td>57</td>
<td>F</td>
<td>English Dominant</td>
<td>Fluent</td>
<td>Mild</td>
<td>7.5yrs</td>
</tr>
<tr>
<td>A-04</td>
<td>56</td>
<td>F</td>
<td>Spanish Dominant</td>
<td>Fluent</td>
<td>Mild</td>
<td>12yrs</td>
</tr>
<tr>
<td>A-05</td>
<td>37</td>
<td>F</td>
<td>Spanish Dominant</td>
<td>Fluent</td>
<td>Moderate</td>
<td>~9yrs</td>
</tr>
</tbody>
</table>

Participants in both groups completed the following tasks: pure-tone hearing screening, self-report medical history questionnaire, self-report language proficiency questionnaire, Annett.
Handedness Inventory (Annett, 1970), and the experimental task. The self-report language questionnaire was rated on a scale from 1-5, with 5 being very proficient and 1 being not proficient. Participants were asked about all modalities of language, including social conversation, reading, writing, comprehension, and vocabulary. Participants in the experimental group were additionally administered the Western Aphasia Battery – Revised (WAB-R; Kertesz, 2006) in order to determine aphasia type and severity. The WAB-R was administered in English, if the participant did not understand or showed difficulty, the test was then translated into Spanish.

3.2 Experimental Design

The current study uses Event Related Potentials (ERP) to examine the peak latency and amplitude of the N400 and P600 ERP components between bilingual individuals with aphasia and bilingual individuals with no history of brain damage during an auditory task. This study compares two groups of different individuals exposed to four different conditions. Therefore, this study is a between-group, repeated measures design. Because the participants were not randomly assigned to groups, this is a quasi-experimental study. The independent variable is dichotomous: individuals with aphasia vs. individuals with no history of brain damage. The dependent variable is continuous, as measured by peak latency and amplitude.

3.3 Experimental Task

3.3.1 Task Design

The experimental task consists of a total of 80 sentences, divided into a total of four blocks, with each block containing 20 sentences, or trials. There are two English blocks and two Spanish blocks. Each sentence in each block contains either a grammatical or ungrammatical language switch. Superlab Presentation Software (Cedrus Corporation, 2008) was used to create and present the task. Audio recordings of the sentences were uploaded to Superlab Presentation Software (Cedrus Corporation, 2008). Event markers, also known as triggers, were added to each sentence. Triggers mark the events of interest for data collection. Three triggers were
added to each trial. Trigger 1 marked the beginning of a trial, trigger 2 marked the beginning of the language switch and trigger 3 marked the end of the sentence. An ISI, or interstimulus interval, of 3000ms was placed at the end of each trial.

3.3.2 Stimuli

The task stimuli consisted of 80 sentences with a language switch inserted in the sentence. The language switch was inserted in either a grammatical or ungrammatical manner. When a bilingual speaker switches between two languages in the middle of an utterance, the switch is made in a position of the sentence to still follow grammatical rules of the languages. This is considered a grammatical language switch. Grammatical language switches were inserted where it is deemed appropriate for a native speaker to make a switch. When the language switch made does not follow the rules of grammar, it is considered an ungrammatical switch. Ungrammatical switches were inserted to violate grammatical rules for the languages. The eighty sentences were broken up into 4 different blocks: English to Spanish – grammatical, English to Spanish – ungrammatical, Spanish to English – grammatical, and Spanish to English – ungrammatical. Sentences were obtained from various standardized language assessments to control for content and structure. A native English-Spanish bilingual female recorded all sentences.

3.3.3 Reliability

All sentences used were taken from standardized behavioral language assessments, including the Clinical Evaluation of Language Fundamentals-5 (Semel et al, 2013, CELF-5), Detroit Test of Learning Apptitude-4 (Hammil & Bryant, 1991, DTLA-4), Rhode Island Test of Language Structure (Engen & Engen, 1983, RITLS). Grammatical language switches were inserted where it is deemed appropriate for a native speaker to make a switch. Ungrammatical switches were inserted to violate grammatical rules for the languages. A native English-Spanish bilingual individual with grammatical knowledge of both languages verified all switches.
In order to control for possible accent of the speaker recording the sentences, five bilingual individuals not participating in the research study rated the audio recordings using a Likert scale of 1-7 for accent severity, where 1 indicated native speech and 7 indicated heavily accented speech. Rating results showed that the speaker was considered to have native to near native speech in both languages. Table 3.3 shows the results of the ratings completed by the five individuals not participating in the study.

**Table 3.3 Likert Rating of Speech Accentedness**

<table>
<thead>
<tr>
<th>RATER</th>
<th>LIKERT SCALE RATING - ENGLISH</th>
<th>LIKERT SCALE RATING - SPANISH</th>
<th>RATING INDICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>7</td>
<td>Native</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>7</td>
<td>Native</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>6</td>
<td>Near Native</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>7</td>
<td>Native</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>6</td>
<td>Near Native</td>
</tr>
</tbody>
</table>

### 3.4 Procedure

All participants were given an informed consent (Appendix A). The purpose of the study and procedures used were explained to the participant by the principal investigator. The participants were informed that participation was completely voluntary and had the option to withdraw from the study at any point. Once all questions were answered, the participant was asked to sign the informed consent.

All participants were required to fill out the self-report medical questionnaire (Appendix B), self-report language proficiency questionnaire (Appendix C), Annett Handedness questionnaire (Appendix D), and participate in a pure-tone hearing screening. The hearing screening was completed in both the left and right ears at 25 decibels at 1000 Hz, 2000Hz, and
4000Hz. Individuals in the experimental group were also administered the WAB-R (Kertesz, 2006) in order to confirm diagnosis of aphasia and determine aphasia type and severity.

Electrophysiological procedures were completed as follows. The participant’s head was measured for circumference, from nasion to inion, and from tragus to tragus. The participant was fitted with the best fitting electrode cap based on his/her head measurements. Electrodes were applied according to Biosemi procedures of conduction gel and amplified electrodes. The participant was seated comfortably in a 6X6 soundproof room and instructed to move as little as possible. An Entuitive Touch Monitor was placed in front of the participant at a distance of 18cm. The participant was instructed to look at the white square in the middle of the black screen that appeared on the touch monitor, and listen to the sentences that were presented auditorially via speakers. Speakers were placed at a distance of 21cm from the participant. No motor or behavioral response was required of the participant.

