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A Comparative Assessment Of Electrophysiological And Behavioral Performance In Individuals With Aphasia Responding To Spoken And Written Sentence Length Commands

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A COMPARATIVE ASSESSMENT OF ELECTROPHYSIOLOGICAL AND
BEHAVIORAL PERFORMANCE IN INDIVIDUALS WITH APHASIA
RESPONDING TO SPOKEN AND WRITTEN SENTENCE LENGTH
COMMANDS

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Dedication

This thesis is dedicated to my mother, Tricia Gray-Franklyn.

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BEHAVIORAL PERFORMANCE IN INDIVIDUALS WITH APHASIA
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COMMANDS

by

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THESIS

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Sha-Renae Alexander

Abstract

The aim of this study is to investigate whether deficits in processing affect auditory and reading comprehension in the same manner. This study compared the behavioral and electrophysiologic performance of four individuals with aphasia and four participants with no brain damage responding to spoken and written sentence length commands using a modified version of the Revised Token Test (McNeil & Prescott, 1978). Electrophysiological responses were recorded from the scalp using event related potentials (ERP). The latency and amplitude of the N400 ERP component were measured and analyzed. Behavioral reaction times and correct responses were collected and examined. Performance differences between the two groups were compared, as were differences between the auditory and reading tasks within groups. Results show that participants with aphasia displayed a statistically significant difference in behavioral reaction times, displaying longer behavioral reaction times than persons with no brain damage. In addition, the participants with aphasia also demonstrated significantly longer behavioral reaction times responding to written sentence length commands than spoken sentence length commands. However, the individuals with no brain damage demonstrated behavioral performance patterns similar to those demonstrated by the individuals with aphasia. No statistically significant difference was found between the two groups for correct response rate, latency and amplitude of the N400 ERP component. The cortical activation patterns between the two groups differed for spoken sentence length commands but not for written spoken length commands. The individuals with no brain damage displayed similar localized activation in the frontal-central electrodes when responding to both spoken and written sentence length commands, while individuals with aphasia displayed highly dispersed pattern activation for the spoken sentence length commands. Notably, previous studies on individuals with no brain damage have reported similar findings to the ones observed in the individuals with aphasia in the current study. The results of this study suggest that sentence comprehension impairments in individuals with aphasia do not appear to be modality specific.

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Chapter 1: Introduction

The first section of this chapter provides information that will provide an overview and frame the content of the current research. Topics in this section will be discussed in more detail in the subsequent chapter. The remainder of this chapter covers the rationale, statement of purpose and research questions.

1.1 Background

Aphasia is an acquired language disorder that results from injury to parts of the brain that are responsible for language. Aphasia causes difficulties with speaking, reading, listening, and/or writing (Papathanasiou, Potagas and Coppens, 2013). According to The National Aphasia Association (2007) approximately one million Americans currently live with aphasia making it more common than cerebral palsy and Parkinson's disease. It is estimated that there are 80,000 new cases of aphasia per year in the United States (National Stroke Association, 2008).

There is great importance in studying aphasia and the recovery of language skills, as many of the underlying language processes present in individuals with aphasia are not yet explicitly described. While aphasia impacts all language modalities, recovery of auditory comprehension appears to be of great importance since it is the modality most often used during the management of aphasia. The Porch Index of Communicative Ability (PICA) (Porch, 1967) and the Revised Token Test (RTT) (McNeil & Prescott 1978) are two behavioral methods widely used in the evaluation and description of auditory processing impairments in individuals with aphasia. Although behavioral characteristics are important when studying the language skills of individuals with aphasia, understanding the functional neural network underlying language processing is also important. Behavioral responses alone are insufficient in determining where in the language processing system the disturbance is occurring (Selinger, Shucard & Prescott, 1980); whether there is difficulty receiving the language input, integrating that input or generating the output.

Neuroimaging technology allows for the examination of neural structures and neural activity during the language process. Functional magnetic resonance imaging (fMRI) is the most widely used

technique to study neuroplasticity in aphasia recovery (Meinzer, Beeson, Cappa, Crinion, Kiran, Saur & Thompson, 2013). Event-related potentials (ERP) and Positron emission tomography (PET) are also common techniques used in aphasia research. PET is an excellent tool for localization of anatomical structures. Electrophysiological methods, such as ERP are capable of measuring cortical activation with millisecond precision. ERP is less invasive and less expensive than fMRI and PET as both use radiation directly injected into the blood stream or from scanners, making ERP an ideal choice for clinical and research purposes.

Deficits in comprehension are common in individuals with aphasia. These comprehension deficits may be seen in both spoken and written language. However, research has primarily focused on auditory comprehension. Due to this imbalance in the literature the relationship between auditory and reading comprehension deficits is still not well understood. Among the studies on auditory comprehension it is widely agreed that individuals with aphasia require longer processing times for auditory messages (D'Arcy et. al., 2003; Eberwein et al., 2007; Faustmann et al., 2004). The limited research on reading comprehension has focused on single word reading and/or the individual's ability to recognize a written word as measured by oral reading or picture to written word matching tasks (DeLong, Quante & Kutas, 2014; Grainger & Holcomb, 2009; Kutas & Hillyard, 1984).

A large part of assessing and treating individuals with aphasia involves giving spoken instructions/commands and expecting the individual to respond. In addition, clinicians also use the written modality to manage aphasia. Despite this, research has not focused on examining the relationship between spoken and written sentence length messages or commands. To our knowledge, very few studies use an experimental paradigm that requires participants to respond by following directives presented orally or in written form such as is done in the current study. Asking the participant to follow a command requires the participant to receive the written message, integrate that message then make a response. This type of task allows investigators to determine at what time point the individual is processing a stimulus. Since ERP can be time locked to a specific event, this methodology is the most

appropriate technique to determine the point in time that processing of spoken and written sentence length commands occur in individuals with aphasia and participants with no brain damage.

1.2 Rationale

While auditory comprehension dominates our daily lives and is the primary modality used for the treatment aphasia, a reading comprehension deficit may affect the social roles of these individuals (e.g. reading environmental signs, understanding menu items, filling out forms). This negative impact on social functioning will only increase as in-person social interactions are rapidly being replaced by electronic on-screen interactions that require more written communication. We also use written cues within our environment to help us gain understanding of the things around us (e.g. product labels, price tags). Written cues have also been widely used in treatment of aphasia as a multimodal approach to rehabilitate language deficits. Researchers have shown that incorporating written cues along with other nonverbal cues has significant improvements on word retrieval deficits (Hickin et al., 2002; Rose, 2013; Rose et al. 2013). Understanding the mechanisms that underlie the process of reading and auditory comprehension in individuals with aphasia and the relationship between the two is important as it may lead to improved treatment strategies/techniques thus improving the quality of life of individuals with aphasia.

It is widely known that one of the primary deficits individuals with aphasia have is difficulty in understanding sentences, however the underlying neural mechanisms of this impairment is poorly understood. This is because the overwhelming majority of studies on comprehension in individuals with aphasia have focused on one sensory modality (Shimojo & Shams, 2001). Because of this, the relationship between reading and auditory comprehension impairments in individuals with aphasia is largely unexplored. Investigating comprehension in individuals with aphasia in a single modality would be acceptable if each modality processed sensory inputs self-sufficiently, as proponents of the dual process theory would argue (Samuels, 1987). However strong evidence was put forth to support a unitary process view, demonstrating the high interrelation between reading and listening comprehension

(Stich et al., 1974; Sinatra, 1990). While some processing components such as visual analysis of letter strings, are specific to reading comprehension (Snow, 1983), semantic processing is required for both auditory and reading comprehension (Sinatra, 1990). Research on the relationship between reading and listening comprehension is discussed in more detail in the proceeding chapter.

This study will increase the knowledge base currently lacking in the literature by examining comprehension in two modalities, spoken and written at the sentence level. One fundamental question is whether sentence comprehension impairments affect the spoken and written modalities in the same ways (DeDe, 2012). Assessment of both modalities would allow for the hypothesis of processing component(s) that is impaired. Understanding the relationship between auditory and written sentence comprehension impairment is also important in order to determine whether treatment focused on one modality can be expected to generalize to the other (DeDe 2013). This kind of knowledge may also lead to the possible development of novel treatment strategies that will lead to generalization across the two modalities.

1.3 Purpose of Study

Auditory and reading comprehension converges at the lexical level (Sinatra, 1990) and requires the combination of the meaning of individual content words into a global meaning of that message. Event related potentials (ERP) provide information about the neural mechanisms and networks that are involved in cognitive and language processes on a real-time basis because they can be time-locked to a stimulus. ERP measures electrical brain activity at the level of the cortex using a skullcap with electrodes attached. This study examines the electrophysiological and behavioral differences in individuals with aphasia and individuals with no brain damage responding to spoken and written sentence length commands. In addition, differences within groups are also examined. The measures of interest for this study include, latency and amplitude of the N400 ERP component, behavioral reaction times and percent response accuracy of the spoken and written sentence length commands.

1.4 Research Questions

The following research questions are addressed:

- 1) Is there a statistically significant difference in the behavioral reaction times between the individuals with aphasia and the individuals with no brain aphasia responding to spoken and written sentence length message?
- 2) Is there a statistically significant difference in the behavioral reaction times within the two groups responding to spoken and written sentence length message?
- 3) Is there a statistically significant difference in the percent response accuracy between the individuals with aphasia and the individuals with no brain damage responding to spoken and written sentence length message?
- 4) Is there a statistically significant difference in the percent response accuracy within the two groups responding to spoken and written sentence length message?
- 5) Is there a statistically significant difference in the peak latency and amplitude of the N400 ERP component between the individuals with aphasia and the individuals with no brain damage responding to auditory and written sentence length commands?
- 6) Is there a statistically significant difference in the peak latency and amplitude of the N400 ERP component between the spoken and written sentence length commands within the two groups?
- 7) Do cortical activation patterns differ between the individuals with aphasia and individuals with no brain damage responding to spoken and written sentence length commands?

Chapter 2: Literature Review

This chapter will discuss the literature that currently exists on aphasia, neuroimaging technology used in aphasia research, ERP, the Revised Token Test, auditory comprehension, reading comprehension and the relationship between comprehension of spoken and written commands.

2.1 Aphasia

Papathanasiou, Potagas and Coppens (2013) define aphasia as an acquired impairment of language resulting from a focal brain lesion in the language-dominant hemisphere. In most people this is the left hemisphere. The language impairment may impact different language modalities (speech, reading, writing and comprehension). Aphasia affects a person's ability to communicate efficiently impacting social functioning and quality of life for the individual with aphasia, their caregivers and loved ones. The impairment can affect all components of language as well as the output (expression) and input (comprehension) modes.

Aphasia can result from various diseases or traumatic events, such as brain tumors, dementia, traumatic brain injury and other progressive neurological disorders, however aphasia is most often caused by stroke (National Aphasia Association, 2007). A stroke occurs when a blood vessel that supplies oxygen to the brain becomes obstructed or is ruptured. As a result, sections of the brain are deprived of oxygen causing brain cells to die. According to the Centers for Disease Control (2012), stroke is the fourth most prominent cause of death in the United States, and the primary cause of long-term severe disability in 2008.

Traditionally aphasia is classified by the clinical presentation of symptom clusters. Most of these syndromes are associated with a specific site of lesion. Table 1.1 provides a description of these symptom clusters that classify various "aphasia syndromes" and the brain areas they are associated with (Obler & Gjerlow, 1999).

Table 1.1: Aphasia symptoms (Obler and Gjerlow, 1999).

<u>Syndrome</u>	<u>Speech</u>	<u>Comprehension</u>	<u>Repetition</u>	<u>Naming</u>	<u>Lesion Site</u>
Broca's aphasia	poor, non-fluent	Good	poor	poor	anterior
Wernicke's aphasia	fluent, empty	Poor	poor	poor	posterior
Conduction aphasia	fluent	Good	poor	poor	arcuate fasciculus
Anomic aphasia	fluent with circumlocutions	Good	good	poor	anywhere
Global aphasia	virtually none	Poor	poor	poor	large
Transcortical motor aphasia	little	Good	good	not bad	outside in frontal lobe
Transcortical sensory aphasia	fluent	Poor	good	poor	outside in parietal lobe
<i>Note:</i> Lesion site refers to areas in or relative to the "language zone". Thus "anterior" means the anterior part of the language area, "anywhere" means anywhere in the language area.					

According to the symptoms provided in Table 1.1, there are two broad types of aphasia, fluent and non-fluent aphasia. The fluent aphasias have posterior brain lesions and exhibit forward flow of speech. On the other hand, non-fluent aphasias have anterior brain lesions and the smooth flow of speech is disrupted (Kreisler, 2000). Several aphasia classification systems exist. The primary differences among the classification systems are the labels that are used rather than the clinical characterization of the aphasia patterns (Ardila, 2010). For example, The Boston Classification System provides two distinctive features of aphasia. These features are fluent or non-fluent and also looks at whether the lesion cortical, subcortical, or transcortical (Goodglass & Kaplan, 1972). Luria (1970) proposed seven aphasia subtypes including motor afferent/kinesthetic, motor efferent/kinetic, acoustic-amnesic, acoustic-agnostic, amnesic, semantic and dynamic. In this approach, the particular level of language at which the impairment manifests is what distinguishes aphasia subtypes. However, attempts to classify aphasias using language characteristics and lesion site account for only approximately 50% of all aphasia types (Benson, 1979)

While aphasia type is the primary desired outcome of assessment, prognosis for recovery is another key element that not only shapes management of the aphasia but also is used in educating families and guiding their expectations. Basso (1992) conducted a review of the literature in order to identify factors that influenced recovery from aphasia. This review of the literature concluded that age, sex, and handedness only play a minor role in recovery from aphasia with the most important prognostic factors in aphasia being initial severity and rehabilitation. There is however a lack of information on how these factors interact with each other and impact recovery.

A recent systematic review examining the effectiveness of speech-language intervention in treating adults with aphasia suggest that individuals with aphasia benefit greatly from behavioral intervention (Brady, Kelly, Godwin, & Enderby, 2012). Shewan and Kertesz (1984) studied the effects of treatment provided by speech-language pathologists, treatment by trained non-professionals and no treatment on the language recovery of individuals with aphasia. Treatment provided by speech-language pathologists was efficacious, while the treatment provided by trained non-professionals was near statistical significance and the group that received no treatment had no statistically significant improvements. The results from this study suggest that individuals with aphasia benefit from intervention at any level. Prins, Snow and Wagenaar (1978) studied the effects of speech-language therapy on the recovery of spontaneous speech versus language comprehension in person with aphasia. The results of this study showed that after one year of treatment individuals with aphasia had significant improvements in language comprehension while there were very little improvements in their spontaneous speech. This suggests that deficits in spontaneous speech and comprehension are relatively distinct, with divergent recovery histories. In addition, the results of the studies cited above suggest that comprehension deficits may benefit from speech language intervention. This further solidifies the need for research that examines spoken and written language comprehension.

2.2 Auditory Comprehension in Individuals with No Brain Damage

Studies of auditory comprehension in individuals with no brain damage are valuable because the information they provide can be used to recognize abnormal patterns in populations with brain damage (Lara, 2012). The vast majority of theories on language comprehension put forth to date take one of two stances of how spoken language is processed: serially or in parallel. The serial processing theories suggest that language is processed occurs sequentially and there is an explicit order in which operations occur, while parallel processing theories suggest that the incoming stimuli involved in language is processed simultaneously. However all such theories do make the claim that the language-processing system is a compositional and hierarchical process that requires the rapid integration of phonological encoding, words accessed from the lexicon and formulation of appropriate syntactic structures in order to generate meaning from the whole structure (Ferreira, Bailey & Ferraro, 2002).

