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EXAMINING THE EFFECTS OF PAUSE TIMES ON

AUDITORY COMPREHENSION UTILIZING

SECONDARY DATA ANALYSIS

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Katelyn Nicole Vera

2019

Dedication

This paper is dedicated to my mom and dad. Without their constant love and support I would not have been able to achieve my dreams.

EXAMINING THE EFFECTS OF PAUSE TIMES ON AUDITORY COMPREHENSION UTILIZING SECONDARY DATA ANALYSIS

by

KATELYN NICOLE VERA

THESIS

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Abstract

In this secondary data analysis research study, existing data were analyzed in order to compare behavioral and electrophysiological performance in an individual with aphasia and an individual with no brain damage. The effects of pauses of different durations (i.e., 1, 2, or 3 seconds) inserted within a spoken message were analyzed by examining behavioral and electrophysiological data. Data analyzed included correct response rate, behavioral reaction time, and N400 event related potential (ERP) component amplitude and latency. The following research questions were examined: Is there a difference between the individual with aphasia and the individual with no brain damage for each pause time 1) in average correct response rate, 2) in behavioral reaction time, 3) in amplitude of the N400 ERP component, 4) in latency of the N400 ERP component, and 5) in brain location engagement relative to electrode placement.

The results of this secondary research study suggest that pause times of different durations have an effect on auditory comprehension. Behavioral results found that longer pause times resulted in improved auditory comprehension for both participants. Both participants appeared to benefit from the 3 second pause, however, the individual with aphasia had a lower correct response rate and more cortical activity than the individual with no brain damage. Clinical implications from this study suggest that pause times inserted in spoken messages may be beneficial since it can provide individuals with aphasia increased time to process the information.

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Chapter 1: Introduction

Aphasia

Aphasia is defined by the American Speech-Language-Hearing Association [ASHA] (2018) as “an acquired neurogenic language disorder resulting from an injury to the brain that affects all language modalities”. Language modalities affected include the production and comprehension of spoken and written language. While aphasia may affect all language modalities, it does not affect the cognitive ability of an individual (ASHA, 2018).

Aphasia is a result of damage to the language areas of the brain most often caused by stroke or cerebral vascular accident. A stroke can be ischemic or hemorrhagic, with ischemic strokes accounting for 90% of all strokes (Johnson, Bonafede, & Watson, 2016). An ischemic stroke occurs when there is a decreased amount of blood flow due to an obstruction such as a clot. Alternatively, a hemorrhagic stroke occurs as a result of a ruptured blood vessel (Lopez et al., 2012). Other causes of aphasia include tumors, traumatic brain injuries, infections, and other neurological etiologies (National Institute on Deafness and Other Communication Disorders [NIDCD], 2017); however, stroke is the most common cause of aphasia. According to the NIDCD (2017) approximately 1,000,000 Americans are currently diagnosed with aphasia and 180,000 new cases are diagnosed each year.

Types of Aphasias

There are several types of aphasias that are classified based on the symptoms and the area of the brain that is damaged (Chapey, 2008). Aphasias are broadly classified as non-fluent and fluent aphasias. Non-fluent aphasias include Broca’s aphasia, transcortical motor aphasia, and global aphasia. Non-fluent aphasias are characterized by speech output that is compromised while auditory comprehension remains intact to varying degrees (Helm-Estabrooks, 2011).

Fluent aphasias include Wernicke’s aphasia, conduction aphasia, and transcortical sensory aphasia. In fluent aphasias, auditory comprehension is compromised while speech output is fluent but meaningless. Other forms of aphasias include anomic aphasia, primary progressive aphasia, alexia, and agraphia (Chapey, 2008). The classifications of aphasias based on the type, location of brain damage, and symptoms of the aphasia are outlined in Table 1.1.