3.5 Data Collection and Analysis

ERP (event related potentials) is a non-invasive technique used to measure electrophysiological activity produced in the brain in response to internal and external stimulus. Electrical activity was collected from 64 electrodes that were placed across the parietal, frontal, temporal, and occipital areas of the scalp, according to the International 10-20 system (Figure 2.1). Six external electrodes placed above the left eye, below the left eye, at both left and right temples, and at both left and right mastoids were used for artifact rejection. Artifacts include vertical and horizontal eye movement, eye blinks, and muscle artifacts. All electrodes were referenced to the left and right mastoids (Handy, 2005).
All data was recorded using ActiView from BioSemi (2008). Sampling rate was set at 2080Hz, bandpass was at set at 0.1 Hz for the low cut off with a 12 dB slope, and a high cut off at 30 Hz, the notch filter was set at 60Hz. Vision Analyzer (Cortech, 2008) was used to analyze and filter all data offline. Data was analyzed at a sampling rate of 512Hz. EEG raw data was segmented to an epoch from 5ms before the presentation of the stimulus to 5000ms after the presentation of the stimulus. Four separate averages of the trials were taken for each participant: English-Spanish Grammatical, English-Spanish Ungrammatical, Spanish-English Grammatical, and Spanish-English Ungrammatical. Peak amplitude and latency of the N400 and P600 were taken for each participant for each average, at three different electrodes: Cz T7, and T8. Grand averages were completed for each group for each average. N400 was operationally defined as the largest negative peak occurring between 350-600ms post-onset of stimulus. P600 was operationally defined as the largest positive peak occurring between 550-800ms post-onset of stimulus. After filtering, two participants from the control group were eliminated from the study, as there was no signal in the electrodes of interest.

3.6 Statistical Analysis and Visual Inspection

Based on the research question, comparison ANOVAs were used to determine if a statistically significant difference in peak latency and amplitude of the N400 and P600 ERP
components between the two groups exists. SPSS 22 (IBM Corp, 2013) was used to run a mixed design ANOVA to obtain within-subjects and between-subject effects of averages of peak amplitude and latency at the Cz, T7, and T8 electrodes. The four language switches were used as repeated measures to obtain effects within subjects. Visual inspection was used to compare Grand Average waveforms of both groups for each different condition (switch type). Cortical activation maps were also inspected. Cortical activation maps were derived at highest peak amplitude and latency.
Chapter 4: Results

4.1 Statistical Analysis

Mixed-design ANOVAs were done to compare the averages of peak amplitude and latency of the N400 and P600 ERP components of the control and experimental groups. Statistical analyses were completed for all three electrode sites of interest: Cz, T7, and T8. The ANOVA was used to calculate if there were any significant effects of the type of switch and the group on the amplitude and latency. No significant main effects were found at any of the electrode sites for either N400 or P600. Statistical results are shown in Table 4.1. Descriptive statistics are shown in tables 4.2 and 4.3.

<table>
<thead>
<tr>
<th>SITE</th>
<th>ERP COMPONENT</th>
<th>SWITCH</th>
<th>SWITCH x GROUP</th>
<th>GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>F(df)</td>
<td>P-Value</td>
<td>F(df)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cz</td>
<td>N400 Amplitude</td>
<td>.83(3, 1)</td>
<td>0.49</td>
<td>2.06(3, 1)</td>
</tr>
<tr>
<td></td>
<td>Latency</td>
<td>.58(3, 1)</td>
<td>0.64</td>
<td>1.0 (3, 1)</td>
</tr>
<tr>
<td></td>
<td>P600 Amplitude</td>
<td>2.04(3, 1)</td>
<td>0.13</td>
<td>.32(3, 1)</td>
</tr>
<tr>
<td></td>
<td>Latency</td>
<td>1.54(3, 1)</td>
<td>0.23</td>
<td>.33(3, 1)</td>
</tr>
<tr>
<td>T7</td>
<td>N400 Amplitude</td>
<td>2.5 (1.2, 1)</td>
<td>0.15</td>
<td>.61(1.2, 1)</td>
</tr>
<tr>
<td></td>
<td>Latency</td>
<td>1.5(3, 1)</td>
<td>0.23</td>
<td>.33(3, 1)</td>
</tr>
<tr>
<td></td>
<td>P600 Amplitude</td>
<td>.33(3, 1)</td>
<td>0.80</td>
<td>.58(3, 1)</td>
</tr>
<tr>
<td></td>
<td>Latency</td>
<td>.89(3, 1)</td>
<td>0.46</td>
<td>.42(3, 1)</td>
</tr>
<tr>
<td>T8</td>
<td>N400 Amplitude</td>
<td>.86(3, 1)</td>
<td>0.47</td>
<td>.39(3, 1)</td>
</tr>
<tr>
<td></td>
<td>Latency</td>
<td>1.29(3, 1)</td>
<td>0.30</td>
<td>2.01(3, 1)</td>
</tr>
<tr>
<td></td>
<td>P600 Amplitude</td>
<td>2.27(3, 1)</td>
<td>0.10</td>
<td>.22(3, 1)</td>
</tr>
<tr>
<td></td>
<td>Latency</td>
<td>.21(3, 1)</td>
<td>0.89</td>
<td>.34(3, 1)</td>
</tr>
</tbody>
</table>

For Cz N400 amplitude, there were no significant main effects. The main effect for the type of switch, \((F(3, 1) = .83, p=.49)\), the main effect for the group \((F(1, 9) = .67, p=.43)\), and the main effect for group x switch \((F(3,1) = 2.06, p=.13)\) were not significant. For Cz N400 latency,
there was no statistically significant difference. The main effect for the type of switch, \( F(3,1) = .53, p=.64 \), the main effect for the group \( F(1,9) = 1.9, p=.20 \), and the main effect for group x switch \( F(3,1) = 1.0, p=.41 \) were not significant. For T7 N400 amplitude, there were no significant main effects. The main effect for the type of switch, \( F(1.2,1) = 2.5, p=.15 \), the main effect for the group \( F(1, 9) = .14, p=.72 \), and the main effect for group x switch \( F(1.2,1) = .61, p=.48 \) were not significant. For T7 N400 amplitude, sphericity was not assumed, so corrections were made and degrees of freedom were corrected, using Greenhouse-Geisser. For T8 N400 amplitude, there was no statistically significant difference. The main effect for the type of switch, \( F(3,1) = .86, p=.47 \), the main effect for the group \( F(1,9) = 1.9, p=.20 \), and the main effect for group x switch \( F(3,1) = 1.0, p=.41 \) were not significant.