Theories of auditory comprehension provide us with some insight into the different stages of comprehension and how disruptions at different stages may produce distinguishing behaviors. However it is difficult to decisively say a particular stage is disrupted without knowing the temporal characteristics associated with a behavior. Neuroanatomical studies allow us to associate the process of auditory comprehension with specific anatomical structures and/or temporal characteristics. For example, Friederici 's (2011) study of ERP in language comprehension in individuals with no brain damage sparked the three-phase model of language comprehension, with different ERP components linked to different phases in the process. The N400 was interpreted as an indicator of lexical-semantic processes and semantic predictability in relation to context and general world knowledge. This component then is said to reflect processes pertinent to language comprehension at different levels (Friederici, 2011).

Friederici, Ruschemeyer, Hahne and Fiebach (2003) used fMRI to identify the specific anatomical structures related to the processing of semantic and syntactic linguistic information in individuals with no brain damage. The participants were required to make judgments on whether sentences were correct or incorrect. Both semantically and syntactically correct sentences corresponded

with increased bilateral activation in the mid section of the superior temporal gyri and the insular cortices.

2.3 Auditory Comprehension in Individuals with Aphasia

Several hypotheses have been put forth to account for the auditory comprehension deficits in aphasia. It is hypothesized that these deficits are related to limitations of memory (Caplan, Michaud & Hufford, 2013; Friedmann & Gvion, 2003), delayed access to/processing of stored linguistic information (Friederici, 1983; Kolk, 1995; Park, McNeil & Doyle, 2002), delayed analysis of the grammatical relationship between the words and/or difficulty integrating the two systems (Swabb, Brown & Hagoort, 1997).

Bradley, Garrett, & Zurif (1980) hypothesize that in the serial model of language processing, closed-class words are key components during the initial syntactic processing of sentences. Friederici (1983) argued that the difficulties with auditory comprehension in individuals with Broca's aphasia can be explained as a delay in the lexical access of closed-class words in this early syntactic processing, that in turn disturbs the proceeding semantic information related to open-class words. This delay is also evident in behavioral reaction times, as individuals with Broca's aphasia display reaction times on word-monitoring tasks, that are significantly more delayed than individuals without brain damage, when targets contain closed-class words (Swinney, Zurif, & Cutler, 1980).

Recovery from post-stroke aphasia, measured by a language task, has been linked to the re-emergence of a previously absent N400 component, suggesting recovery of diminished lexical-semantic processes (Faustmann, Murdoch, and Copland, 2004). It also appears that recovery in auditory sentence comprehension is associated with decreased latency of the N400 component. These results suggest that the temporal characteristics of semantic and syntactic integration are pertinent to language comprehension (Faustmann, Murdoch, and Copland, 2004).

Swabb, Brown, & Hagoort (1997) found differences in ERP waveforms between individuals with aphasia and individuals with no brain damage. In this study, participants were presented with spoken

congruous and incongruous sentences. The participants were not required to make overt responses. ERP signals were recorded during the presentation of the auditory stimulus. The individuals with aphasia exhibited a smaller N400 than individuals with no brain damage, but the difference was not statistically significant. The conclusion is that all groups exhibited N400s but the latency is shifted in time for individuals with aphasia with comprehension deficits.

The literature suggests that sentence comprehension deficits in individuals with aphasia are best understood as a processing deficit rather than a complete loss of ability to construct language structures (Caplan et al., 2007; Thompson & Choy, 2009), suggesting that individuals with aphasia process auditory stimuli in the same way as individuals with no brain damage but may take a longer time to carry out this process. Consistent with the evidence for delayed access in individuals with aphasia, studies have shown that providing more time for individuals with aphasia to access and process the information of a specific word, affects auditory sentence comprehension performance (Park, McNeil & Doyle, 2002; Salvatore, 1976). For example, Park et al. (2002) in a study that investigated the effect of inter-word intervals on the auditory comprehension of individuals with agrammatic aphasia, found that auditory sentence comprehension improved when inter word intervals were increased. However there was variability in individual responses to different lengths of intervals.

Auditory comprehension of spoken single words has been well studied. However, auditory comprehension of spoken sentence length messages has not. As a result, the temporal characteristics of spoken sentence length messages are still not clear. The studies previously discussed utilize picture-matching, syntactic error recognition or word monitoring tasks. Very few studies examine language comprehension by asking the participant to respond to a spoken or written command by carrying out that command or following some type of instruction. Verbal directions are a part of everyday life. Social interactions and success in the workplace and educational settings depend heavily on an individual's ability to comprehend and follow spoken and written directions. In order to follow spoken directions individuals must have strong knowledge of basic concepts as well as the ability to store and process the auditory stimulus at an incredibly fast rate.

2.4 Reading Comprehension in Individuals with no Brain Damage

Much like studying auditory comprehension, theoretical frameworks that describe the normal reading comprehension process aid in identifying the component(s) of that process that are potentially disrupted in individuals with aphasia. Several models exist that discuss the component processes that support reading and writing.

Interactive models advocate that both top-down and bottom-up processes are simultaneously activated during reading. Various interactive models differ however in the subcomponents involved and nature and timing of their interactions (Stanovich, 1980; Verhoevan & Perfetti, 2008). One such model put forward by Perfetti (1999) captures this dynamic process describing two core processes required for reading: word identification and comprehension. Both core processes include a set of secondary processes that support the overall goals of each. The reading process begins with visual word recognition. Then, the visual input is converted into a linguistic representation. As this word identification process goes on, the reader tries to form connections to a continuously updated representation of the text. Figure 1 provides a schematic of the integrative model of reading adapted from Perfetti (1999).

For example, in the first published study of the N400 ERP component, Kutas & Hillyard (1980) found that in a written sentence-processing task, semantically inappropriate words elicited a N400 ERP component. They argued that the N400 ERP component reflects the presence of semantic incongruities that in turn interrupt the on-going sentence processing and the “reprocessing” that occurs as individuals seek to extract meaning from the now senseless sentence. Kutas & Hillyard (1984) concluded that the N400, rather than reflecting contextual violations, reflects semantic priming or processing during reading tasks.

Perfetti & Hart (2001) put forward the lexical quality hypothesis, which suggests that efficient reading comprehension depends the rapid retrieval of accurate lexical representations (orthographical, phonological, and meaning components). Lexical representations are considered high quality when all three components are strongly connected so that the retrieval of one component (e.g., a word’s spelling) also leads to the retrieval of the other components associated with the same word (correct pronunciation

and meaning). Any variation in the quality of any of these components has implications for reading skill, including comprehension.

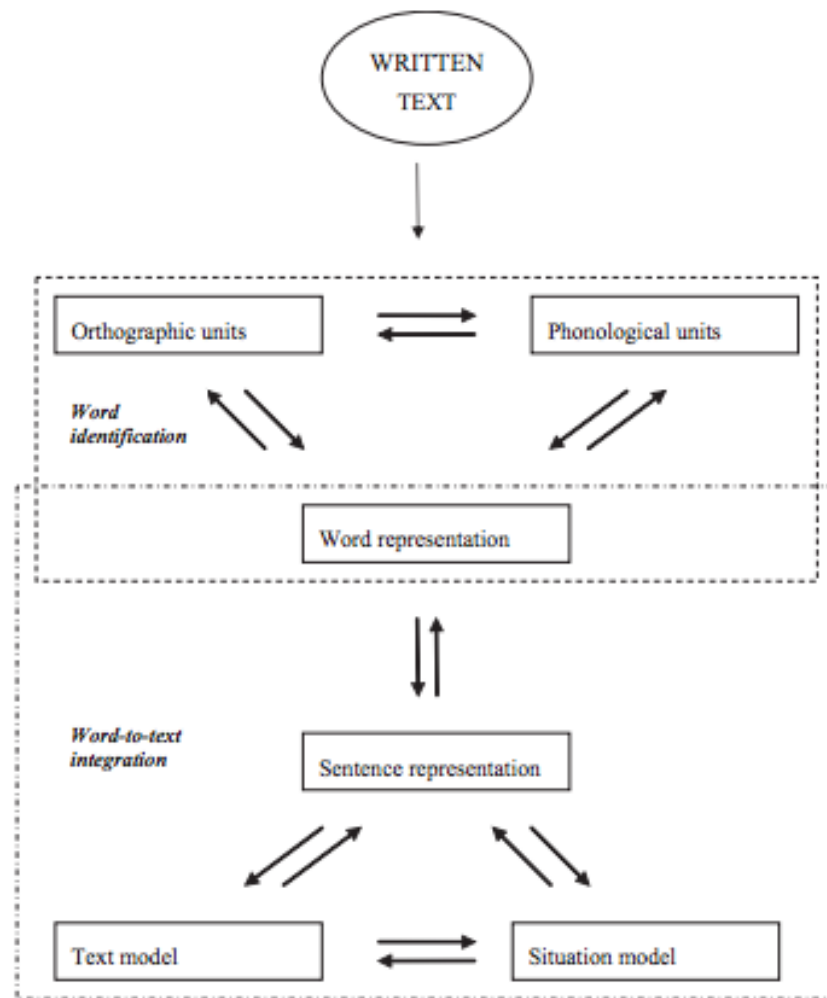


Figure 2.1: An Interactive Activation Model of Reading (Perfetti, 1999).

Perfetti, Chin-Lung and Smalhofer (2008) used ERP to investigate how differences in comprehension skill are manifested in the processes of word-to-text integration. They found that for skilled comprehenders, integration processes were signaled by the presence of an N400 ERP component when a core word had an explicit connection to a preceding word. Less skilled readers showed decreased latency and amplitude of the N400 ERP component suggesting a delay in integrating words with previous texts. Their results indicates that an key factor in reading comprehension is word

knowledge in context and that the lexical quality hypothesis (Perfetti & Hart, 2001) accounts for individual differences in accessing semantic representations of words.

Similarly, Grainger & Holcomb (2009) found that three ERP components reflect three successive processing stages involved in mapping visual features onto meaning during visual word recognition: The N/P150, N250 and N400. The N/P150 component reflects the initial mapping of visual features onto letter representations. The N250 reflects the mapping of letter-level information onto whole-word-form representations and the N400 reflecting the final mapping of whole-word representations onto meaning suggesting that comprehension of the written word requires individuals to access their semantic inventory in the same fashion as they do for comprehension of spoken language.

2.5 Reading Comprehension in Individuals with Aphasia

In a long-term assessment of client needs, McKevitt and colleagues (2011) reported that 23% of respondents reported a need around reading difficulties following a stroke. There are numerous studies on the treatment of reading impairments of single words and alexia in individuals with aphasia. These treatment studies acknowledge the prevalence of reading disorders and reading comprehension difficulties in individuals with aphasia but little is known about how individuals with aphasia process reading stimuli. Taylor and Francis (1989) described several variations of acquired dyslexias that may be present in individuals with aphasia. These reading difficulties however are described at the phonological and word identification levels.

Few studies to date have examined comprehension of the written word at the cortical level. Those studies that examined written language comprehension use tasks that require individuals to match picture to written word, or visual recognition of a spoken word. For example, Sung et.al (2011) examined reading times in individuals with aphasia by presenting sentences from the Computerized Revised Token Test (CRTT) in a self-paced word-by-word reading method. Results showed that individuals with aphasia displayed much longer reading times than individuals with no brain damage when the task required them to integrate larger amounts of information. This supports the efficiency

models of aphasia that claim limited cognitive capacity is what creates receptive and expressive difficulties in individuals with aphasia.

2.6 The Relationship Between Reading and Auditory Comprehension

Differences between oral and written language stem from their course during development in young children as well as the nature of their perceptual characteristics (Diakidoy et al., 2005). The acquisition of auditory language processing skills is natural and progressive process that precedes the acquisition of written language. Written language has to be explicitly taught (Snow, 1983). Auditory comprehension of words appears to be the first emerging language skill in infants as it appears relatively earlier than the ability to produce words (Nelson, 1973) and therefore is the basis for development of language. It is believed that oral language skills are a prerequisite skill for reading development as learning to read draws heavily from the phonological representations acquired from auditory language processing (Snow, 1991). Following the lexical quality hypothesis (Perfetti & Hart, 2001) accurate phonological representations is a key component of reading comprehension, therefore individuals with aphasia who demonstrate poor phonological awareness skills will also have difficulties with reading comprehension.

The physical differences between spoken and written language may also account for modality-specific effects. The permanence of written messages allows the reader to control the rate at which they read. Thus, this characteristic may allow for additional time to process the written message. However spoken messages are fleeting (Catts & Kamhi, 2005) requiring individuals to process the spoken word at an incredibly fast rate. Therefore, it may be that the fleeting nature of the spoken signal renders it more complex and suggests that an auditory comprehension task would be more challenging (DeDe, 2012). These perceptual characteristics may differentially affect written and auditory sentence comprehension.

In an fMRI study by Michael, Keller, Carpenter and Just (2001) examining verbal and written sentence comprehension, participants were instructed to read or listen to a sentence then respond to true/false questions about the preceding sentence. Results show that subtle differences in the underlying

cognitive processes of listening and reading comprehension exist. The activation for listening comprehension was more anterior and inferior than for reading comprehension, in Broca's area. The authors suggest that this activation pattern indicates increased semantic processing during listening comprehension. For Wernicke's area, the activation for listening comprehension was more anterior than for reading. In a number of regions activation for reading was much more left lateralized than for listening comprehension which had significantly greater bilaterality. Activation around Broca's area indicate that reading and listening sentence processing activate distinctive but interrelated areas, with extra activation areas corresponding with auditory comprehension. Fiez and Petersen (1998) suggest that this extra activation suggest that listening comprehension places a greater demand on working memory resources and lexical-semantic processing than reading comprehension.

Similarly, Buchweitz, Mason, Tomitch and Just (2009) compared the brain activation patterns accompanying comprehension of written and spoken Portuguese sentences using fMRI. In this study, participants were asked to read and listened to general knowledge then determine whether the sentences were true or false. The results suggest that reading comprehension correlated with increased left-lateralized temporal lobe activation along with left inferior occipital lobe activation. On the other hand, listening comprehension correlated with bilateral activation of the entire temporal lobe. In addition, readers with lower working memory capacity had increased activation in right-hemisphere areas, possibly as a result of a higher demand being placed on executive processes. This study shows how the different modalities of language comprehension are activated in the brain. It also suggests that working memory capacity impacts reading abilities and that may have implications for understanding how individuals with aphasia process reading material since it is well known that individuals with aphasia may have a low working memory capacity (Caplan & Waters, 1999; Wright & Shisler, 2005). The results of this study are similar to the results of Michael, Keller, Carpenter and Just (2001).

2.7 Reading vs. Auditory Comprehension in Individuals with Aphasia

A thorough search of the literature yielded only a small number of studies that directly compare reading and auditory comprehension in individuals with aphasia. Gardner, Denes, and Zurif (1975) examined the ability of individuals with aphasia to detect anomalies in an auditory task versus a written task. Participants were presented with one hundred written and spoken sentence pairs, one correct and one incorrect, and were required to identify the incorrect sentence. Results showed that individuals with anterior perisylvian lesions had increased accuracy on the auditory task, while individuals with posterior perisylvian lesions had increased accuracy on the written task. Some studies used picture-matching tasks to compare the two modalities. For example, Gallaher and Canter (1982) presented a spoken or written sentence stimulus along with four picture plates and participants were required to select the picture plate that matched the sentence they read or heard. The results of this study showed that individuals with Broca's aphasia performed better on the written version of the task. On the other hand, Peach, Canter and Gallaher (1988) found that there was no significant modality effects in their study on individuals with anomic and conduction aphasia where the participants were required to point to the picture that corresponded with the written or spoken sentence. The results of these studies suggest that modality-specific impairments in comprehension are limited to only some individuals with aphasia.