Table 1.1

Classifications of Aphasias

Non-Fluent Aphasias			**Fluent Aphasias**		
Type	**Location of Brain Damage**	**Symptoms**	**Type**	**Location of Brain Damage**	**Symptoms**
Broca’s Aphasia	Posterior inferior frontal gyrus	Agrammatic effortful speech, short utterances, intact auditory and reading comprehension	Wernicke’s Aphasia	Posterior portion of superior temporal gyrus of left hemisphere	Deficits in auditory and reading comprehension, fluent but paraphasic speech
Transcortical Motor Aphasia	Anterior to the frontal horn of the left lateral ventricle	Phonemic and global paraphasias, syntactic errors, and perseverations	Transcortical Sensory Aphasia	Angular gyrus and posterior portion of the middle temporal gyrus	Paraphasias with poor auditory comprehension
Global Aphasia	Frontal, parietal, and temporal regions	Deficits in production and comprehension of language	Conduction Aphasia	Supramarginal gyrus	Fluent speech, impaired repetition, omissions, and substitutions

Note. Adapted from Chapey (2008)

Auditory comprehension deficits are present in all aphasia types, however, the extent of the deficit varies (Helm-Estabrooks, 2011). Auditory comprehension is a key component in communication since it is necessary for understanding linguistic information presented auditorily (Nascimento, Muniz, & Costa, 2014). Therefore, any deficits in auditory comprehension skills may result in a decreased ability to communicate. Furthermore, individuals with aphasia may not realize when a breakdown in auditory comprehension occurs, further impairing the deficit (Knollman-Porter, Dietz, & Dahlem, 2018). A compromised ability to communicate may impact an individual's life in different ways.

Impact of Aphasia on Quality of Life

An acquired deficit in auditory comprehension may have a profound effect on an individual's quality of life. Given that communication is an integral aspect of socialization, any disruption may lead to social isolation and higher levels of depression for an individual (Nascimento et al., 2014; Spaccavento et al., 2014). Parr (2007) found that social exclusion exists for individuals with aphasia at infrastructural, interpersonal, and personal levels. Infrastructural aspects of social exclusion include an inability to return to work, financial hardships, as well as reduced access to adequate information regarding rehabilitation services. Interpersonal exclusion consists of loss of relationships with family members, service providers, and other service users such as other members in their environment. Lastly, personal aspects of exclusion include isolation, boredom, depression, loss of identity, loss of control in life participation, as well as frustration and anger (Parr, 2007).

While auditory comprehension deficits present challenges for an individual with aphasia, it also indirectly affects family members, friends, and caregivers. For example, spouses of individuals with aphasia report the need for support in conducting day-to-day tasks since the individual with aphasia may have previously performed these tasks. Additionally, they report the need for respite given the emotional toll and responsibility that accompanies caring for an individual with aphasia (Le Dorze & Signori, 2010). The impact of aphasia affects the quality of life not only of the individual with aphasia, but also individuals within their environment.

Cost of Stroke and Aphasia

In addition to the social and personal repercussions, there are financial consequences of stroke and aphasia. Stroke is one of the top ten cost of Medicare claims and is expected to increase as the population ages (Johnson et al., 2016). There are direct and indirect financial costs to consider. Benjamin et al. (2017) reported that in 2012 and 2013 the average annual direct and indirect cost of stroke care was approximately $33.9 billion dollars. Direct costs include doctors' and hospital fees, medications, rehabilitation, and home health care. Indirect costs include loss of productivity and income. Furthermore, Ellis, Simpson, Bonilha, Mauldin, and Simpson (2012) reported the Medicare cost of managing aphasia for one year to be approximately $1,700 more than the one year costs for managing strokes without aphasia. This figure includes attributable costs such as hospital stays, health care providers, nursing homes, outpatient care, and medical equipment.

The financial costs of stroke and the additional costs of treating aphasia present a financial burden on society as well as the individual with aphasia and their families. The financial costs of aphasia are compounded by the social and personal struggles that an individual may face. These social and personal struggles include depression, social isolation, and inability to participate in life events. Therefore, it is important to study aphasia in order to improve the quality of life of those individuals affected by this devastating language disorder.