For Cz N400 latency, there were no significant main effects. The main effect for the type of switch, \( F(3,1) = .58, p=.64 \), the main effect for the group \( F(1,9) = 1.9, p=.20 \), and the main effect for group x switch \( F(3,1) = 1.0, p=.41 \) were not significant. For T7 N400 latency, there were no significant main effects. The main effect for the type of switch, \( F(3,1) = 1.3, p=.23 \), the main effect for the group \( F(1,9) = .17, p=.69 \), and the main effect for group x switch \( F(3,1) = .33, p=.81 \) were not significant. For T8 N400 latency, there were no significant main effects. The main effect for the type of switch, \( F(3,1) = 1.29, p=.30 \), the main effect for the group \( F(1,9) = 2.42, p=.15 \), and the main effect for group x switch \( F(3,1) = 2.01, p=.14 \) were not significant.

For Cz P600 amplitude, there were no significant main effects. The main effect for the type of switch, \( F(3,1) = 2.04, p=.13 \), the main effect for the group \( F(1,9) = .03, p=.87 \), and the main effect for group x switch \( F(3,1) = .32, p=.81 \) were not significant. For T7 P600 amplitude, there were no significant main effects. The main effect for the type of switch, \( F(3,1) = .33, p=.80 \), the main effect for the group \( F(1,9) = .22, p=.81 \), and the main effect for group x switch \( F(3,1) = .58, p=.64 \) were not significant. For T8 P600 amplitude, there were no significant main effects. The main effect for the type of switch, \( F(3,1) = 2.27, p=.10 \), the main
effect for the group \((F(1,9) = 2.45, p=.15)\) and the main effect for group x switch \((F(3,1) = .22, p=.88)\) were not significant.

Lastly, for Cz P600 latency, there were no significant main effects. The main effect for the type of switch, \((F(3,1) = 1.54, p=.23)\), the main effect for the group \((F(1,9) = .17, p=.69)\), and the main effect for group x switch \((F(3,1) = .33, p=.81)\) were not significant. For T7 P600 latency, there were no significant main effects. The main effect for the type of switch, \((F(3,1) = .89, p=.46)\), the main effect for the group \((F(1,9) = 1.7, p=.22)\), and the main effect for group x switch \((F(3,1) = .42, p=.74)\) were not significant. For T8 P600 latency, there were no significant main effects. The main effect for the type of switch, \((F(3,1) = .21, p=.89)\), the main effect for the group \((F(1,9) = 4.00, p=.08)\), and the main effect for group x switch \((F(3,1) = .34, p=.34)\) were not significant.

Because there was no statistically significant differences between N400 peak amplitude and latency, or P600 peak amplitude and latency between or within the subjects, the null hypothesis cannot be rejected.

**Table 4.2 Means and Standard Deviations for N400**

<table>
<thead>
<tr>
<th>SWITCH</th>
<th>GROUP</th>
<th>Cz</th>
<th>T7</th>
<th>T8</th>
<th>Cz</th>
<th>T7</th>
<th>T8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>E-S</strong></td>
<td>Control</td>
<td>-4.41(4.79)</td>
<td>-5.57(4.43)</td>
<td>-5.91(9.76)</td>
<td>.44(.05)</td>
<td>.46(.23)</td>
<td>.41(.22)</td>
</tr>
<tr>
<td></td>
<td>Experimental</td>
<td>-2.81(2.56)</td>
<td>-3.43(1.97)</td>
<td>-4.10(2.32)</td>
<td>.35(.21)</td>
<td>.44(.25)</td>
<td>.46(.08)</td>
</tr>
<tr>
<td><strong>Ungrammatical</strong></td>
<td>Control</td>
<td>-2.35(3.13)</td>
<td>-3.19(1.87)</td>
<td>-.84(1.50)</td>
<td>.30(.24)</td>
<td>.40(.21)</td>
<td>.18(.20)</td>
</tr>
<tr>
<td></td>
<td>Experimental</td>
<td>-3.89(2.85)</td>
<td>-4.39(3.87)</td>
<td>-5.28(4.36)</td>
<td>.40(.24)</td>
<td>.45(.09)</td>
<td>.47(.08)</td>
</tr>
<tr>
<td><strong>S-E</strong></td>
<td>Control</td>
<td>-6.78(9.28)</td>
<td>-6.83(11.34)</td>
<td>-7.77(12.46)</td>
<td>.44(.08)</td>
<td>.47(.04)</td>
<td>.39(.20)</td>
</tr>
<tr>
<td></td>
<td>Experimental</td>
<td>-8.72(13.65)</td>
<td>-11.66(12.51)</td>
<td>-8.63(10.85)</td>
<td>.38(.22)</td>
<td>.48(.11)</td>
<td>.51(.08)</td>
</tr>
<tr>
<td><strong>Grammatical</strong></td>
<td>Control</td>
<td>-3.99(3.76)</td>
<td>-2.57(2.24)</td>
<td>-3.26(3.42)</td>
<td>.41(.21)</td>
<td>.37(.19)</td>
<td>.43(.23)</td>
</tr>
<tr>
<td></td>
<td>Experimental</td>
<td>-1.48(2.03)</td>
<td>-1.59(2.36)</td>
<td>-6.94(7.02)</td>
<td>.20(.27)</td>
<td>.26(.24)</td>
<td>.37(.22)</td>
</tr>
</tbody>
</table>
4.2 Grand Average Waveforms

Grand average waveforms were taken at Cz to visually compare peak amplitude and latency of both groups at each language switch. Cz was used as it is centrally located and can give a better measure of overall electrical activity. Grand average waveforms are averages of all participant data compiled and averaged into a group. Waveforms for both groups were overlapped to show comparison. Figure 4.1 shows all grand averages at a Cz for all four types of language switches. The control group is depicted with a black line, while the experimental group is depicted with a red line. Black arrows are used to mark the region of the N400 ERP component, defined as the largest negative peak 350-600ms post onset of stimulus. Blue arrows are used to mark the region of the P600 ERP component, defined as 550-800ms post onset of stimulus.

During the grammatical switches, both groups demonstrate larger amplitude in the N400 component over the P600 component. The opposite effect is noted in the ungrammatical switches, a larger positive region in the P600 time frame. Overall, both groups follow a similar pattern in processing. In the English-Spanish grammatical switch, the control group
demonstrates a large N400 peak, suggesting semantic processing. The experimental group has both minimal N400 and P600 activity. During the English-Spanish ungrammatical switch, only a minimal N400 peak is seen, in contrast to large late positive activity. In the control group, the Spanish-English grammatical switch demonstrates a similar pattern as the English-Spanish grammatical switch, a large N400 peak with minimal late positive activity. The experimental group has a large amount of late positive activity, with a minimal N400 peak. During the Spanish-English ungrammatical switch, the experimental group does not show an N400 peak, but shows a larger P600 peak than in the grammatical switches. The control group has a minimal N400 peak, with most of the activity occurring as late positive peaks.