Working memory is a factor that is implicated in comprehension of written information. Sung et al. (2009) reported that working memory capacity significantly predicted performance on an auditory comprehension task (CRTT) and on a reading comprehension task (CRTT-R_{WF}), which required participants to follow commands on a touchscreen monitor. In this study, the task utilized had each preceding word in the sentence disappear with the onset of the proceeding word. Despite the separate modalities, both tasks, presented information very rapidly thus, placing higher demands on working memory. This required the participant to remember the preceding word in order to respond accurately. Participants with aphasia how had a low working memory capacity performed significantly lower than those with a high working memory capacity on the CRTT subtests with syntactically more complex structures.

McNeil, Sung, and Pratt (2008) examined the concurrent validity of the CRTT and three reading versions of the CRTT-R. Results suggest there were no significant differences among the four conditions for individuals with aphasia. However for individuals with no brain damage the scores on the CRTT were significantly higher than all three reading conditions. McNeil et al. (2008) concluded that the high correlation between performance on both versions of the task for individuals with aphasia reflect similar linguistic processing for both modalities. While for individuals with no brain damage the four conditions were largely unrelated, which possibly reflects a different set of processing skills or strategies for each modality.

When manipulating word frequency, Dede (2012) presented twenty-one sentence pairs to individuals with aphasia, containing high- and low-frequency words in self-paced listening and reading tasks followed by yes/no comprehension questions. Results showed that individuals with aphasia had decreased accuracy when responded to sentences containing low-frequency words in the reading compared to listening tasks. Individuals with aphasia also displayed longer reaction times during the reading task than listening (Dede, 2012). In a later study (Dede, 2013) examining the effects of syntactic complexity on listening compared o reading comprehension a similar task was used however sentences differed in their complexity. Complex sentences contained an object relative clause while the simple sentences contained a subject relative clause. Greater effects of syntactic complexity were observed in reading than listening, however the effects were not exaggerated when compared to that of individuals with no brain damage, indicating that sentence comprehension difficulties in individuals with aphasia may not be modality specific.

2.8 Neuroimaging Techniques Used in Aphasia Research

Recovery from aphasia is usually measured by behavioral responses on standardized tests. While these behavioral assessment instruments provide standardized measures and baseline performance data, they are not reflective of one specific cognitive process but of many individual cognitive processes

(Lara, 2012). Additionally, behavioral measures do not provide insight into how and when processing occurs nor the anatomical structures associated with this processing.

Neuroimaging technology allows for the observation of the anatomical structures and their correlation with processing in individuals with aphasia. They also allow us to examine the cortical characteristics of language processing. Functional Magnetic Resonance Imaging (fMRI), Event Related Potentials (ERP) and Positron Emission Tomography (PET) are some of the most commonly used neuroimaging technologies used in aphasia research.

fMRI uses the oxygen content in the blood to produce several consecutive images of activity in response to a stimulus. PET measures the metabolism of the brain and therefore detects rapid changes or dysfunction in the brain produced in response to a stimulus. Both fMRI and PET provide information about the anatomical areas associated with a specific cognitive process while ERP measures electrical activity at the cortical level produced in the brain in response to internal or external stimulus. Electrical signals recorded from scalp electrodes are used to produce wave patterns of activity and cortical activation maps. ERP is non-invasive since the electrical activity is measured through a skullcap with electrodes attached. On the other hand, PET require injecting a person with a radioactive isotope while fMRI uses a magnetic field and requires the participant to remain completely still. Furthermore ERP is more cost-effective, therefore it is ideal for examination of cognitive and language processes such as comprehension in the clinical and research settings. It can be used with pathological populations because it does not require an overt response from the participant and may therefore offer a more direct look at automatic lexical processing, uninfluenced by post-lexical processes or response preparation (Zipse, Kearns, Nicholas, & Marantz, 2011).

2.9 Event Related Potentials (ERP)

ERP measures electrical activity at the cortex level by using an electrode cap with electrodes attached. Electrical activity is measured in response to internal and external stimulus. The electrical activity can be time-locked to a specific stimulus, which allows inferences to be drawn about cognitive

activities such as memory, attention and language at the level of the cortex (Handy, 2005). ERP waveforms are comprised of a sequence of positive and negative voltage deflections; these series are referred to as components and reflect underlying processes (Luck, 2012). ERP components are generally discussed with reference to three parameters: the polarity of the waveform (positive (P) or negative (N)), the latency of the waveform (measured as the time post onset of the stimulus) and the amplitude of the waveform (measured in microvolts) (Fonteneau, Frauenfelder & Rizzi, 1998).

Given that ERP has precise temporal resolution of one millisecond, ERP can be used to determine the time point at which language processing occurs, whether it is auditory processing or visual processing. However, there are several limitations with ERP methodology. One of these limitations is that ERP signals are generated from many electrodes; therefore it is not possible to determine the exact anatomical structure that is responsible for the activation. As a result, signals are described as summations of many electrode signals (Fabiani, Gratton, & Coles, 2000).

Several language related ERP components have been identified. The language related ERP components are left anterior negative peak (ELAN) occurring between 120 and 200 ms, suggesting the beginning syntactic structure building processes, a centroparietal negative peak (N400) occurring between 300 and 500 ms, suggesting a semantic response, and a centroparietal positive peak (P600), suggesting late syntactic processes (Friederici, 2011).

Kutas and Federmeier (2011) reviewed 30 years of research on the N400 ERP component and found that the N400 is highly correlated to how individuals process the meaning of a stimulus regardless of modality. In addition, the literature suggests that the amplitude of the N400 is an indicator of the difficulty a reader experiences during integration of lexical information, while the latency is generally stable across participants, task and modality (Fonteneau, Frauenfelder & Rizzi, 1998; Kutas & Federmeier, 2011). Kutas & Petten (1994) demonstrated that the N400 component was elicited in a number of different languages, during various tasks using various modalities including written and spoken stimuli. Therefore, it is the component of interest for this study.

2.10 The Revised Token Test (RTT)

The Revised Token Test (McNeil & Prescott, 1978) is based on the assumption of preserved linguistic representation and rules but impaired access to this knowledge in individuals with aphasia. While the RTT (1978) was developed as a test of auditory comprehension, the theoretical basis for it is equally applicable to reading comprehension (McNeil et al., 2008). Reading comprehension is a cognitive task that, while involving another modality, entails similar task demands such as perceptual analysis and interpretation, lexical, semantic and phonological activation and access. Most of the psycholinguistic variables that affect auditory comprehension also affect reading comprehension such as stimulus length and syntactic complexity (McNeil et al., 2008). These similarities along with parallel versions of a widely accepted assessment of sentence comprehension, is what allows this study to directly compare the two modalities (reading and auditory) to investigate whether there are modality specific impairments in individuals with aphasia and at what point in the process do these differences occur.

Chapter 3: Methods

3.1 Experimental Design

This study compares the performance of two groups of individuals, individuals with aphasia and individuals with no brain damage responding to spoken and written sentence length commands. Individuals with aphasia were assigned to the experimental group. Individuals with no brain damage were assigned to the control group. A 2x2 mixed factorial design was used in this study, as it examines both between and within subject performance. This design consists of one within subject variable (sentence length commands), with two levels (spoken and written), and one between subjects variable (groups), with two levels (experimental and control).

3.2 Variables

The independent variables are the participants and the sentence length commands. Both variables are dichotomous and include the individuals with aphasia and the individuals with no brain damage and spoken and written sentence length commands, respectively. Inclusion criteria for the individuals with aphasia include diagnosis of aphasia reported from speech-language pathologists who had previously administered a standardized test to the individual, no history of speech-language problems prior to current diagnosis of aphasia, diagnosis of left CVA by a medical doctor, normal or corrected to normal vision, normal or corrected to normal hearing and medically stable to participate in the study. Inclusion criteria for the individuals with no brain damaged include no history of head trauma, brain damage or learning disability as reported on responses on the Self Report Medical Questionnaire (Appendix A), normal or corrected to normal vision and normal or corrected to normal hearing. The sentence length commands were adopted from the Revised Token Test (McNeil & Prescott, 1978) and are defined as syntactically independent clauses. The dependent variables are continuous and include latency, amplitude of the N400 ERP component, percent response accuracy, and behavioral reaction time. The N400 ERP component was defined as the largest negative deflecting peak occurring between 350 to 650 ms post stimulus onset. Latency of the N400 was defined as the specific onset time of the peak and

measured in milliseconds (ms). Amplitude was defined as the height of the peak and measured in microvolts (mv). Behavioral reaction time was measured from the time the spoken/written message ended to the time the participant touched the visual display of choices on the touch screen monitor.

3.3 Research Sample

3.3.1 Recruitment

All participants were English-speaking individuals recruited from the El Paso area. Written informed consent was obtained from all participants under the provision of the University of Texas El Paso (UTEP) Institutional Review Board (IRB) (Appendix B & C).

3.3.2 Participants

Table 3.1 shows the characteristics of individuals participants. Participants were between the ages of 35 and 65 years. The experimental group consisted of four individuals with aphasia, one male and four females with a mean age of 53 years ($M = 53$ years). The control group consisted of five individuals with no brain damage, two males and three females with a mean age of 51 years ($M = 51$ years). All participants were right handed as determined by responses on the Annett Hand Preference Questionnaire (Appendix D). All participants completed a self-report medical screening questionnaire to ensure that the participant was healthy and able to participate in the study. One participant from the experimental group did not complete the auditory version of the task due to behavioral issues that resulted in participant dropping out of the study. One of the participants from the control group did not successfully complete both tasks due to equipment malfunction and was unable to return for testing due to scheduling issues. Both participants were excluded from the study. Aphasia diagnosis was based on standardized behavioral assessment instruments performed by graduate clinicians and supervised by a certified speech language pathologist. Time post onset is an estimation based on participant self-report.

Table 3.1: Participant Characteristics

<u>Experimental Group</u>	<u>Age</u> (yrs.)	<u>Gender</u>	<u>Post Onset</u> (yrs.)	<u>Type of Aphasia</u> WAB-R (Kertesz, 1982)
AS1	37	F	9+ (estimated)	Mixed (Wernicke's/Conduction)
AS2	63	M	4.5	Moderate Wernicke's
AS3	56	F	12.17	Mild Conduction
AS4	55	F	7.25	Mild Conduction
Mean	52.75		8.23	
<u>Control Group</u>				
NS1	40	F		
NS3	50	M		
NS4	48	M		
NS5	62	F		
Mean	50			

3.4 Experimental Task

Participants were tested individually at the ERP and Aphasia Laboratory in the Speech Language Pathology Research Facility of the College of Health Sciences at the University of Texas at El Paso. The experimental tasks used in the present study were modifications of the auditory and reading versions of the RTT (1978). The RTT (1978) requires listeners/readers to maneuver circles and squares of two sizes (big and small) and of different colors (white, black, red, blue and green) in relation to the sentence length stimuli (Eberwein, et al., 2007). The Revised Token Test (McNeil & Prescott, 1978) was chosen for this research project because it is based on the assumption of preserved linguistic representation and rules but impaired access to this knowledge in individuals with aphasia. While the RTT (McNeil & Prescott, 1978) was originally developed as a test of auditory comprehension, the theoretical basis for it is equally applicable to reading comprehension (McNeil et al., 2008). Recently, the RTT (McNeil & Prescott, 1978) has been computerized (Computerized Revised Token Test,

CRTT(McNeil et al., 2008)), along with development of an equivalent written form of the test (Computerized Revised Token Test - Reading, (CRTT-R)).

Investigations of these computerized versions support the validity of both versions. In addition these investigations suggest a high correlation between both versions of the RTT (McNeil & Prescott, 1978) with the Reading Comprehension Battery for Aphasia (RCBA) (LaPointe & Horner, 1998) and Porch Index of Communicative Ability (PICA) (Porch, 2001) for individuals with aphasia for measuring language-processing difficulties regardless of modality and language function (McNeil et al., 2008). The well-established validity and reliability of the RTT (McNeil & Prescott, 1978) and the validity of the developing CRTT made the Revised Token Test suitable for use in this study.

Modifications to the RTT (1978) were done so that the RTT (McNeil & Prescott, 1978) can be used in an ERP study. A modified computerized version of the RTT allows for control over prosody, intensity and rate of presentation. Two versions of the test (spoken and written commands) were used to compare the performance between the two groups of individuals responding to spoken and written sentence length commands. The auditory version of the modified computerized version of the RTT (1978) used in this experiment was adopted from Lara (2012). In this task, the visual stimuli were presented on the touch screen in a 3 X 3 matrix and were presented using Superlab Stimulus Presentation Software (Superlab, 2008). The spoken commands were computer generated and had consistent intensity, prosody and rate of presentation across the entire task. The commands were presented via speakers located at a distance of 34 cm from the edge of the table at 75 dB SPL measured by a RadioShack Sound Pressure Meter at the level of the participant's ear. The sound pressure level used was adopted from McNeil et al., (2008) during reliability testing of the CRTT. The RTT (1978) consists of ten subtests increasing in grammatical complexity with ten trials in each subtest. The modified version used in this study consisted of seven of the ten original subtests (Lara, 2012).

This auditory task was further modified to include a reading version for use in this study. The auditory commands included in Lara (2012) were typed in Arial font, size 36 and full sentences were presented on the middle of the screen. In order to mirror the fleeting nature of the auditory commands, the duration of the display of written commands were limited to 4.5 seconds. This display time was

chosen based on the average length of the auditory commands. Placing a limited duration on the written commands increases the working memory load of the task, and was perhaps more equivalent to that encountered in the auditory presentation of the task (McNeil et al., 2008). The format of the text used in the reading task was adopted from the Computerized Revised Token Test– Reading (CRTT-R) (McNeil et al., 2008). Visual displays, sequence of triggers and the sequence of subtests remained the same. The following is an example of an auditory/written sentence length message; “Touch the green circle”. A complete list of the sentence length commands within each subtest is provided in Appendix E. The order in which the tasks were presented and the trials within each subtest for both tasks were randomized for each participant to decrease the possibility that the participant would memorize the spoken commands. Participants also completed each task within a minimum of 24 hours between each task.

3.5 Triggers

Events are time windows within a trial and represent the presentation of a stimulus (sentence length commands, visual choices and ISIs). Triggers mark the events within a trial and are time-locked to each event. Following the trigger sequence used by Lara (2012), participants were instructed to look at the observational white sample (Trigger 1) that appeared on a black screen on the touch monitor. Participants were instructed to touch the white sample to initiate an experimental trial. Immediately, the auditory/written sentence length message (Trigger 2) was presented. A blank screen followed, indicating an inter-stimulus interval (ISI) of 1000 ms (Trigger 3). Following the 1000 ms ISI, the visual display of choices (Trigger 4) appeared. The participant responded by touching the appropriate cell that contains the choice that matches the auditory/written command. Immediately following the participant's response, the screen went blank for an ISI of 3000 ms (Trigger 5=1500ms, Trigger 6=1500ms). This signaled the end of the trial. This cycle was repeated for each individual trial for both tasks. Figure 3.1 illustrates a schematic representation of the trigger sequence adopted from Lara (2012).