Chapter 2: Literature Review

Normal Auditory Comprehension

McNeil and Kimelman (1986) described language comprehension and processing as “the various mental operations one goes through to reach an understanding of a printed, signed, spoken, or more infrequently tactually presented message”. Auditory comprehension occurs when spoken language is received through the auditory cortex, processed, and interpreted. Friederici (2011) explained that a variety of sub-processes are required in order to comprehend spoken messages. These sub-processes begin with an acoustic-phonological analysis of the speech signal that is processed in the auditory cortex. Speech signals are also discriminated from non-speech signals in this area. After the initial phase of acoustic-phonological analysis, sentence comprehension is broken down into three phases of linguistic processing. At the first phase, phrases are based on word category information. The second phase consists of semantic and syntactic elements of the sentence that structure the meaning of the sentence and thus comprehension of the message. A third phase is sometimes included where different information types may be required in order to map the semantic and syntactic information. Examples of these information types include context or world knowledge that would add enhanced comprehension of the sentence. These three phases combine with linguistic prosody and can further enhance comprehension of a sentence by adding thematic focus. This can also help the listener discern declarative statements from questions (Friederici, 2011).

Auditory Comprehension in Individuals with Aphasia

Auditory comprehension is compromised to varying degrees in all types of aphasia. An individual utilizes semantics and their semantic network in order to comprehend language. Semantics refers to the meaning of words and an individual’s semantic network is the storage of this word knowledge. Individuals store words based on categories and attributes related to the word (e.g., the word cat has categories and attributes such as animal, pet, fur, four legs, etc.). The organization of the semantic network aids in the retrieval and comprehension of the word. A review of the literature was performed to determine whether auditory comprehension in individuals with aphasia is a loss of performance or a total loss of function (i.e., a delay in access to the semantic network or a complete loss of the semantic network) (McNeil & Kimelman, 1986; Milberg & Blumstein, 1981; Robson, Sage, & Lambon-Ralph, 2012).

McNeil and Kimelman (1986) suggested that individuals with aphasia present a deficit in linguistic performance and that these deficits are not a loss of function. Furthermore, they suggested that individuals with aphasia retain long term storage of information and have not lost knowledge of the information or access to it. In their article, McNeil and Kimelman (1986) proposed a schema of levels and processes of auditory comprehension with the understanding that auditory comprehension is multifaceted and interactive. They explained that in individuals with aphasia there are deficits in processing intensity (i.e., loudness), frequency (i.e., pitch), and duration. These components are necessary cues in auditory comprehension and can enhance understanding of a spoken message. The authors proposed that these deficits lead to further deficits in linguistic performance. In their schema, they also indicated that there are components of auditory comprehension that remain intact such as world knowledge and linguistic knowledge. McNeil and Kimelman (1986) concluded that while there are deficits in linguistic performance, there is not a total loss of linguistic function. This suggests that individuals with aphasia may have deficits in auditory comprehension due to delayed access (i.e., performance) to the semantic network rather than a complete loss of the semantic network (i.e., linguistic function).

Similarly, Robson et al. (2012) examined whether auditory comprehension deficits in individuals with Wernicke's aphasia are related to a disruption in the acoustic and/or phonological analysis, semantic impairment, or a combination of phonological-semantic impairment. In this study, the authors used a case-study comparison design that included nine individuals with Wernicke's aphasia. Word repetition, forward digit span, and minimal pair discrimination were used to assess phonological integrity. Word repetition tasks required participants to repeat words (e.g., mouse) and nonwords (e.g., blik). Forward digit span tasks required the participants to repeat a sequence of numbers and was used to assess phonological short-term memory. Assessment of phonological input processing was completed using minimal pair discrimination of words (e.g., cat and cap) and nonwords (e.g., wat and wap).

To assess semantic association, participants were presented with pictures and written forms of a probe item (e.g., pyramid) and two choices (e.g., palm tree and fir tree). Participants were required to select the picture and/or word that was semantically related to the probe item (e.g., pyramid and palm tree). A similar test was administered with a difference of four choice items instead of two. Additionally, participants were required to complete various matching tasks (i.e., environmental sound to picture, environmental sound to written word, spoken word to picture, and written word to picture). Robson et al. (2012) found that the participants with Wernicke's aphasia included in this study had a deficit in the acoustic-phonological process. They also found that the majority of the participants had an additional deficit in semantic processing. These combined deficits resulted in increased severity in auditory comprehension deficits in the participants with Wernicke's aphasia.