Overall, both groups follow the trend of large N400 peaks during grammatical switches and large P600 activity during ungrammatical switches. Though peak amplitude and latency differences are apparent between the groups, both groups follow a similar pattern of processing.
Figure 4.1 Grand Averaged Waveforms

Grand averaged waveforms of both groups were overlapped to compare peak amplitude and latency at the Cz electrode site for each language switch. The control group is shown in black, while the experimental group is shown in red. Black arrows mark the N400 regions (350-600ms post onset). Blue arrows mark the P600 region (550-800ms post onset). a) English-Spanish Grammatical switch; b) English-Spanish Ungrammatical switch; c) Spanish-English Grammatical switch; d) Spanish-English Ungrammatical switch.
4.3 Cortical Activation Maps

Cortical activation maps were taken to visually inspect the level of electrical activity during the task. The maps were derived from electrode Cz, as it is centrally located and can provide a better view of activity in each region. Each map was taken at the highest peak amplitude for the corresponding peak. Maps for each group were placed side by side in order to compare activity levels between the two groups. A comparison of activation maps was done for each different language switch. The maps are shown in Figure 4.2 – Figure 4.5.

4.3.1 N400 ERP Component

Figure 4.2a shows the cortical activation maps of the control and experimental groups during the English-Spanish Grammatical switch at Cz for the N400 ERP component. The control group displays high levels of localized activation in various regions, as well as some negative activity. The experimental group only displays high activation in the left frontal region. The activity is not as localized as that in the control group. In Figure 4.2b, the control group, again, shows high levels of activation in various regions, including the left temporal region, the region that is associated with language. The experimental group once again shows high activation in the frontal region, and minimal activation in the left temporal region. During the Spanish-English grammatical switch, Figure 4.3a, the control group shows similar activation to the previous grammatical switch suggesting the order of language did not affect activity levels. The experimental group shows minimal activation, with higher activity occurring in the lower left temporal region, with some additional negative activity occurring as well. During the Spanish-English ungrammatical switch, the control group demonstrated high activity in the frontal regions. The experimental group had some high activity in the right temporal and temporal-parietal area; a large amount of negative activity was noted on the right temporal and parietal regions. It is important to note that in this last switch, the experimental group did not have a negative deflecting peak within the operational definition of the N400. The cortical map was taken at the same time point as the control group for comparison purposes.
Overall, for cortical activation maps of the N400 ERP component at the Cz electrode site, the control group showed higher activation levels than the control group during all switches. The two grammatical switches showed similar activation, with localized high activity in various regions. The English-Spanish ungrammatical switch showed the highest amounts of activation, with high activation being noted in the temporal region. The experimental groups showed minimal activation in the temporal region, and most activation was seen in the frontal region. The null hypothesis is rejected, as there are differences between the cortical activation maps between the two groups at N400.

4.3.2 P600 ERP Component

Figures 4.4 and 4.5 are cortical activation maps that were taken at the Cz electrode site during the highest peak amplitude within the operational definition of the P600 ERP component, 550-800ms. Figure 4.4a is the cortical activation map at P600 during the English-Spanish grammatical switch. The control group shows high activity in various regions, including the parietal, frontal, and some temporal activation. All this high activity however, is very localized. The experimental group shows high activity in large portions of the right frontal region. Figure 4.4b is activation during the English-Spanish ungrammatical switch. The control group shows high levels of activation in both temporal regions with some activation in the parietal region. The experimental group, conversely, shows mostly negative activation. There is slight high activation in the frontal region, but not much else is activated.

Figure 4.5a is the Spanish-English grammatical switch. The control group activation follows the same pattern as previous maps, with high activation in various regions. The experimental group only has one point of high activation, in the frontal region. During the Spanish-English ungrammatical switch, the control group activation maps shows activity similar to previous maps from the experimental group, with high activation only present in the frontal regions. The experimental group also has activation in the frontal region, but its more marked in the right hemisphere vs. the left.
The cortical activation maps for the P600 showed much more negative activation for the experimental group, with the control group keeping high activity in various regions. The null hypothesis is rejected here as well, as there are differences between the cortical activation maps of the two groups at P600.
Cortical activation maps taken at the highest peak amplitude of the N400 at the Cz electrode. Control and experimental group maps are placed side-by-side for comparison. a.) Activation during the English-Spanish Grammatical switch; b.) activation during the English-Spanish Ungrammatical switch.
FIGURE 4.3 CORTICAL ACTIVATION MAPS OF CZ N400 DURING SPANISH-ENGLISH SWITCHES

Cortical activation maps taken at the highest peak amplitude of the N400 at the Cz electrode. Control and experimental group maps are placed side-by-side for comparison. a.) Activation during the Spanish-English Grammatical switch; b.) activation during the Spanish-English Ungrammatical switch.
Cortical activation maps taken at the highest peak amplitude of the P600 at the Cz electrode. Control and experimental group maps are placed side-by-side for comparison. a.) Activation during the English-Spanish Grammatical switch; b.) activation during the English-Spanish Ungrammatical switch.
Cortical activation maps taken at the highest peak amplitude of the N400 at the Cz electrode. Control and experimental group maps are placed side-by-side for comparison. a.) Activation during the Spanish-English Grammatical switch; b.) activation during the Spanish-English Ungrammatical switch.
Chapter 5: Discussion

5.1 Interpretation of the Results

The aim of this study was to compare the processing of language switches between a group of bilingual individuals with aphasia and a group of bilingual individuals with no history of brain damage. These language switches occurred under four different conditions: English-Spanish with a grammatical switch, English-Spanish with an ungrammatical switch, Spanish-English with a grammatical switch, and Spanish-English with an ungrammatical switch. ERP were used to look at electrical activity in response to the switches. The ERP components of interest were the N400 and P600, as they are the two components associated with language. Statistical analysis of the effects of each variable on peak amplitude and latency of the ERP components, as well as visual inspection of cortical activation maps and grand averaged waveforms, were used to compare the two groups.