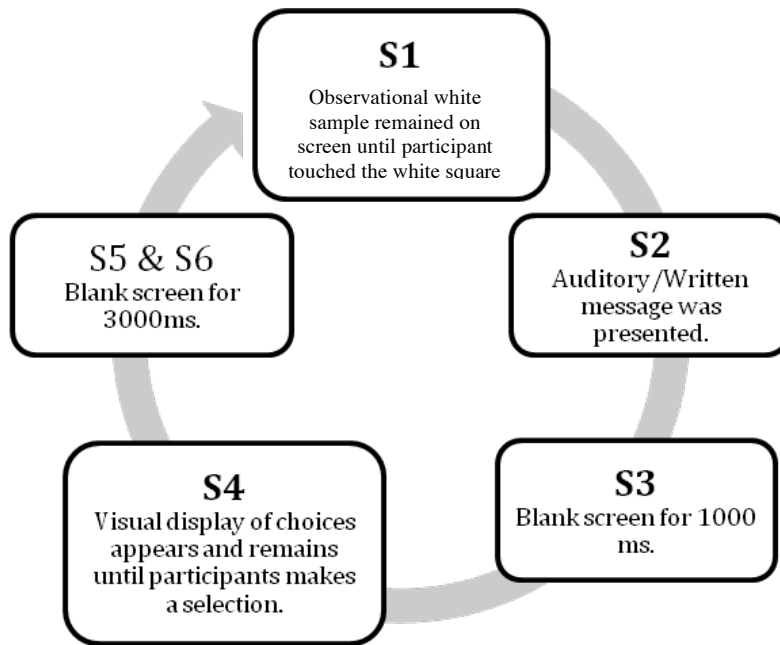


Figure 3.1: Schematic representation of the trigger sequence adopted from Lara (2012).

3.6 Experimental Procedure

Experimental procedure was completed as follows. Participant was seated in a 6' X 6' soundproof room in front of the Entuitive Touch monitor. The participant was instructed to keep movement to a minimum only moving to maneuver the tokens that appeared on the touch screen. The participant was then instructed to start each trial with their index finger placed on a mark positioned 34 cm from the touch monitor. The participant was instructed to touch the white sample (Figure 3.2) to initiate a trial and to listen to/read the spoken/written sentence length message. In addition, the participant was instructed to keep the index finger on the mark until the auditory or written spoken sentence length message ended or disappeared. Once the auditory or written stimulus was presented, the participant was instructed to touch the visual display of choices (Figure 3.3) that appeared on the touch screen, selecting only the one that match the previously presented stimulus. The participant was instructed to return the index finger to the mark and wait for the white square in the center of a black screen (Figure 3.2) to appear. This signaled the beginning of the next trial. Participants were instructed

to move only to touch the screen when either a white sample (Figure 3.2) or visual display of the choices (Figure 3.3) appeared on the touch monitor.

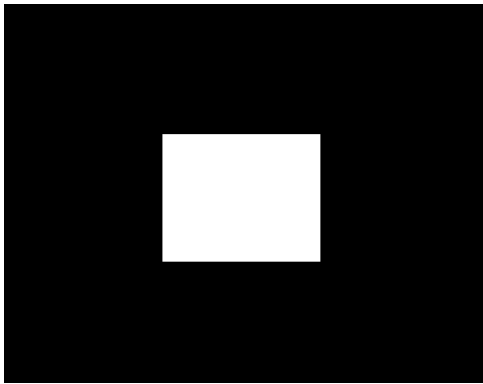


Figure 3.2: White Sample

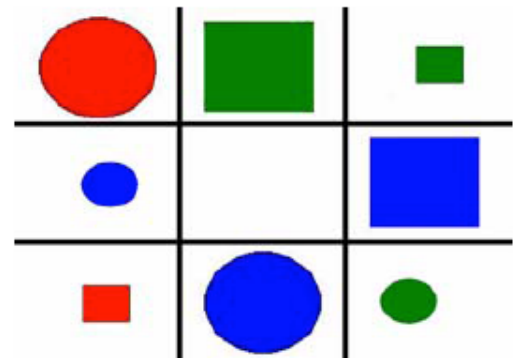


Figure 3.3: Visual choices

3.7 Electrophysiological Procedure

Each participant's head dimensions were measured and fitted with the "best fitted" electrode cap. Measurements were taken by measuring the head from nasion (bridge of the nose) to the inion (mid-occipital ridge on the back of the head) and from the preauricular point of each ear. The electrode cap size was selected based on the above-mentioned measurements. Once the electrode cap was selected, it was fitted on the participant's head. Each electrode was filled with Signa conduction gel to decrease impedance and 64 electrodes were secured to the electrode cap and 6 external electrodes were attached to the participant to allow for the later filtering out of external factors such as head and eye movements, following the International 10-20 System (Jasper, 1958). Figure 3.4 provides a schematic for the placement of the 64 electrodes on the scalp. The 10-20 international system is the standard method for applying scalp electrodes during EEG tasks. It is based on the relative correlation between the position of an electrode on the scalp and the corresponding cortical area underneath and each electrode is lettered accordingly. The numbers 10 and 20 signify the distances between neighboring electrodes as being either 10% or 20% of the complete measurement of the skull from right to left or front to back (Jasper, 1958).

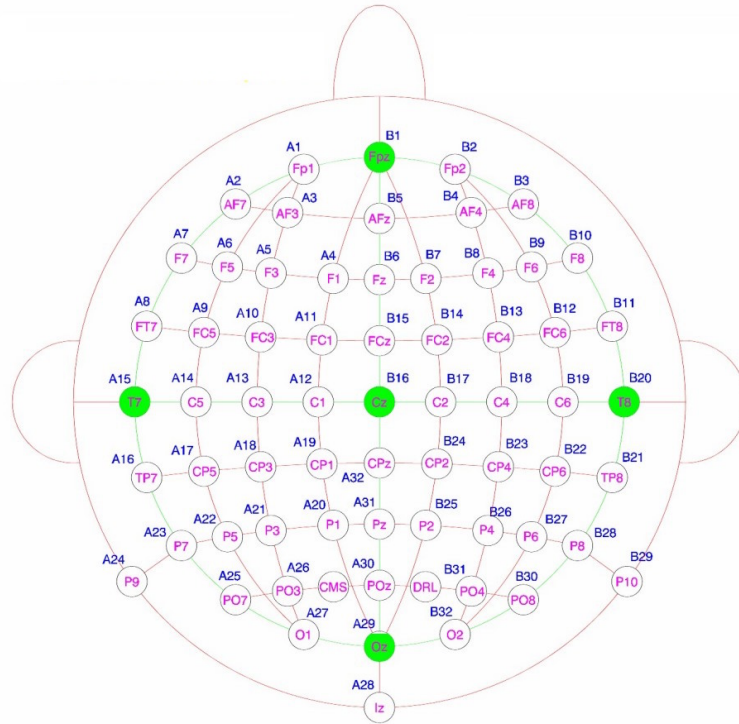


Figure 3.4: Placement of 64 electrodes following the International 10-20 System (Jasper, 1958)

3.8 Data Collection

3.8.1 ERP Recordings

Electrical activity was recorded from the scalp with 64 electrodes that were connected to the electrode cap. Two reference electrodes were positioned on the mastoids, left and right, and all electrodes were referenced to these. Vertical eye movements were recorded using external electrodes that were placed above and below the left eye while horizontal eye movements were recorded using external electrodes positioned on the left and right temples (Handy, 2005). Electrical signals from the 64 scalp locations were recorded using the ActiveTwo software program from Bio Semi. The electrodes transmitted electrical signals at a sampling rate of 2048 Hz. Bandpass was set at 0.1 Hz for the low cut off with a 12 dB slope, and a high cut off at 30 Hz.

3.8.2 Data Filtering and Artifact Rejection

The ERP data was filtered and analyzed off-line using the Brain Vision Analyzer from Cortech Solutions (2008) with the sampling rate changed to 512 Hz. Filtering the continuous EEG data diminishes disturbing noise thus providing a clearer picture of the ERP waveform. The artifact rejection function on the Brain Vision Analyzer software detected epochs or time segments that contain artifacts and marked them as rejected. Artifacts include things such as blinks and eye movements. Band-rejection filtering was set at 60Hz (notch filter) to eliminate interference from the electricity network.

3.8.3 Data Segmentation

The continuous EEG was segmented into time blocks called "epochs" measured from trigger to trigger within each trial. Related epochs from each trial were later grouped together and averaged. This analysis results in the spontaneous electrical activity from the scalp being largely eliminated and the activity resulting specifically from the processing of the stimulus remains (Fonteneau, Frauenfelder & Rizzi, 1998).

3.9 Data Analysis

3.9.1 Analysis of Behavioral Responses

The number of correct responses were automatically recorded and saved using Superlab Software Program for later analysis for both groups for both the auditory and reading task. The mean behavioral reaction time was also measured and recorded for all participants using the Superlab Stimulus Presentation Software (2008) from Cedrus Corporation.

3.9.2 Analysis of ERP Data

ERP data was examined, corrected and analyzed using the Brain Vision Analyzer (Cortech Solutions, 2008). Electrode channels were edited to eliminate unwanted noise from disturbing electrodes. Grand averages were calculated and bad intervals skipped.

3.9.3 Statistical Analysis

After review of recent literature on ERP research, the ANOVA was chosen for statistical analysis, as this is the analysis of choice used in all of the recent publications on ERP (Silva-Pereyra, Rivera-Gaxiola & Kuhl 2005; DeLong, Quante & Kutas, 2014; Knoeferle, Urbach & Kutas, 2014). A 2x2 mixed-design ANOVA was used to analyze percent correct response rate, behavioral reaction times, peak amplitude and latency of the N400 for between group performances. The two-way mixed ANOVA was also used to determine whether a statistically significant difference exists between the auditory and reading tasks within group performance. The primary purpose of using a two-way mixed ANOVA is to understand if there is an interaction between these two factors (participants and comprehension task) on the dependent variables.

3.9.4 Spatial Analysis

Spatial analysis was completed to generate topographic maps that illustrate the cortical activation patterns, relative to electrode placement on the scalp, of both groups during each task. Individual participant waves were averaged and CDS maps were generated based on the group average. Topographic maps were generated at the N400 peak. Electrode Cz is located centrally, rendering it the most ideal electrode from which to generate these topographic maps.

Chapter 4: Results

4.1 Behavioral Responses

The behavioral responses for each participant and group means are summarized in Table 4.1.

Table 4.1: Individual behavioral responses to spoken and written sentence length commands

	<u>Written</u>		<u>Spoken</u>	
	<u>% of Correct Responses</u>	<u>Reaction time (ms)</u>	<u>% of Correct Responses</u>	<u>Reaction time (ms)</u>
<u>Experimental Group</u>				
AS1	65.5	10,452.52	23.3	9,414.90
AS2	40.0	14,408.27	/	/
AS3	87.7	12,629.57	87.7	9,665.34
AS4	73.3	11,199.56	63.3	9,711.77
Mean (SD)	66.6 (.043)	12,172.48 (429.92)	58.1 (.123)	9,597.34 (491.81)
<u>Control Group</u>				
NS1	82.2	9,045.19	78.8	7,061.06
NS3	88.8	9,663.87	90.0	7,000.69
NS4	87.7	9,019.40	86.6	6,715.90
NS5	85.5	9,522.69	76.6	9,089.00
Mean (SD)	86.1 (.038)	9,312.79 (372.33)	83.0 (.106)	7,466.66 (425.93)

The percentage of correct responses was calculated for all participants for both tasks. The data for correct response rate for all participants was collected using Superlab Stimulus Presentation Software. A 2x2 mixed-design ANOVA was calculated to examine the effects of the comprehension modality (reading and listening) and groups (experimental and control) on the percentage of correct responses. No significant main effects or interactions were found. The modality x group interaction ($F(1,5) = 1.725, p = .246$), the main effect for modality ($F(1,5) = 3.426, p = .123$), and the main effect for group ($F(1,5) = 2.733, p = .159$) were not significant. Neither the modality nor group influenced the percentage of correct responses.

Behavioral reaction times were calculated for all participants during both tasks. Behavioral reaction time was measured as the time from the ending of the spoken/written message to the time the participant touches their visual choice on the touch screen monitor. Behavioral reaction times were collected using Superlab Stimulus Presentation Software. A 2x2 mixed-design ANOVA was calculated to examine the effects of the comprehension modality (reading and listening) and groups (experimental and control) on behavioral reaction times. A significant main effect for modality was found ($F(1,5) = 23.531, p = .005$). A significant main effect for group was found ($F(1,5) = 19.604, p = .007$). The modality x group interaction was not significant ($F(1,5) = .001, p = .984$). The group did not influence the effect of the task modality.

4.2 Electrophysiological Responses

The peak latencies and amplitudes for the N400 ERP component for each participant and group means are summarized in Table 4.2. Peak latency for the N400 component was defined as the largest negative deflecting peak occurring between 350-650 ms after the onset of the visual choices (S4). Peak latency for the N400 component was measured from electrode Cz, as it is located centrally, rendering it the most ideal electrode from which to measure overall performance. A 2x2 mixed-design ANOVA was calculated to examine the effects of the comprehension modality (reading and listening) and groups (experimental and control) on the latency of the N400 component. No significant main effects or interactions were found. The modality x group interaction ($F(1,5) = 1.545, p = .269$), the main effect for modality ($F(1,5) = .427, p = .523$), and the main effect for group ($F(1,5) = .002, p = .979$) were not significant. Neither the modality nor group influenced the latency of the N400 component.

Peak amplitude of the N400 was defined as the height of the peak and is measured in millivolts (mv). Peak amplitude for the N400 component was also measured from electrode Cz. A 2x2 mixed-design ANOVA was calculated to examine the effects of the comprehension modality (reading and listening) and groups (experimental and control) on the amplitude of the N400 component. No significant main effects or interactions were found. The modality x group interaction ($F(1,5) = 4.244, p$

= .094), the main effect for modality ($F(1,5) = .027, p = .875$), and the main effect for group ($F(1,5) = 5.174, p = .072$) were not significant. Neither the modality nor group influenced the amplitude of the N400 component.

Table 4.2: Individual peak latencies and amplitudes for the N400 ERP in response to spoken and written sentence length commands.

	<u>Written</u>		<u>Spoken</u>	
	Latency (ms)	Amplitude (mv)	Latency (ms)	Amplitude (mv)
<u>Experimental Group</u>				
AS1	424	-2.296	438	-4.501
AS2	426	-0.702	/	/
AS3	563	-0.324	373	-1.764
AS4	438	-4.425	359	-3.820
Mean (SD)	462.75 (32.08)	-1.937 (.956)	390 (52.27)	-3.362 (1.04)
<u>Control Group</u>				
NS1	412	-2.192	607	-1.761
NS3	373	-0.422	404	-0.741
NS4	439	1.047	354	2.674
NS5	453	-0.281	410	1.432
Mean (SD)	419.25 (27.78)	-0.462 (.828)	443.75 (45.27)	0.401 (.902)

The ERP waveforms for the N400 ERP component measured at electrode site Cz are shown in Figure 4.1, 4.2, 4.3 & 4.4. It can be seen from Figure 4.1 that the onset of the N400 component in response to spoken sentence length commands, for individuals with aphasia was within the expect time window, occurring at 390ms with amplitude of -3.362 mv. The individuals with no brain damage did not produce an N400 within that time window. In response to written sentence length commands, individuals with aphasia displayed a slightly delayed onset of the N400 (462.75 ms) compared to the individuals with no brain damage (419.25) (Figure 4.2). Individuals with aphasia displayed increased amplitude of the N400 (-1.937 mv) compared to individuals with no brain damage (-0.462 mv).