In another example, Milberg and Blumstein (1981) investigated the effects of semantic priming in order to determine whether semantic deficits in individuals with aphasia are the result of an underlying deficit in semantic organization or the result of delayed access to semantic features. Semantic priming is the observation of a word response (i.e., target word) to the presentation of a semantically related word (i.e., prime) to determine the effect of the prime. The authors suggested that if individuals with Wernicke's aphasia have a deficit in semantic organization, the result is a decreased or absent semantic priming effect. However, if the deficit is delayed access to the semantic organization, semantic priming effects will be intact. Participants in their study included 13 individuals with aphasia and six individuals with no brain damage that served as controls.

A lexical-decision task including a prime word and a target word was visually presented to the participants. Prime words included related and unrelated words to the target word as well as non-words (e.g., colp). Target words consisted of monosyllabic real words (e.g., dog) and non-words (e.g., ank). Prime words were presented before presentation of the target word in order to determine if there was an associative priming effect. Participants were required to determine if the target word was a real word. Another task included a metalinguistic semantic judgement that required the participant to consciously decide the semantic relations of two words. Real word prime and target word pairs were visually and verbally presented and consisted of coordinate (e.g., bread-butter) and superordinate (e.g., dance-waltz) relations. The participants were required to determine if the prime word and target word were related.

The results of the study by Milberg and Blumstein (1981) showed that the individuals with Wernicke's aphasia responded more quickly when a target word followed a semantically related prime than when it followed an unrelated or non-word prime. The performance of the participants with aphasia was similar to that of the participants with no brain damage. However, participants with Wernicke's aphasia had a longer response time suggesting the presence of delayed access to the semantic network.

The literature suggests that auditory comprehension deficits in individuals with aphasia is due to a loss of performance rather than a complete loss of function (McNeil & Kimelman, 1986; Milberg & Blumstein, 1981; Robson et al., 2012). Specifically, Milberg and Blumstein (1981) and Robson et al. (2012) suggested that individuals with aphasia present with deficits in acoustic-phonological and semantic processing and require increased processing time. Therefore, the literature reviewed suggests that deficits in auditory comprehension in individuals with aphasia are a result of delayed access to the semantic network rather than a complete loss of the semantic network.

Treatment of Auditory Comprehension

Communication partners of individuals with aphasia are often provided with strategies to improve auditory comprehension skills in the individual with aphasia. These strategies include reducing linguistic complexity, reducing the rate of speech, and insertion of pauses within the spoken message. While limited, behavioral studies have specifically examined the effects of pauses inserted within the spoken message on auditory comprehension in individuals with aphasia. The use of pause times inserted within a spoken message is thought to provide increased processing time, resulting in improved comprehension in individuals with aphasia (Liles & Brookshire, 1975; Salvatore, 1976).

In one study, Liles and Brookshire (1975) investigated the effects of pause times on auditory comprehension in 20 individuals with aphasia. Participants were required to carry out tasks presented by a spoken message that increased in length and complexity. Participant performance was compared on two experimental conditions, a no pause insertion and a 5 second pause insertion. The pauses were inserted within the spoken message at grammatically appropriate junctures. Results of the study show that participants had a higher correct response rate for the 5 second pause. Liles and Brookshire (1975) suggested that the insertion of pauses of a 5 second duration provided increased time for the participants to process the auditory information resulting in increased accuracy of responses. An additional finding from this study was that as the complexity of the spoken message increased, no statistically significant difference was found between the correct response rate of the participants between the 5 second pause and the no pause condition.

Similarly, Salvatore (1976) investigated the effects of pause times on auditory comprehension in an individual with aphasia. In this single-subject-design study, the participant was required to carry out tasks presented by spoken messages that increased in length and complexity similar to those used by Liles and Brookshire (1975). Pauses of different durations (i.e., no pause, 1, 2, and 4 second) were inserted within the spoken messages. The results of this study showed that accuracy of responses increased when the 2 and 4 second pauses were inserted within the spoken message. However, the no pause and the 1 second pause conditions did not yield similar results. Salvatore (1976) suggested that the no pause and 1 second pauses did not result in increased correct response rate because the omission of the pause and a short 1 second pause did not provide the participant with additional time to process the spoken message.