The study found that though there were visual differences in peak amplitude and latency between the two groups, both groups follow a pattern previously seen by Abutalebi et al. (2007). The study by Abutalebi et al. (2007) reported that when French/Italian bilinguals were presented with grammatical and ungrammatical language switches, processing resulted in different patterns. The grammatical language switches resulted in a pattern of brain activity that was associated with semantic processing, while the ungrammatical switches showed a pattern more associated with syntactic processing. According to the literature, this would suggest that the semantic processing would result in a larger N400. The syntactic processing caused by the ungrammatical switches would then result in a larger P600 (Moreno et al., 2002). A P600 increase can be seen because of the syntactic anomaly that is found in the language switch, requiring syntactic processing to correct the error and process the sentence (Ansaldo et al., 2007; Moreno et al. 2002). In the grand average waveforms for the control group during the English-Spanish switches, the grammatical switch created a larger N400 peak than a P600 peak. For the experimental group, both the N400 and P600 peaks had similar amplitudes that were much lower.
than that of the control group. This suggests that semantic processing was not considerably more active than syntactic processing, even though there were no syntactic anomalies in the sentences. This can be due to the fact that there is a lesion in the language processing areas. If damage has occurred in the area that controls semantic processing, it would be expected to see a decrease in electrical activity. The ungrammatical switch produced a pattern with much higher activity in the P600 area than in the N400 area, suggesting syntactic processing was taking place.

During the Spanish-English switches, the grammatical switch in the control group showed a similar pattern as that of the English-Spanish switches. The group demonstrated a similar amplitude and latency for the N400 peak. This is expected, as all participants in the control group reported being balanced bilinguals, therefore more work should not have occurred when the base language is changed. The experimental group had a much larger N400 in the Spanish-English grammatical switch than in the English-Spanish switch, suggesting semantic processing was taking place. This is of interest, as we know that aphasia in a bilingual individual can affect each language in different ways (Paradis, 1989). It is possible that word and concept retrieval was affected more in one language than the other, therefore creating different activity patterns for semantic processing. During the Spanish-English ungrammatical switch, the experimental group once again followed a similar pattern of that of the control group. More electrical activity was seen in the P600 than in the N400. This is also of interest because syntactic processing remained at the same level in both languages, while semantic processing did not. These findings are not too surprising, as all the participants in the experimental group were diagnosed with a fluent aphasia. One of the characteristics of fluent aphasias is a word-finding deficit. Agrammatism, which is the lack of proper grammar, is a characteristic seen more in the non-fluent aphasias (Manasco, 2014).

Results of the statistical analysis resulted in no statistically significant difference or effects between the groups and switches, though changes were clearly seen in the waveforms. Of the five participants in the experimental group, two were only of mild severity; therefore, their deficits are not as marked as the rest of the participants. These two participants behaved more
like individuals with no history of brain damage, possibly skewing the numbers. Similarly, the control group had participants who behaved more like individuals with aphasia. Because of the small sample size, these variations in performance can have a high impact on means and therefore result in statistically non-significant results.

Analysis of the cortical activation maps resulted in marked differences in activation patterns between the two groups. For the cortical maps taken at the N400, during the English-Spanish grammatical switch, the control group had various regions of negative activity, as well as high activity. The experimental group had high activation localized to the frontal-temporal region; there was no overlap in activation. The N400 amplitude for this switch was low, suggesting there was no semantic processing occurring, resulting in no activation of these sites. The English-Spanish ungrammatical switch resulted in high activation in the control group, but not the experimental group. The control group had activation in all regions, while the experimental group only had activation in the frontal region. During the Spanish-English grammatical switch, the control group once again had activation in various regions. However, this time, the experimental group showed activation in the left temporal region. During the ungrammatical switch, both groups showed minimal activation.

For the P600, during the English-Spanish grammatical switch, the control group showed various regions of high activation while the experimental group showed more activation in the frontal region. Non-localized moderate activation was noted for the experimental group. For the English-Spanish ungrammatical switch, the control group had large amounts of moderate to high activity, while the experimental group showed only mostly negative activity. During the Spanish-English grammatical switch, the control group once again high activation in various regions, while the control group does not. The ungrammatical switch resulted in minimal activation for both groups.

The high activation in various regions of the control group can be a result of the many connections that are created in the bilingual brain. Because the languages are not in only one shared area (Paradis, 1989), it is possible this activation indicates the connection of the
languages. Furthermore, some of this activation may be due to the mechanisms that go into effect in order to control interference between the two languages (Abutalebi et al., 2007). The fact that we do not see this level of activation in the experimental group can be indicative of the lack of control of interference between the two languages, therefore resulting in pathological mixing. The temporal activation in the experimental group during the Spanish-English grammatical switch can be the result of semantic processing taking place. This activation is not present in the English-Spanish grammatical switch. Because the majority of the participants in the experimental group reported being Spanish dominant, it is possible semantic processing for English was never regained post-stroke.

Through visual examination of the grand average waveforms and the cortical activation maps, it is evident that while the individuals with aphasia follow a similar pattern of processing as the individuals with no history of brain damage during the ERP waveforms, it is not indicative of cortical activation required to process it. The cortical activation maps from the ungrammatical switch for the experimental group does not go along with the similar pattern of waveforms between the groups. As reported by Moreno et al. (2002), it is possible the activity displayed in the P600 is related, to a certain extent, to the unexpectedness of the switch, and not entirely to syntactic processing.

5.2 Clinical Implications

The study showed that although there was not a statistically significant difference in peak amplitude and latency of the N400 and P600 ERP components between the two groups or for each type of language switch, there are clear differences in the processing of language switches between the two groups and between the types of switches. Based on the results of the grand average waveforms and cortical activation maps, the individuals with aphasia did not process the language switches like the individuals with no history of brain damage. The idea that these individuals with aphasia lack control of interference between the two languages suggests that a speech language pathologist cannot focus on one language and not expect there to be interference...
from the other. For this reason, a bilingual approach may be more appropriate to allow the patient to use both languages. Furthermore, as many healthcare providers may not be highly proficient in more than one language, it is likely that this population is a culprit of ungrammatical switches. Though individuals with aphasia may be producing language switches, it is not indicative that they can process these language switches, especially when they are ungrammatical. Therefore, healthcare providers should be mindful of when they are switching between the two languages and making sure the patient understood what was said.

5.3 Limitations

There were several limitations to this study that require the results to be interpreted with caution. The first limitation was due to equipment malfunction. The wires connecting the electrodes to the output device appeared to have a short and would at times lose connectivity during the task. The task would then have to be repeated. This may have influenced the results because the participant was already familiar with the task. In addition, this could have contributed to the loss of signal from certain electrodes after filtrations. Another limitation is the small sample size used. This study examined electrophysiological activity in a pathological population and therefore recruiting participants that meet the criteria for the study was difficult. As a result, the number of participants available for inclusion was limited. This also results in a third limitation, as only individuals with fluent aphasia were recruited. Therefore, because of the small sample size and restriction of aphasia type, the results cannot be generalized to a larger population or to those with a non-fluent or mixed aphasia.