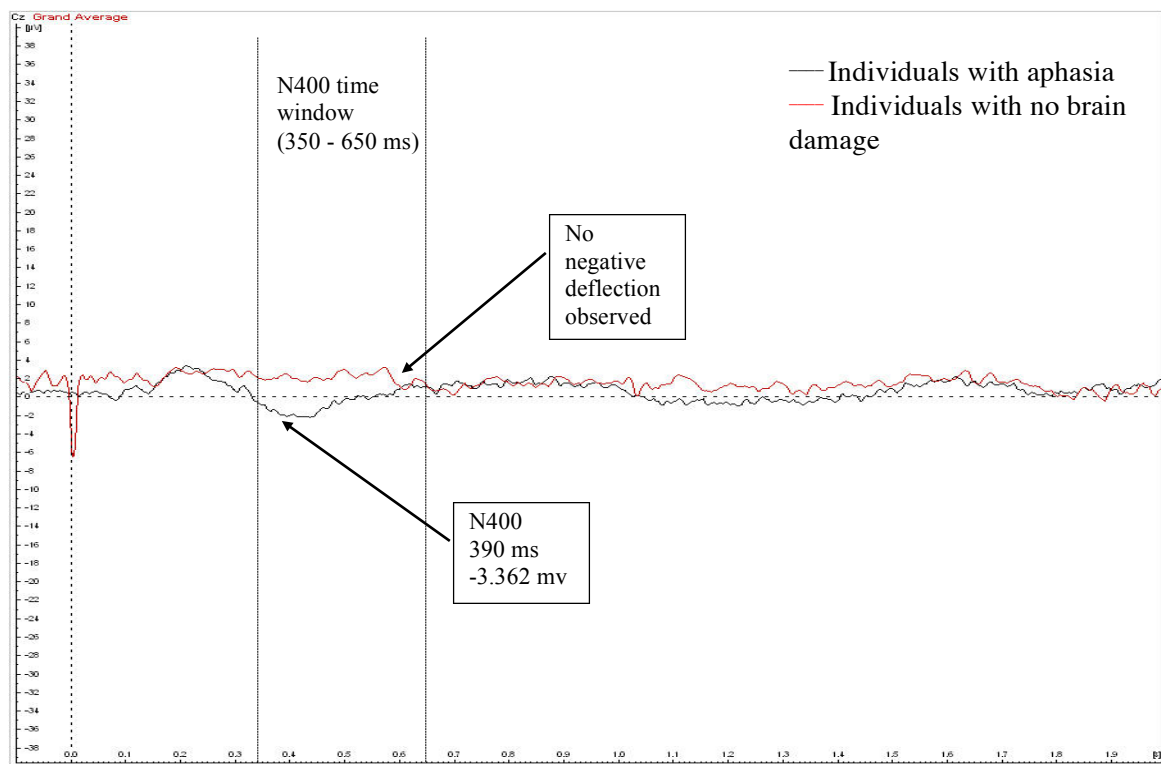


Figure 4.1: ERP waveform showing N400 in response to spoken sentence length commands.

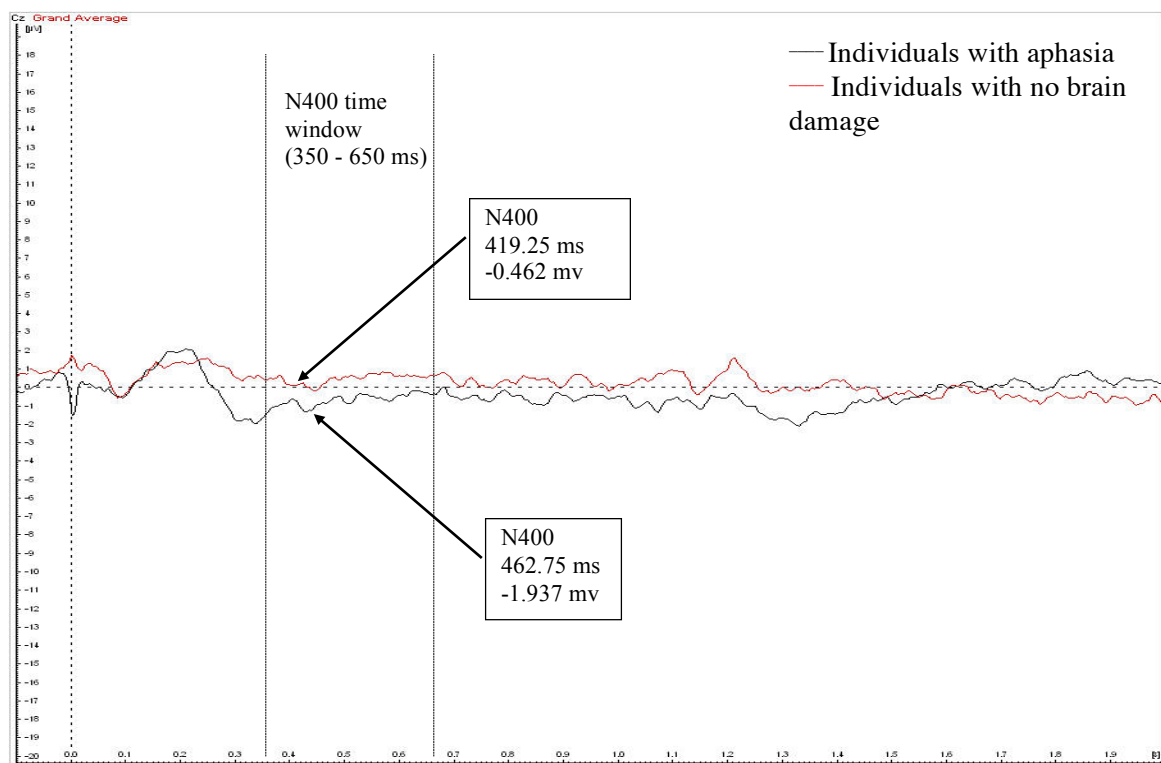


Figure 4.2: ERP waveform showing N400 in response to written sentence length commands.

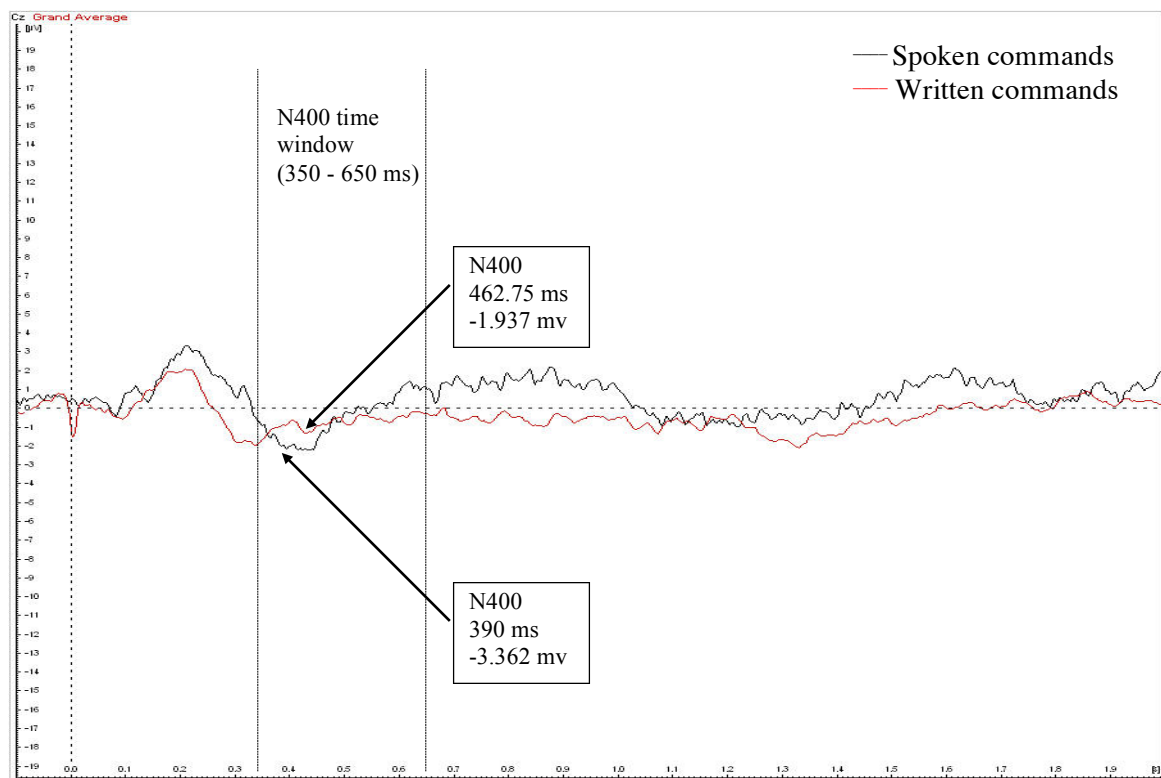


Figure 4.3: ERP waveform showing N400 for individuals with aphasia.

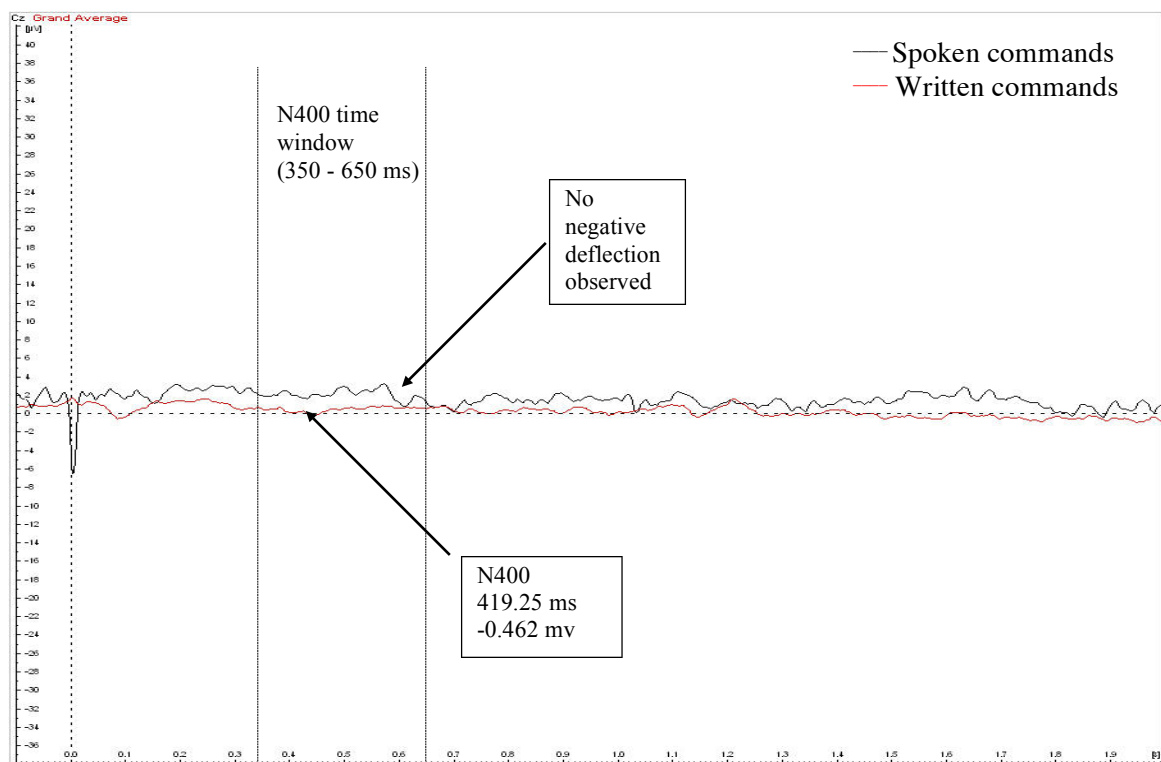


Figure 4.4: ERP waveform showing N400 for individuals with no brain damage.

Visual inspection of Figure 4.3 indicates that individuals with aphasia displayed increased latency of the N400 in response to written sentence length commands compared to spoken sentence length commands. They also displayed decreased amplitude of the N400 for written commands compared to the spoken commands. The individuals with no brain damage did not display an N400 in response to the spoken sentence length commands (Figure 4.4), however they displayed an N400 in response to the written sentence length commands.

4.3 Cortical Activation Patterns

Topographical maps were derived from electrode Cz to examine overall cortical activation patterns. Topographic distribution was defined as the specific regions on the scalp where the N400 was elicited. On the topographic maps, red indicates areas of high positive activation; yellow indicates moderate positive activation; green indicates areas of neutral activation while blue indicates areas of negative activation. Figure 4.5 and 4.6 illustrates the topographic maps for the two groups on each task, generated at the N400 ERP component.

In response to spoken sentence length commands (Figure 4.5), the individuals with aphasia exhibited more overall activation than the individuals with no brain damage that exhibited more localized activations. The individuals with aphasia displayed high positive activation in the right frontal electrode sites, while there was moderate positive activation in the left frontal electrode sites. They also displayed high positive activation in the left parietal electrode sites while there was neutral activation on the corresponding right electrode sites. There was a very small area of moderate positive activation in a right temporal electrodes site. Notably the individuals with aphasia displayed negative activation in one left occipital electrode site with moderate activation in all other occipital electrodes.

The individuals with no brain damage displayed equally small and moderate positive activation in both the left and right frontal electrode sites and exhibited only small and moderate activation in the left parietal electrode sites. They displayed large high positive activations in the frontal-central electrode sites.

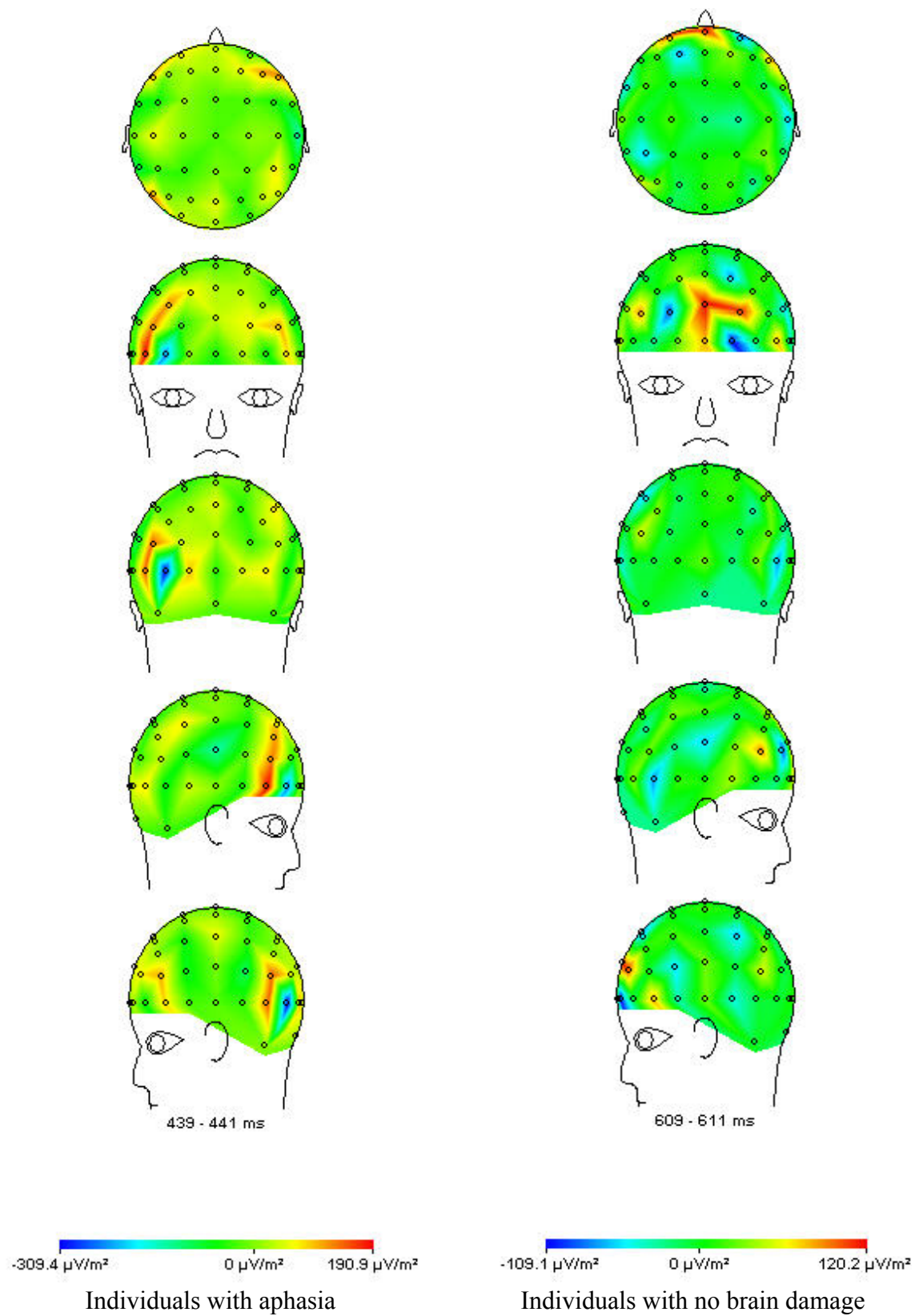


Figure 4.5: Cortical activation patterns in response to spoken sentence length commands.