5.4 Future Research

Because of the various limitations of the study, future research in this area can start with addressing those issues. Studies with a larger sample size would be beneficial to examine whether similar results would be obtained with a larger sample size. In addition, if this study would have included individuals with non-fluent aphasia, there could have been changes in the results of the study, since the lesion responsible for non-fluent aphasia is in a different location,
affecting different structures and processing. Future research should also examine behavioral responses to code switches. This study did not require any behavioral response, so simply because the participants demonstrated cortical activation in terms of amplitude similar to those of individuals with no brain damage, it does not mean that comprehension was intact. The next step would be to have the participants follow simple commands with code-switches inserted in them. Reaction times and accuracy could then be measured and analyzed.

5.5 Conclusion

The results of this study indicate that although individuals with aphasia display similar patterns of processing of grammatical and ungrammatical language switches on ERP waveforms as individuals with no history of brain damage, it is not indicative of the same processing ability. Cortical activation maps indicate different activation in bilingual individuals with aphasia. Further research needs to be conducted to verify and expand on these results. Research should focus on comprehension of language switches in both grammatical and ungrammatical contexts. In the meantime, this study has implications that can be applied clinically by both speech language pathologists and healthcare providers in general.
References


Appendix

Appendix A – Consent From

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

Protocol Title: Processing of Language Switches in Bilingual Individuals with Aphasia: an Event-Related Potential Comparison
Principal Investigator: Lizette Rodarte, B.S.
Advisor: Patricia Lara PhD., CCC-SLP, Department of Rehabilitation Sciences; Speech-Language Pathology Program
Thesis Committee Members:

UTEP College of Health Sciences: Masters of Science in Speech-Language Pathology Program – ERP and Aphasia Laboratory

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 N400 and P600 peak latency and amplitude in individuals with aphasia and individuals with no brain damage listening to grammatical and ungrammatical language switches inserted within a sentence. This study examines brain activity in response to grammatical and ungrammatical language switches.

The rationale:
Aphasia is language disorder that affects speech, sign, reading, writing and auditory comprehension. Aphasia is caused by damage to the language areas of the brain. In most people, this is the left side of the brain. While aphasia may result from a variety of different causes, the most common is stroke. It is estimated that approximately one million people in the United States suffer from aphasia and that 25 to 40% of individuals who survive a stroke will acquire the disorder. This means that approximately 100,000 Americans will acquire aphasia each year. With the rise in bilingualism, it is expected that out of all the new cases, approximately 45,000 of them will occur in multilingual individuals (Paradis, 2001). The literature shows that language switching is rule-governed and since individuals with aphasia have demonstrate lack of proper grammar, it is important to examine how those who suffer from aphasia access their lexical and syntactic information when listening to both grammatical and ungrammatical language switches. Aphasia can lead to social isolation, depression, financial hardships, loss of personal relationships and social stigma on the victim and their families. As a result, research has focused on finding better assessment and treatment options.

Approximately, 20 subjects (10 individuals with aphasia and 10 individuals with history of no brain damage) will be enrolling in this study at UTEP. You are being asked to be in this study because you have been diagnosed with (1) a left hemisphere stroke, (2) aphasia, (3) a subject with no history of brain damage. If you decide to enroll in this study, your involvement will last approximately one-two hours.
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, a self-report bilingual proficiency questionnaire, the Annett Handedness Inventory. In addition, you will be assessed by the principal investigator using an aphasia test to determine whether you are a candidate for this study. You will be asked to come in for a second visit. During the second visit, the principal investigator will measure your head to find the electrode cap that fits you best. 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 and asked to listen to sentences that will be presented orally.

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 Lizette Rodarte at (915-269-9891), her advisor Dr. Patricia Lara and to the UTEP Institutional Review Board (IRB) at (915-747-8841) orrb.orsp@utep.edu.

6. Benefits
There will be no 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 recovery of bilingual aphasia and that may lead to better assessment and treatment options.

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
Internal Funding:
Funding for this study is provided by the UTEP Department of Speech-Language Pathology.

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 taking part in this research 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 Lizette Rodarte at (915) 269-
9891 or lrodarte2@miners.utep.edu. You may also contact the principal investigator’s advisor, Dr. Patricia Lara at (915) 747-7250 or at plara2@utep.edu. If you have questions or concerns about your participation as a research subject, 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 (Lizette Rodarte) and her research 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 Lab at the UTEP Speech, Hearing and Language Clinic (1101 N. Campbell, El Paso, TX. 79902). For further protection, only the principal investigator and her advisor will have access to the locked cabinet. Computer information will be stored in the lab computers and password secured. Only the principal investigator and her 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:

Name: ____________________________ Date: ________________

Signature: ____________________________ Time: ________________
Appendix B – Self-Report Medical History Questionnaire

Self-Report Medical History Questionnaire

UTEP

ERP and Aphasia 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 from 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.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
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<tbody>
<tr>
<td>strong reaction to cold weather</td>
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<tr>
<td>circulation problems</td>
<td></td>
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<tr>
<td>tissue disease</td>
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<tr>
<td>skin disorders (other than facial acne)</td>
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<tr>
<td>arthritis</td>
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<td>asthma</td>
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<tr>
<td>lung problems</td>
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<tr>
<td>heart problems/disease</td>
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<td>diabetes</td>
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<td>hypoglycemia</td>
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<td>hypertension</td>
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<td>low blood pressure</td>
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<td>hepatitis</td>
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<td>neurological problems</td>
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<td>epilepsy or seizures</td>
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<tr>
<td>brain disorder</td>
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<td>stroke</td>
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11. Have you ever been formally diagnosed 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.
Appendix C – Self-Report Bilingual Proficiency Questionnaire

Self-Report
Bilingual Proficiency Questionnaire

Today’s Date __________ Date of Birth __________ Age _______
Place of Birth __________ Gender: Male____ Female____
Occupation __________________
Highest level of education completed ______________________
Ethnic Background ______________________
Participant ID number ______________________

1. In the table below, list all the languages that you speak, read, write, or understand in the order in which you learned them first.

<table>
<thead>
<tr>
<th>Languages</th>
<th>Speak</th>
<th>% of time spoken</th>
<th>Read</th>
<th>Write</th>
<th>Understand</th>
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<tbody>
<tr>
<td>1.</td>
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<td>2.</td>
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<td>3.</td>
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</tbody>
</table>

2. Use the following scale to rate how fluently you speak each of the languages you listed in question 1
   1. My speech is so halting and fragmentary that conversation is made virtually impossible.
   2. My speech is usually hesitant: I am often forced into silence by language limitations.
   3. My speech in everyday conversation and discussions is frequently disrupted while I search for the correct manner of expression.
   4. My speech in everyday conversation and discussions is generally fluent, with occasional lapses while I search for the correct manner of expression.
   5. My speech in everyday conversation and discussions is fluent and effortless approximating that of a native speaker.

Ratings:
Language 1 _____ Language 2 _____ Language 3 _____

3. Use the following scale to rate your use of vocabulary when speaking each of the languages listed in question 1.
   1. My vocabulary limitations are so extreme that conversation is virtually impossible.
2. My misuse of words and very limited vocabulary make conversation quite difficult.

3. I frequently use the wrong words: conversation is somewhat limited because of inadequate vocabulary.
4. I occasionally use inappropriate terms and/or must rephrase ideas because of inadequate vocabulary.
5. My use of vocabulary and idioms approximates that of a native speaker.

**Ratings:**
Language 1 _____ Language 2 _____ Language 3 ______

4. Use the following scale to rate your ability to read social correspondence and newspaper articles in each of the languages you listed in question 1.
   1. I cannot understand even simple written text.
   2. I have great difficulty following written text.
   3. I understand most of what I read if I read it slowly and repeatedly.
   4. I understand nearly everything I read at normal speed, although I may occasionally need to read some parts again.
   5. I understand social correspondence and newspaper articles without difficulty.

**Ratings:**
Language 1_____Language 2_____Language 3_______

5. Use the following scale to rate your ability to write each of the languages you listed in question 1.
   1. I make errors in grammar and word order that so severe that understanding what I have written is virtually impossible.
   2. Grammar and word order errors make understanding what I have written difficult. I often have to rephrase and restrict myself to basic sentence patterns.
   3. I make frequent errors of grammar and word order which occasionally obscures meaning.
   4. I occasionally make grammatical and/or word order errors, however they do not obscure meaning.
   5. My grammatical usage and word order approximates that of a native user.

**Ratings:**
Language 1 _____ Language 2 _____ Language 3 _____

6. Use the following scale to rate your ability to understand each of the languages you listed in question 1.
   1. I cannot understand even simple conversation.
2. I have great difficulty following what is said. I can understand only social conversation spoken slowly and with frequent repetitions.
3. I understand most of what is said at slower than normal speed with repetitions.
4. I understand most of what is said at normal speed, although occasional repetition may be required.
5. I understand everyday conversation and normal discussions without difficulty.

Ratings:

<table>
<thead>
<tr>
<th>Language 1</th>
<th>Language 2</th>
<th>Language 3</th>
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Participant ID number___________________________________
Appendix D – Annett Hand Preference Questionnaire

<table>
<thead>
<tr>
<th>Annett Hand Preference Questionnaire</th>
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<tbody>
<tr>
<td>Name________________________Age____________Sex__________________</td>
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</table>
| Were you one of twins, triplets at birth or were you single born?_________________
| Please indicate which hand you habitually use for each of the following activities by writing R (for right), L (for left), or E (for either).
| (1) to write a letter legibly?____________________________________________ |
| (2) to throw a ball to hit a target?________________________________________ |
| (3) to hold a racket in tennis, squash or badminton?_________________________ |
| (4) to hold a match whilst striking it?_____________________________________ |
| (5) to cut with scissors?__________________________________________________ |
| (6) to guide a thread through the eye of a needle (or guide needle on to thread)?__________________________________________________________ |
| (7) at the top of a broom while sweeping?___________________________________ |
| (8) at the top of a shovel when moving sand?________________________________ |
| (9) to deal playing cards?_________________________________________________ |
| (10) to hammer a nail into wood?___________________________________________ |
| (11) to hold a toothbrush while cleaning your teeth?__________________________ |
| (12) to unscrew the lid of a jar?___________________________________________ |

If you use the right hand for all of these actions, are there any one-handed actions for which you use the left hand? Please record them here.__________________________

If you use the left hand for all of these actions, are there any one-handed actions for which you use the right hand? Please record them here.__________________________

Annett (1970)
Appendix E – Stimuli

English-Spanish Grammatical

1. The kindergartner no puede cruzar la calle solo (cannot cross the street by himself).
2. The girls and boys construlleron el Castillo para jugar (built the play castle.)
3. After the students had finished the book, la maestra les pidio que escribrieran un reporte (the teacher asked them to write a report.)
4. Before they walked across the stage, los estudiantes se formaron en orden alfabetica (the students lined up in alphabetical order.)
5. Before the students were dismissed, la maestra les dijo que entregaran sus tareas. (they were told by the teacher to turn in their assignments.)
6. The math teacher sorted, labeled, boxed, y entrego las calculadoras (and delivered the calculators).
7. The sun shone brightly today, y me lastimo los ojos (and it hurt my eyes.)
8. When the train passes, the whistle blows para mantener gente fuera de las vias (to keep people off the track.)
9. At ten, I go to bed; y veo mis programas de noche favoritos (and I watch my favorite late night television shows.)
10. We had a party last Monday y tuvimos hamburguesas y papitas para comer (and had hamburgers and hot dogs to eat.)
11. Last winter, the kids made a big round snowman y le pusieron un sombrero chico y negro en la cabeza (and put a little black hat on his head).
12. The baseball team from the local high school played fifteen games y terminaron en Segundo lugar (and they ended in second place).
13. During my physical exam, me revisaron los oidos, pulmones, y corazon (I had my ears, lungs, and heart checked.)
14. The girl sang a song para su mama y papa (for her mother and father.)
15. She put soap and water on the tablecloth y tallo fuerte para quitar la mancha (and rubbed hard to remove the spot.)
16. One portion supplies all the body’s minimum daily requirements de vitaminas y minerals (of vitamins and minerals.)
17. After driving for forty-five minutes, llegaron al la orilla del mar (they arrive at the seashore.)
18. The woman who is holding the baby tiene puesto un gorro (has a hat on.)
19. The boy went to school y la nina se quedo en casa (and the girl stayed home.)
20. The girl is riding her bicycle y el nino esta esperando (and the boy is waiting.)