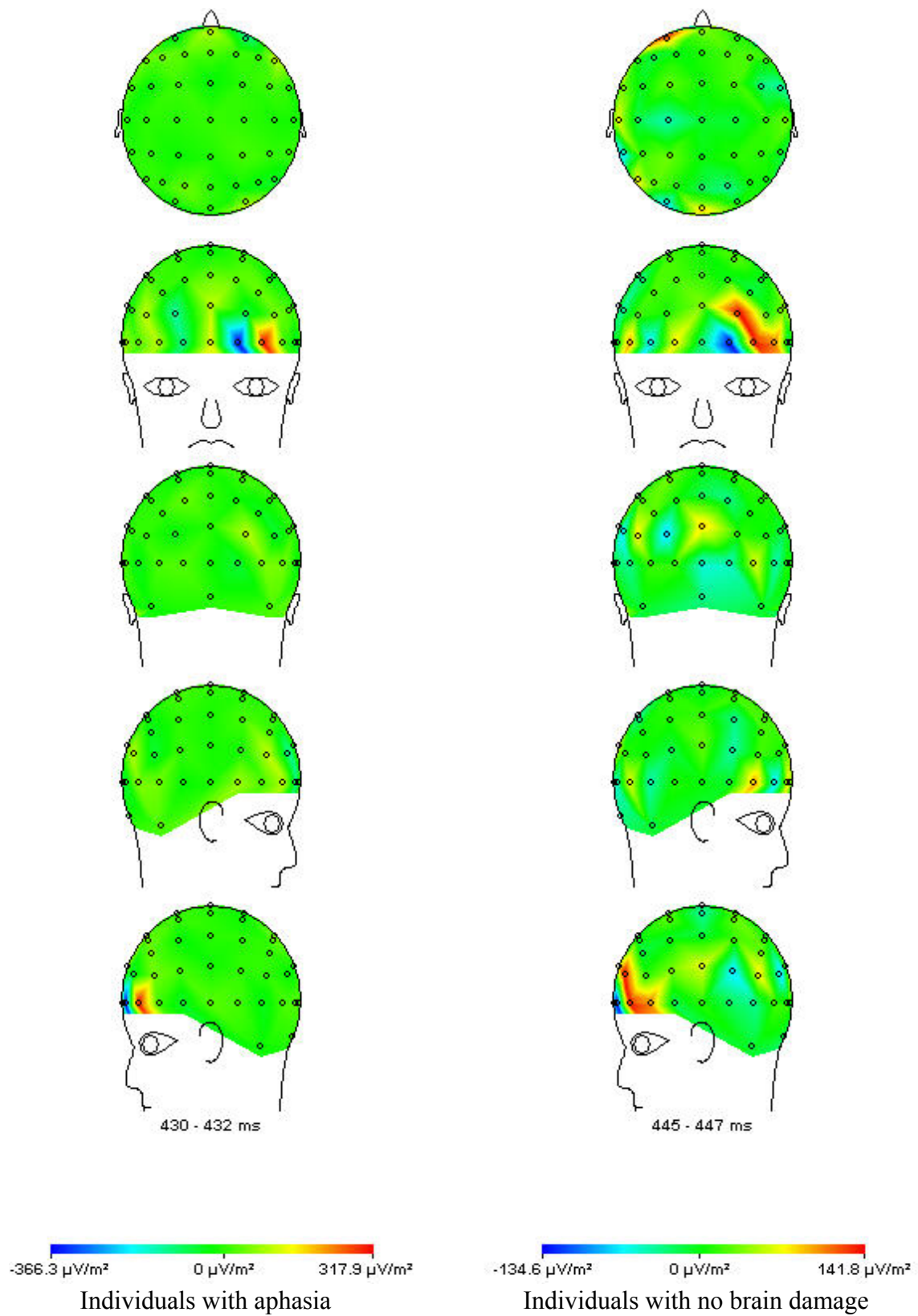


Figure 4.6: Cortical activation patterns in response to written sentence length commands.

In response to written sentence length commands (Figure 4.6) individuals with aphasia displayed localized activation. High positive activation was localized around one left frontal electrode site, with minimal positive activation in the corresponding right electrode sites. The individuals with no brain damage displayed a similar activation pattern however activation was extended to a larger area of the frontal electrode sites. There appeared to be a higher positive activation in the right frontal electrodes in individuals with no brain damage when compared to individuals with aphasia. Individuals with no brain damage also displayed higher activations in the left central and parietal electrode sites than the persons with aphasia. Both groups displayed negative activation around one frontal-central electrode site.

Individuals with aphasia exhibited more localized frontal activation in response to the written sentence length commands compared to the dispersed cortical activation displayed in response to spoken sentence length commands. The high right side activations were not displayed in response to written commands. The areas of high activation in response to spoken commands were minimally activated or neutral in response to the written commands, the same trend was observed for areas of high activation in response to the spoken commands.

The individuals with no brain damage displayed frontal localization in response to both types of commands. Activation was more centralized for spoken commands while activation for written commands was localized to the left frontal electrode sites. Also, there was small minimal right frontal activation in response to both types of commands.

4.3.1 T7 versus T8

Since no statistically significant difference was found for peak latency and amplitude of the N400 measured at Cz, the peak latency and amplitude for both groups in response to both types of commands was visually inspected at electrode sites T7 and T8 to identify any possible differences. Electrode T7 corresponds with the left temporal region while electrode T8 corresponds with the right temporal region. Figures 4.7 and 4.8 show the cortical activation patterns of individuals with aphasia at electrode sites T7 and T8, in response to spoken and written sentence length commands respectively.

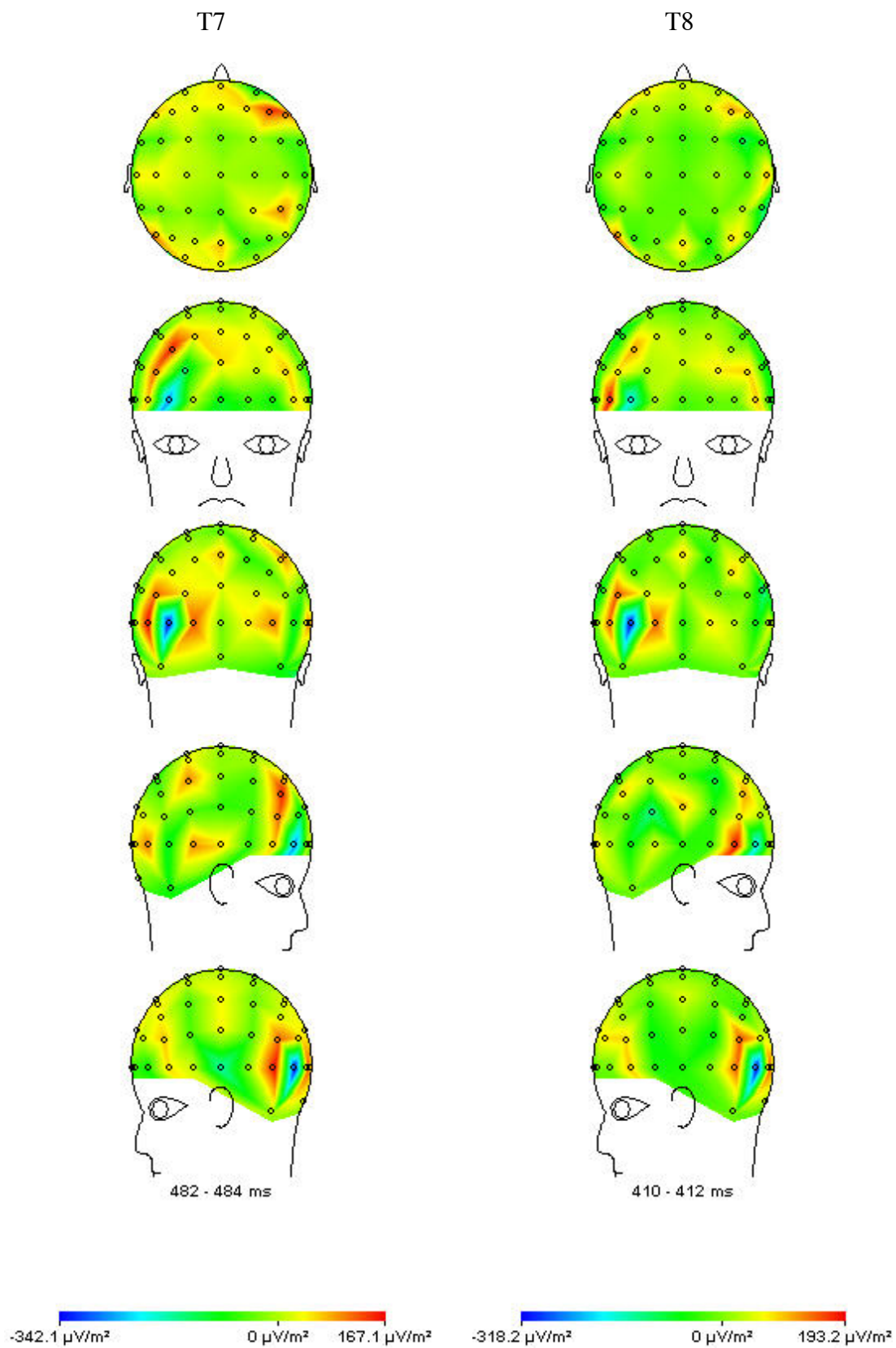


Figure 4.7: Cortical activation patterns for individuals with aphasia in response to spoken sentence length commands.

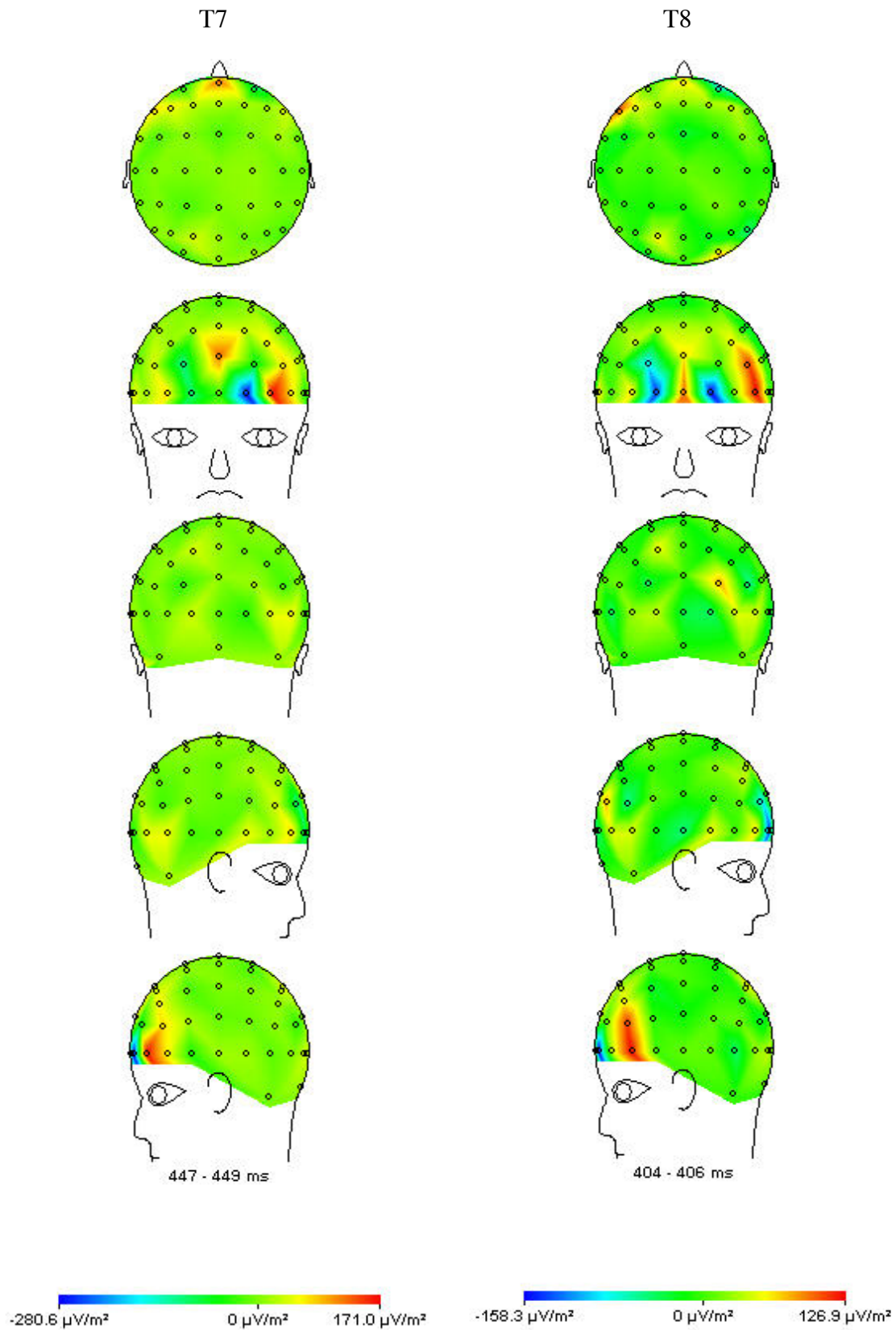


Figure 4.8: Cortical activation patterns for individuals with aphasia in response to written sentence length commands.

Visual inspection of Figure 4.7 shows that in response to spoken sentence length commands, the individuals with aphasia exhibited a more dispersed pattern of positive activations at electrode site T7 than that of T8. At T7 they displayed increased right side activation primarily in the temporal electrode sites. While in response to written sentence length commands (Figure 4.8), the individuals with aphasia displayed only a slightly more dispersed pattern of positive activations at electrode site T7. At electrode site T8 there was a similar pattern of activation however it appeared to be slightly more localized around the left frontal electrodes.

Chapter 5: Discussion

The purpose of this study is to examine the electrophysiological and behavioral differences in individuals with aphasia and individuals with no brain damage responding to spoken and written sentence length commands. In addition, differences within groups are also examined. An understanding of the temporal aspects involved in sentence comprehension will broaden current understanding of comprehension and language processing in individuals with aphasia and how modalities influence that processing. Additionally the knowledge gained from this study may lead to development of improved assessment and treatment strategies for individuals with aphasia.