English-Spanish Ungrammatical

1. My mother is the nurse who trabaja en la clinca de la comunidad (works in the community clinic.
2. When the students finished studying, they decided to get something to eat before llendo se a la casa (going home.)
3. The librarian has twelve new eighth-grade science libros reservados para nosotros (books reserved for us.)
4. If we had gone straight home after the game, we would not aver llegado tarde (have missed our curfew.)
5. Bring the broom and sweep the cuarto del frente (front room.)
6. The art teacher goes to school three días de la semana (days a week.)
7. Each year, when the circus came to town, father would llevar toda la familia (take the whole family.)
8. My daughter has a pretty new doll that cierra los ojos y se duerme (shuts its eyes and goes to sleep.)
9. Many men and women go to the movies at noche y en fines de semana (night and on weekends.)
10. In my uncle’s home, there was a soft red alfombra en el piso de la sala (carpet on the floor in the living room.)
11. The patient had a broken leg, a bad heart, and vision mala (poor vision).
12. The tour bus is coming to pick up the people from the hotel to ir a nadar (go swimming.)
13. The man is watching the girl who esta en el agua (is in the water).
14. The photograph on the yellow pared esta chueca (wall was crooked).
15. The bank offers a gift if you open a cuenta antes del fin del mes (account before the end of the month.)
16. The dog is barking because no tiene comida (he has no food.)
17. The boy opened the door and el perro entro (the dog came in.)
18. The girl picked the flowers before the nino corto el zacate (boy cut the grass.)
19. Father cut the grass while estaba lloviendo (it was raining.)
20. The teacher put the big black libro en el cajon del escritorio (book in the drawer of the desk.)

Spanish-English Grammatical
1. El libro no fue devuelto a la biblioteca (The book was not returned to the library) by the teacher.
2. El entrenador no pudo encontrar los uniformes (The coach could not find the uniforms) that the team wore last year.
3. La nina llego a comprar leche (The girl stopped to buy some milk), even though she was late for class.
4. El nino compro un libro para su amigo (The boy bought a book for his friend) who likes short stories.
5. Si la lluvia no para antes del medio dia (If the rain doesn’t stop before noon), the field trip will have to be cancelled.
6. La clase que venda los mas boletos al baile (The class that sells the most tickets to the dance) will win a prize.
7. Si no tengo que trabajar este fin de semana (If I don’t have to work this weekend), I should be able to complete my research paper.
8. Tres hombres pasaron un dia agradable la semana pasada (Three men spent an enjoyable day last week) on a fishing trip.
9. Como un conductor, tengo que comprar un calcamonia nueva (As a driver, I must buy a new sticker) for my car’s license plate once each year.
10. Armarios de porcelana, llenos de todos tipos de platillos fragiles y cristal tallado (China closets, filled with all kinds of fragile dishes and cut glass), lined the walls of the living room.
11. **Tuvimos que comprar gas y aciete** (We had to get some gas and oil) and a new tire for the car.
12. **El cabello crece mas rapido en una gente** (Hair grows faster on some people) than on others.
13. **La gente que esta protestando le esta gritando a la gente** (The people who are picketing are yelling at the people) who want to work.
14. **El recogido de basura va ser un dia tarde** (The garbage pickup will be a day late) because of the holiday this week.
15. **Debes de llegar a un alto completo** (You must come to a complete stop) before you can turn right on a red light.
16. **Muchas de las cartas al editor** (Most of the letters to the editor) disagreed with the newspapers point of view.
17. **La maceta roja** (The red flowerpot) was on the windowsill.
18. **La maestra le dijo a la ninia** (The teacher told the girl) to pick up the book.
19. **Mama le puso de comer al gato** (Mother fed the cat) and father put the dog out.
20. **El nino se quito la camisa** (The boy took off his shirt) before he went in the water.

**Spanish-English Ungrammatical**

1. **El consejo escolar dono las** (The school board donated the) computers and printers.
2. **El estudiante que gano el premio en el** (The student who won the award at the) art show was very excited
3. **Porque manana es Sabado, nos podemos** (Because tomorrow is Saturday, we can) stay up late tonight.
4. **El entrenador le dio el trofeo al** (Coach gave the trophy to the) team that won the track meet on Saturday.
5. **Los estudiantes colectron y arreglaron los jugetes y** (The students collected and repaired the toys, and) sold them at the fair.
6. **Hoy tenemos que comer temprano, ir a la** (Today we must have lunch early, go to the) library, and finish our art projects.
7. **El martes tuvimos pan recien hecho que** (On Tuesday, we had some fresh bread that) we bought at the bakery.
8. **La policia cerro nuestra calle para que los** (The police roped off our street so that the) children might play safely.
9. **En el dia del juego, el clima** (On the day of the football game, the weather) was clear but chilly.
10. **Compre una lata de cafe, pan, y un** (I bought a can of coffee, a loaf of bread, and a) gallon of milk.
11. **Tres de los cinco lapices en la** (Three of the 5 pencils on the) table needed sharpening.
12. **La pelicula se trata de un ladron** (The current movie is about a) handsome who smuggles valuable paintings.
13. **La fiesta se cambio para adentro porque** (The party was moved indoors because) it started to rain.
14. **El latido del Corazon era recio y regular con** (The heartbeat was loud and regular with) a strong, even pulse.
15. **Los vientos altos y arboles callidos causaron** (The high winds and fallen trees caused) power failures in many areas.
16. No me siento bien, así es que pienso que me voy a (I don’t feel well, so I think I will) sit down.
17. Decidieron ir a nadar porque el agua (They decided to go swimming because the water) is warm and calm.
18. Mama esta cocinando la comida y la (Mother is cooking the food and the) girl is setting the table.
19. Mama esta lavando los trastes mientras la Nina esta (Mother is washing the dishes while the girl is) eating lunch.
20. La maestro vio a los ninos salir (The teacher watched the boy go) out the door.
Vita

Lizette Rodarte was born and raised in El Paso, TX where she received her Bachelor of Science in Biological Sciences with a Biomedical Concentration from the University of Texas at El Paso in December of 2008. Ms. Rodarte went on to conduct research in Biomedical Sciences Department at the university. Research was focused on studying viral replication of the *Nodamura* virus in attempts to develop a novel vaccine candidate for West Nile Virus. Ms. Rodarte continued her expansion of biomedical research as a Medical Research Assistant at Texas Tech University Health Sciences Center at El Paso in the Department of Biomedical Science in the Center of Excellence for Infectious Diseases from August 2010 through August 2013. Her research focused on the synthesis of a CD-7 protein for use in targeted delivery of siRNAs to suppress HIV infection in humanized mice, in attempts to develop a novel treatment for HIV infection in humans. She has also conducted IRB approved human subject research to work with individuals diagnosed with HIV.

Starting in August 2012, Ms. Rodarte returned to the University of Texas at El Paso to complete post-baccalaureate courses in Speech-Language Pathology. She is currently pursing her Masters of Science in Speech-Language Pathology with an expected graduation date of May 2015. Her interest in bilingualism and adult communication disorders led her to complete her thesis on processing of language switches.

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