The research questions addressed are: 1) Is there a statistically significant difference in the behavioral reaction times between the individuals with aphasia and the individuals with no brain aphasia responding to spoken and written sentence length message? 2) Is there a statistically significant difference in the behavioral reaction times within the two groups responding to spoken and written sentence length message? 3) Is there a statistically significant difference in the percent response accuracy between the individuals with aphasia and the individuals with no brain damage responding to spoken and written sentence length message? 4) Is there a statistically significant difference in the percent response accuracy within the two groups responding to spoken and written sentence length message? 5) Is there a statistically significant difference in the peak latency and amplitude of the N400 ERP component between the individuals with aphasia and the individuals with no brain damage responding to auditory and written sentence length commands? 6) Is there a statistically significant difference in the peak latency and amplitude of the N400 ERP component between the spoken and written sentence length commands within the two groups? 7) Do cortical activation patterns differ between the individuals with aphasia and individuals with no brain damage responding to spoken and written sentence length commands?

The results obtained in this study show that individuals with aphasia require additional time to process both written and spoken commands compared to individuals with no brain damage. However given this additional time, the individuals with aphasia were able to respond with a similar degree of

accuracy as the individuals with no brain damage. Both groups displayed significantly longer reaction times in response to written sentence length commands and all participants (except NS3) appeared to respond more accurately to the written sentence length commands, however it was not significantly different from the accuracy of responses to the spoken sentence length commands. Variability of individual data may be responsible for the lack of significant differences. For example, analyses of individual data showed that one of the individuals with aphasia, AS1 displayed a significant difference in accuracy of responses with a 280% increase in accuracy on the written task versus the spoken task. Also participant AS2 did not complete both tasks and this should be considered when comparing both modalities as well as both groups.

Despite variability among participants these findings are similar to the findings of Peach et al., (1988), where individuals with anomic and conduction aphasia did not show any modality effects in their accuracy of responses. In addition, like Peach et al., (1988) study the individuals with aphasia that participated in this study were all diagnosed with a fluent aphasia (conduction and/or Wernicke's), and that may account for the similar findings. However Peach et al.'s (1988) study used a picture-matching task while the current study used novel procedure that required participants to produce an overt response to indicate understanding of the sentence length message. Therefore with the use of this novel procedure along with variability of data it a sound comparison is unable to be made.

These results confirm the findings of previous research that did not find any modality specific effects on sentence comprehension in individuals with aphasia (Dede, 2013; McNeil et al., 2008). Although the current study did not specifically investigate syntactic complexity, the commands increased in complexity and as such are similar to the stimuli used by Dede (2013), which may account for the similar findings. Notably, Dede (2013) reported that although performances were fairly equal, the syntactic complexity effects were slightly exaggerated in the written modality while the current study indicates that effects were marginally exaggerated in the spoken modality. Overall these behavioral analyses suggest that sentence comprehension impairments in individuals with aphasia do not differentially impact the two modalities. This is consistent with the view that sentence comprehension impairments affect central linguistic, rather than modality-specific, operations (McNeil et al., 2008).

The statistical analysis showed that there was no statistically significant difference between modalities and also between the two groups for latency and amplitude of the N400 component. A closer analysis of individual data provides a possible explanation for the failure to find a statistically significant difference for latency and amplitude of the N400 that has been reported in previous studies (Kutas & Hillyard, 1984; Swaab et. al., 1997). One participant with no brain damage, NS4 did not produce an N400 for either modality. Furthermore, another participant with no brain damage, NS5 did not produce an N400 in response to the spoken sentence length commands. These two participants displayed behaviors that, based on the literature, would be expected from individuals with aphasia. This variety in individual performance coupled with the small sample size, may account for that failure to find a statistically significant difference.

Cortical activation patterns elicited from electrode site Cz show that individuals with aphasia had highly dispersed areas of activation throughout left and right frontal and parietal electrodes in response to spoken sentence length commands while the participants with no brain damage displayed a frontal and central distribution. Conversely both groups displayed a similar activation pattern in response to written sentence length commands, with positive activations localized around the left frontal electrodes with the individuals with aphasia displaying a smaller area of activation. Previous fMRI studies on non-brain damaged individuals have shown that reading comprehension produces more left-lateralized activation while listening comprehension produces bilateral activations (Buchweitz et al., 2009; Keller et al., 2001). Both groups in this current ERP study displayed this pattern of activation. fMRI studies have also suggest that listening comprehension places a greater demand on processing resources and therefore creates additional areas of activation than reading comprehension (Fiez and Petersen, 1998) in individuals with no brain damage. However in the current study the individuals with no brain damage did not display a difference in amount of activation between modalities but the individuals with aphasia did, suggesting that the individuals with aphasia need to use all available resources for processing auditory information.

As previously mentioned the control group in the current study displayed behaviors contrary to the literature on non-brain damaged individuals while displaying behaviors more typical of pathological

populations. Therefore it is difficult to determine whether the highly dispersed levels of positive activation that the individuals with aphasia displayed in response to spoken sentence length messages can be attributed to an abnormally excessive demand on processing resources or whether this additional activation is characteristic of typical processing of spoken messages. However, we acknowledge that this study had very small sample sizes that may have contributed to group averages.

In summary, the findings from this study indicates that individuals with aphasia did not show different modality effects compared to individuals with no brain damage. However closer inspection of electrode sites T7 and T8 indicated that the cortical activation patterns of the individuals with aphasia showed more activation in the right temporal electrodes than the left. This suggests that individuals with aphasia may be pulling resources from the right analogous areas of the cortex in their attempts to derive meaning from sentences. These activation patterns were different from the ones displayed by the individuals with no brain damage that did not display any positive activation in the right temporal electrode sites. These results support the theory of neuroplasticity and the reorganization of brain function that have been proposed in previous studies that report greater areas of activation in the right hemisphere (Basso, Gardelli, Grassi & Mariotti 1999).

5.1 Limitations

The ERP waveforms discussed are averages of many individual trials and, as such important individual differences cannot be accounted for. These individual differences may have influenced the findings. Additionally the small sample size of the study may not be considered sufficient to support the conclusions made. However, considering the great difficulty in recruiting pathological populations, the results of this study does contribute to the current knowledge regarding comprehension of spoken and written sentence length commands. Finally, this study did not control for time post onset as most of the participants are well beyond the acute stage of aphasia and all have been receiving speech-language therapy for several years. Failure to control for these may confound distinctive features between the groups. It is an open question whether modality differences would be observed within a single study

with a small sample size, therefore future research should focus on controlling for variables such as site of lesion, age and time post onset and also increase the sample size of the pathological population.

5.2 Clinical Implications

This study suggests that sentence comprehension impairments in individuals with aphasia do not systematically affect one modality to a greater extent than the other. These results have the implications for development of improved assessment, treatment techniques and prognostic indicators. These results along with that of future studies should be used to further evaluate and possibly extend the principles of Complexity Account of Treatment Efficacy (Riley & Thompson, 2015; Thompson & Shapiro, 2007; Thompson, Shapiro, Kiran, & Sobecks, 2003) that proposes treating syntactic and phonological complexity, to treatment of the more complex or most impaired modality to determine if generalizations occur in the other modality.

References

- Ardila, A. (2010). A proposed reinterpretation and reclassification of aphasic syndromes. *Aphasiology*, 24(3), 363-394.
- Basso A., Gardelli M., Grassi, M. P., & Mariotti, M. (1989). The role of the right hemisphere in recovery from aphasia. Two case studies. *Cortex*, 25, 555-566.
- Basso, A. (1992). Prognostic factors in aphasia. *Aphasiology*, 6(4), 337-348.
- Benson, D. F. (1979). *Aphasia, Alexia, and Agraphia*. New York: Churchill Livingstone
- Bradley, D., Garrett, M., & Zurif, E. (1980). Syntactic deficits in Broca's aphasia. In D. Caplan (Ed.), *Biological studies of mental processes* (pp. 269–286). Cambridge, MA: MIT Press.
- Brady, M. C., Kelly, H., Godwin, J. & Enderby, P. (2012). Speech and language therapy for aphasia following stroke. *Cochrane Database of Systematic Reviews*, Issue 5. Art. No.: CD000425.
- Buchweitz, A., Mason, R. A., Tomitch L. M. B. & Just, M. A. (2009). Brain activation for reading and listening comprehension: An fMRI study of modality effects and individual differences in language comprehension. *Psychology and Neuroscience*, 2(2), 111-123.
- Caplan, D., DeDe, G., Michaud, J. & Reddy, A. (2007). A study of syntactic processing in aphasia I: behavioral (psycholinguistic) aspects. *Brain and Language*, 101, 103–50.
- Caplan, D., Michaud, J., & Hufford, R. (2013). Short-term memory, working memory, and syntactic comprehension in aphasia. *Cognitive Neuropsychology*, 30(2), 77-109.
- Caplan, D., & Waters, G. (1999b). Verbal working memory capacity and language comprehension. *Behavioral Brain Sciences*, 22, 114–126.
- Catts, H. W., & Kamhi, A. G. (2005). *Language and reading disabilities* (2nd ed.). Boston: Pearson/Allyn and Bacon.
- Centers for Disease Control and Prevention. (2012). Prevalence of Stroke - United States, 2006–2010. *Weekly*, 61(20);379-382. Retrieved from <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6120a5.htm>
- DeDe, G. (2012). Effects of Word Frequency and Modality on Sentence Comprehension Impairments in People With Aphasia. *American Journal Of Speech-Language Pathology*, S103-S114.
- DeDe, G. (2013). Reading and Listening in People With Aphasia: Effects of Syntactic Complexity. *American Journal Of Speech-Language Pathology*, 22(4), 579-590.
- DeLong, K. A., Quante, L., & Kutas, M. (2014). Predictability, plausibility, and two late ERP positivities during written sentence comprehension. *Neuropsychologia*, 61150-162.
- Diakidoy, I. N., Stylianos, P., Karefillidou, C., & Papageorgiou, P. (2005). The Relationship Between Listening and Reading Comprehension of Different Types of Text at Increasing Grade Levels. *Reading Psychology*, 26(1), 55-80.
- Eberwein, C. A., Pratt, S. R., McNeil, M. R., Fossett, T. D., Szuminsky, N. J., & Doyle, P. J. (2007). Auditory Performance Characteristics of the Computerized Revised Token Test (CRTT). *Journal Of Speech, Language & Hearing Research*, 50(4), 865-877.

- Fabiani, M., Gratton, G. & Coles, M. G. H. (2000). Event-related brain potentials: Method, theory, and application. In J. T. Cacioppo, Louis G. Tassinary, & G. G. Berntson (Eds.), *Handbook of psychophysiology, 2nd ed.* Cambridge, UK: Cambridge University Press.
- Faustmann, A., Murdoch, B. E. and Copland, D. A. (2004) Auditory sentence processing in an aphasic patient at different stages of recovery: An ERP investigation. *Brain and Language*, 91 1: 183-184.
- Ferreira, F., Bailey, K. G., & Ferraro, V. (2002). Good-Enough Representations in Language Comprehension. *Current Directions In Psychological Science (Wiley-Blackwell)*, 11(1), 11.
- Friederici, A. (1983). Aphasics' perception of words in sentential context: Some real-time processing evidence. *Neuropsychologia*, 21, 351–358.
- Friederici, A. D. (2011). The Brain Basis of Language Processing: From Structure to Function. *Physiol Rev*, 91, 1357–1392.
- Friedmann, N., & Gvion, A. (2003). Sentence comprehension and working memory limitation in aphasia: A dissociation between semantic-syntactic and phonological reactivation. *Brain & Language*, 86(1), 23.
- Fiez, J.A., & Petersen, S. E. (1998). Neuroimaging studies of word reading. *Proceedings of the National Academy of Sciences*, 95, 914–921.
- Gallagher, A. J., & Canter, G. J. (1982). Reading and listening comprehension in Broca's aphasia: Lexical versus syntactical errors. *Brain & Language*, 17, 183–192.
- Gardner, H., Denes, G., & Zurif, E. (1975). Critical reading at the sentence level in aphasia. *Cortex*, 11, 60–72.
- Goodglass, H. & Kaplan, E. (1972). *Boston Diagnostic Aphasia Examination*. The Psychological Corporation. Boston, Mass.
- Grainger, J., & Holcomb, P. J. (2009). Watching the word go by: On the time-course of component processes in visual word recognition. *Language and Linguistic Compass*, 3, 128–156.
- Handy, Todd. (2005). *Event-Related Potentials A Methods Handbook*. Cambridge, Ma: MIT Press.
- Hickin, J., Best, W., Herbert, R., Howard, D. & Osborne, F. (2002) Phonological therapy for word-finding difficulties: A reevaluation. *Aphasiology*, 16(10-11), 981-999
- Jasper, H. (1958). The ten-twenty electrode system of the International Federation. *Electroencephalogram Clinical Neurophysiology*, 10, 371-375.
- Kertesz, A. (1982) *Western Aphasia Battery*. Orlando, FL: Grune & Stratton, Inc.
- Knoeferle, P., Urbach, T. P., & Kutas, M. (2014). Different mechanisms for role relations versus verb–action congruence effects: Evidence from ERPs in picture–sentence verification. *Acta Psychologica*, 152 133-148.
- Kolk, H. (1995). A time-based approach to agrammatic production. *Brain and Language*, 50, 282–303.
- Kreisler, A., Godefroy, O., Delmaire, C., Debachy, B., Leclercq, M., Pruvo, J.P. & Leys, D. (2000). The anatomy of aphasia revisited. *Neurology*, 54, 1117–1123

- Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science*, 207(4427), 203–205.
- Kutas, M., & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature*, 307(5947), 161–163.
- Kutas, M. & Van Petten, C. (1994). Psycholinguistics electrified: event-related brain potential investigations. In M. A. Gernsbacher (Ed.), *Handbook of Psycholinguistics*. San Diego: Academic Press.
- Kutas, M. and Federmeier, K.D. (2011) Thirty years and counting: finding meaning in the N400 component of the event-related brain potential (ERP). *Annual Review of Psychology*, 62, 621–647.
- Lara, P. (2012). *Assessing cortical electrophysiologic and behavioral activity in individuals with aphasia and participants with no brain damage responding to spoken sentence length messages*. (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses Database. (1080790220).
- Luck, S. J., and Kappenman, E. S., ed. (2012). *The Oxford Handbook of Event-Related Potential Components*. Oxford University Press.
- Luria, A. R. (1970). *Traumatic aphasia: Its syndromes, psychology, and treatment*. New York: Mouton
- McKevitt, C., Fudge, N., Redfern, J., Sheldenkar, A., Crichton, S., Rudd, A. R., . . . Wolfe, C. D. A. (2011). Self-reported long-term needs after stroke. *Stroke*, 42(5), 1398–1403.
- McNeil, M., & Prescott, T. (1978). *Revised Token Test*. Austin, TX: Pro-Ed, Inc.
- McNeil, M., Sung, J. E., and Pratt, S. (2008). Concurrent Validation of the Computerized Revised Token Test (CRTT) and Three Experimental Reading Versions (CRTT-R) in Normal Elderly Individuals and Persons With Aphasia. *Clinical Aphasiology Conference*. Jackson Hole, WY.
- Meinzer, M., Beeson, P. M., Cappa, S., Crinion, J., Kiran, S., Saur, D., & ... Thompson, C. K. (2013). Neuroimaging in aphasia treatment research: Consensus and practical guidelines for data analysis. *Neuroimage*, 73215–224.
- Michael, E. B., Keller, T. A., Carpenter, P.A., & Just, M. A. (2001). fMRI investigation of sentence comprehension by eye and by ear: modality fingerprints on cognitive processes. *Human Brain Mapping*, 13(4), 239–52.
- National Aphasia Association. (2007). Retrieved November 17, 2013, from <http://www.aphasia.org>
- National Stroke Association. (2008). <http://www.stroke.org>
- Nelson, K. (1973). Structure and Strategy in Learning to Talk. *Monographs of the Society for Research in Child Development*. 38.
- Obler, L. K., & Gjerlow, K. (1999). *Language and the Brain*. Cambridge, UK: Cambridge University Press.
- Papathanasiou, I., Potagas, C., & Coppens, P. (2013). *Aphasia and Related Neurogenic Communication Disorders*. Burlington, MA: Jones & Bartlett Learning.
- Park, G. H., McNeil, M. R., & Doyle, P. J. (2002). Lexical access rate of closed-class elements during auditory sentence comprehension in adults with aphasia. *Aphasiology*, 16(8), 801–814.

- Peach, R. K., Canter, G. J., & Gallaher, A. J. (1988). Comprehension of sentence structure in anomic and conduction aphasia. *Brain & Language*, 35, 119–137.
- Pearson, P. D., & Fielding, L. (1982). Listening comprehension. *Language Arts*, 59, 617–629.
- Perfetti, C. A. (1999). Comprehending written language: A blueprint of the reader. In C. M. Brown, & P. Hagoort (Eds.), *The neurocognition of language processing* (pp. 167–208). London: Oxford University Press.
- Perfetti, C., Chin-Lung, Y., & Schmalhofer, F. (2008). Comprehension skill and word-to-text integration processes. *Applied Cognitive Psychology*, 22(3), 303–318.
- Perfetti, C. A., & Hart, L. (2001). The lexical bases of comprehension skill. In D. Gorfien (Ed.), *On the consequences of meaning selection* (pp. 67–86). Washington, DC: American Psychological Association.
- Porch, B. E. (1967). *The Porch Index of Communicative Ability*. Palo Alto, CA: Consulting Psychologists Press.
- Prins, R. S., Snow, C. E., & Wagenaar, E. (1978). Recovery from aphasia: Spontaneous speech versus language comprehension. *Brain and Language*, 6, 192–211.
- Rasmussen, S. (2005). *An ERP study of stimulus equivalence in aphasic and non-brain damaged individuals*. (Master's thesis). Retrieved from ProQuest Dissertations and Theses Database. (305384933).
- Riley, E. & Thompson, C. (2015) Training pseudoword reading in acquired dyslexia: a phonological complexity approach. *Aphasiology*, 29(2), 129–150
- Rose, M. L. (2013). Releasing the Constraints on Aphasia Therapy: The Positive Impact of Gesture and Multimodality Treatments. *American Journal Of Speech-Language Pathology*, 22(2), S227–S239.
- Rose, M. L., Attard, M. C., Mok, Z., Lanyon, L. E., & Foster, A. M. (2013). Multi-modality aphasia therapy is as efficacious as a constraint-induced aphasia therapy for chronic aphasia: A phase 1 study. *Aphasiology*, 27(8), 938–971.
- Salvatore, A. (1976). Training an aphasic adult to respond appropriately to spoken commands by fading pause duration within commands. In R. Brookshire (Ed.), *Clinical aphasiology*. Minneapolis, MN: BRK Publishers.
- Samuels, S. J. (1987). Factors that influence listening and reading comprehension. In R. Horowitz & S. J. Samuels (Eds.), *Comprehending oral and written language* (pp. 295–325). San Diego, CA: Academic Press.
- Selinger, M., Shucard, D. W., & Prescott, T. E. (1980). Relationships between behavioral and electrophysiological measures of auditory comprehension. In R. H. Brookshire (Ed.), *Clinical Aphasiology: Conference Proceedings*, Minneapolis, MN: BRK Publishers.
- Shewan, C. M., & Kertesz, A. (1984). Effects of speech and language treatment on recovery from aphasia. *Brain and Language*, 23(2), 272–299.
- Silva-Pereyra, J., Rivera-Gaxiola, M., & Kuhl, P. K. (2005). An event-related brain potential study of sentence comprehension in preschoolers: semantic and morphosyntactic processing. *Cognitive Brain Research*, 23(2/3), 247–258.

- Sinatra, G. M. (1990). Convergence of listening and reading processing. *Reading Research Quarterly*, 25, 115–130.
- Snow, C. E. (1983). Literacy and language: Relationships during the preschool years. *Harvard Educational Review*, 53, 165–189.
- Snow, C. E. (1991). The theoretical basis for relationships between language and literacy development. *Journal of Research in Childhood Education*, 6(1), 5–10.
- Stanovich, K. E. (1980). Toward an interactive-compensatory model of individual differences in the development of reading fluency. *Reading Research Quarterly*, 16, 32–71.
- Sticht, T. G., Beck, L. J., Hauke, R. N., Kleinman, G. M., & James, J. H. (1974). *Auditing and reading: A developmental model*. Alexandria, VA: Human resources Research Organization.
- Sung, J. E., McNeil, M. R., Pratt, S. R., Dickey, M. W., Hula, W. D., Szuminsky, N. J. & Doyle, P. J. (2009). Verbal working memory and its relationship to sentence-level reading and listening comprehension in persons with aphasia. *Aphasiology*, 23(7), 1040-1052.
- Sung, J. E., McNeil, M. R., Pratt, S. R., Dickey, M. W., Fassbinder, W., Szuminsky, N. J., Kim, A. & Doyle, P. (2011) Real-time processing in reading sentence comprehension for normal adult individuals and persons with aphasia. *Aphasiology*, 25(1), 57-70.
- Superlab. (2008), Retrieved on April 30, 2008 from <http://www.superlab.com>.
- Swaab, T., Brown, C., & Hagoort, P. (1997). Spoken sentence comprehension in aphasia: Event-related potential evidence for a lexical integration deficit. *Journal of Cognitive Neuroscience*, 9, 39–66.
- Thompson, C., & Choy, J. (2009). Pronominal resolution and gap filling in agrammatic aphasia: Evidence from eye movements. *Journal of Psycholinguistic Research*, 38(3), 255–283.
- Thompson, C., & Shapiro, L. (2007). Complexity in treatment of syntactic deficits. *American Journal of Speech-Language Pathology*, 16, 30–42.
- Thompson, C., Shapiro, L., Kiran, S., & Sobecks, J. (2003). The role of syntactic complexity in treatment of sentence deficits in agrammatic aphasia: The complexity account of treatment efficacy (CATE). *Journal of Speech, Language, and Hearing Research*, 46, 591–612.
- Verhoeven, L., & Perfetti, C. (2008). Advances in text comprehension: model, process and development. *Applied Cognitive Psychology*, 22(3), 293–301.
- Webster, J., Morris, J., Connor, C., Horner, R., McCormac, C., & Potts, A. (2013). Text level reading comprehension in aphasia: What do we know about therapy and what do we need to know?. *Aphasiology*, 27(11), 1362–1380.
- Wright, H. H. & Shisler, R. J. (2005). Working Memory in Aphasia Theory, Measures, and Clinical Implications. *American Journal of Speech-Language Pathology*, 14, 107–118.
- Zipse, L., Kearns, K., Nicholas, M., & Marantz, A. (2011). A MEG Investigation of Single-Word Auditory Comprehension in Aphasia. *Journal Of Speech, Language & Hearing Research*, 54(6), 1577–1596.

Appendix A

SELF-REPORT MEDICAL HISTORY QUESTIONNAIRE

Self-Report Medical History Questionnaire UTEP Brain, Voice and Language Laboratory

The following information is required by the Institutional Review Board to screen for possible participation in EEG studies. We must know if you have had any medical problems that might keep you 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.

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

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

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

12. Do you have

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

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

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

Appendix B

CONSENT FORM

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

Protocol Title: A Comparative Assessment of Electrophysiological and Behavioral Performance in Individuals with Aphasia Responding to Spoken and Written Sentence Length Messages.

Principal Investigator: Sha-Renae Alexander, B.A.

Advisor: Dr. Patricia Lara, C.C.C.-SLP, Speech Language Pathology Department

Dissertation Committee Members:

UTEP College of Health Sciences: Speech Language Pathology-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 performance of individuals with aphasia and participants with no brain damage responding to spoken or written sentence length messages. This study examines brain activity in response to spoken and written messages.

The rationale: Aphasia is an acquired language disorder that affects a person's communicative and social functioning, their quality of life as well as the quality of life of their relatives and caregivers. The impairment can affect all modalities of language including speech, writing, comprehension and reading. It is widely known that one of the primary deficits persons with aphasia have is difficulty in understanding sentences, however the underlying processes of this impairment is poorly understood. The majority of research that has been done on sentence comprehension in persons with aphasia has focused on auditory comprehension. Because of this, little is known about the relationship between reading and auditory comprehension impairments in persons with aphasia. This study intends to intervene on that gap by looking at comprehension in two modalities at the sentence level. One fundamental question is whether sentence comprehension impairments affect the spoken and written modalities in the same ways (DeDe, 2012). Understanding the relationship between auditory and written sentence comprehension is also important in order to determine whether evaluation and treatment focused on one modality can be expected to generalize to the other (DeDe 2013). This kind of knowledge may also lead to the possible development of novel treatment strategies that will lead to generalization across the two modalities.

Approximately, 20 subjects (10 individuals with aphasia and 10 individuals with no history of brain damage) will be enrolling in this study at UTEP. You are being asked to be in the study because you have been diagnosed with (1) a left hemisphere stroke, (2) aphasia, (3) are an individual with no history of brain damage.

If you decide to enroll in this study, your involvement will last about approximately two one-hour sessions on two separate days.

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 and the Annet Handedness Inventory. In addition, the principal investigator will measure your head and fit you with the electrode cap, apply the conduction gel

Revised: 04/15/09

Page 1 of 3



Approved on: 08/12/2014
Expires on: 08/11/2015
Study Number: Alexander
638075-1

and attach the electrodes. You will then be seated in a soundproof room in front of a computer touch monitor to complete the experimental task. The experimental task requires that you listen to or read the commands presented through speakers and/or on the touchscreen monitor and then follow the command by touching the appropriate visual picture that is shown on the touch screen monitor. Examples of commands that you will hear are "touch the black square", "put the little red circle below the big black square". You will be asked to come in for a second visit. At the second visit, the principal investigator will again measure your head to find the 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 in front of a computer touch monitor to complete the experimental task. The experimental task requires that you listen to or read the commands presented through speakers and/or on the touchscreen monitor and then follow the command by touching the appropriate visual picture that is shown on the touch screen monitor.

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 Sha-Renae Alexander at ((915) 503-7602) or her advisor Dr. Patricia Lara at (915) 747-7250 and to the UTEP Institutional Review Board (IRB) at (915-747-8841) or rb.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 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 UTEP Department of Speech 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 contact Sha-Renae Alexander at ((915) 503-7602) or at saalexander2@miners.utep.edu. You may also contact the principal investigator's advisor, Dr. Patricia Lara at (915) 747-7250 5 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 (Sha-Renae Alexander) 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 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: _____

Printed name: _____ Signature

Date: _____ Time: _____



Appendix C

IRB APPROVAL LETTER



THE UNIVERSITY OF TEXAS AT EL PASO
Office of the Vice President for Research and Sponsored Projects
Institutional Review Board
El Paso, Texas 79968-0587
phone: 915 747-8841 fax: 915 747-5931

FWA No: 00001224

DATE: August 12, 2014

TO: Sha-Renae Alexander, BA

FROM: University of Texas at El Paso IRB

STUDY TITLE: [638075-1] A Comparative Assessment of Electrophysiological and Behavioral Performance in Individuals with Aphasia Responding to Spoken and Written Sentence Length Messages.

IRB REFERENCE #: 638075-1

SUBMISSION TYPE: New Project

ACTION: APPROVED

APPROVAL DATE: August 12, 2014

EXPIRATION DATE: August 11, 2015

REVIEW TYPE: Expedited Review

Thank you for your submission of New Project materials for this research study. University of Texas at El Paso IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This study has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

Appendix D

ANNETT HAND PREFERENCE QUESTIONNAIRE

Annett Hand Preference Questionnaire

Name_____ Age_____ Sex_____

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

LIST OF SENTENCE LENGTH COMMANDS

SUBTEST 1

Touch the Green Square

Touch the Blue Circle

Touch the White Square

Touch the Red Circle

Touch the Blue Square

Touch the White Circle

Touch the Black Square

Touch the Green Circle

Touch the Red Square

Touch the Red Circle

SUBTEST 2

Touch the Big Green Circle

Touch the Big Black Circle

Touch the Little Blue Square

Touch the Big Red Square

Touch the Little Red Circle

Touch the Little Green Square

Touch the Little White Square

Touch the Big White Circle

Touch the Big Blue Circle

Touch the Little Black Square

SUBTEST 3

Touch the Green Square and the Black Square

Touch the Blue Circle and the Green Square

Touch the White Circle and the Blue Square

Touch the Black Circle and the White Square

Touch the Green Circle and the Red Square

Touch the Red Square and the White Circle

Touch the White Square and the Green Circle

Touch the Black Square and the Red Circle

Touch the Red Circle and the White Circle

Touch the Blue Square and the Black Circle

SUBTEST 4

Touch the Big Green Square and the Little Black Square

Touch the Big Black Square and the Little Red Circle

Touch the Big Blue Circle and the Little Green Square

Touch the Big White Circle and the Little Blue Square

Touch the Little Blue Square and the Big Black Circle

Touch the Little Green Circle and the Big Red Square

Touch the Little Black Circle and the Little White Square

Touch the Little White Square and the Big Green Circle

Touch the Little Red Circle and the Big Blue Circle

Touch the Big Red Square and the Big White Circle

SUBTEST 5

Put the Black Square By the Red Circle

Put the Black Circle Above the White Square

Put the Blue Square Before the Black Circle

Put the Red Circle On the Blue Circle

Put the Blue Circle Behind the Green Square

Put the Green Square Under the Black Square

Put the White Circle Below the Blue Square

Put the White Square Next to the Green Circle

Put the Red Square in Front of the White Circle

Put the Green Circle Beside the Red Square

SUBTEST 6

Put the Big Red Square In Front of the Big White Circle

Put the Big Blue Circle Before the Little Green Square

Put the Little Green Circle Under the Big Red Square

Put the Big Black Square Above the Little Red Circle

Put the Little Black Circle Below the Little White Square

Put the Little Blue Square Behind the Big Black Circle

Put the Big Green Square By the Little Black Square

Put the Big White Circle Next to the Little Blue Square

Put the Little Red Circle Beside the Big Blue Circle

Put the Little White Square On the Big Green Circle

SUBTEST 7

Put the Black Circle to the left of the White Square

Put the Red Square to the left of the White Circle

Put the Black Square to the Right of the Red Circle
Put the Blue Circle to the Left of the Green Square
Put the Green Circle to the Left of the Red Square
Put the White Square to the Right of the Green Circle
Put the Red Circle to the Right of the Blue Circle
Put the White Circle to the Right of the Blue Square
Put the Blue Square to the Left of the Black Circle
Put the Green Square to the Right of the Black Square

Vita

Sha-Renae Alexander was born in St. Andrew, Jamaica on August 9, 1989. She attained her undergraduate degree in Speech and Language Science at the University of the West Indies, St. Augustine in Trinidad and Tobago in 2012. She entered the graduate program of Speech-Language Pathology at the University of Texas at El Paso in fall of 2013 and graduates in spring of 2015. She plans to practice the medical/clinical settings working with the adult and geriatric populations.

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El Paso, TX, 79902

This thesis/dissertation was typed by Sha-Renae Alexander.