In another example, Blumstein, Katz, Goodglass, Shrier, and Dworetsky (1985) reported that clinical observations provide some evidence that show that individuals with aphasia improve comprehension of spoken messages when an examiner speaks more slowly. Therefore, Blumstein et al. (1985) examined the effects of the temporal aspects of a speaker's speech in sentence processing in individuals with aphasia. The participants included 34 individuals with aphasia and four individuals with no brain damage who served as controls. Participants were presented with sentences that were manipulated into four conditions. The four conditions included naturally slow speech (i.e., the examiner recorded sentences at a rate of 110 words per minute), word duration (i.e., words in sentences were increased by elongating the vowel in each syllable), word segmentation (i.e., pauses were inserted between words), and syntactic parsing (i.e., pauses were inserted at syntactic boundaries). Each sentence condition contained eight stimulus sentences. The same 32 stimulus sentences were also recorded at a normal rate (i.e., 180 words per minute), resulting in 64 stimulus items.

The experimental task required that participants point to one of three pictures that matched the stimulus sentence presented auditorily. Although some improvement was noted during the slowing conditions, the only significant improvement was noted in the syntactic parsing condition for the individuals with Wernicke's aphasia. The syntactic parsing condition was the condition where pauses were inserted at syntactic boundaries. Blumstein et al. (1985) concluded that sentence comprehension in individuals with aphasia improved when pauses were inserted within the spoken message.

The literature that examines the effects of pauses on auditory comprehension in individuals with aphasia is limited. In addition, these studies use behavioral methodology that does not identify the areas of the brain engaged during the processing of spoken messages or the temporal processes underlying auditory comprehension. Advances in technology can allow for examination of neurophysiological processes that may aid in a better understanding of auditory comprehension deficits. One of the technologies that examines the neurophysiological processes is event related potentials (ERPs).

Event-Related Potentials

ERPs measure the functional activity at the level of the cortex reflected in the electrical activity that is produced in the brain in response to internal or external stimuli. The electrical activity is measured through the skull with electrodes that are attached to a skullcap. The use of

ERPs to examine neurophysiological behavior on the effects of pauses in spoken messages will add to the literature that is currently lacking. Furthermore, the findings from this study may assist in development of treatments that target spoken message comprehension, thus improving the quality of life for individuals with aphasia-related comprehension deficits.

Friederici (2011) acknowledged the use of neuroimaging techniques such as magnetoencephalography (MEG), magnet resonance imaging (MRI), and functional magnetic resonance imaging (fMRI) to study language processing. Although MRI and fMRI techniques allow for the study of language processing, they can be invasive requiring intravenous injections of dye and/or exposure to radiation. They also do not have the temporal resolution evident in ERPs (Kutas & Federmeir, 2000). Therefore, the use of ERPs may be more advantageous when studying language processing since it is less invasive for an individual and offers the advantage of temporal resolution.

Neurophysiological activity in the brain occurs when a large number of neurons fire while processing information (Sur & Sinha, 2009). Electroencephalography (EEG) recordings are collected via electrodes placed on an individual's scalp and is the raw data that captures a wide range of cortical activity. This placement allows for measurement of post synaptic potentials produced by the neurons which allow for observation of cortical activity. ERPs are a product of the EEG recordings that allow for observation of time-locked responses to stimuli (D'Arcy et al., 2003). ERP components can have a positive (P) or negative (N) peak. The amplitude of the neural response of an ERP component is measured in microvolts, while the latency of the neural response (i.e., after the presentation of stimuli) is measured in milliseconds (Kaan, 2007). An ERP component is depicted by a letter followed by a number. The letter indicates the polarity (i.e., positive or negative) while the number indicates the latency of the response in milliseconds (e.g., the N400 ERP component indicates a negative peak at 400 ms after presentation of stimuli).

Event-Related Potentials and Language Comprehension

An ERP component that has been found to be associated with language comprehension at the word and sentence level is the N400 ERP component (Friederici, 2011; Kaan, 2007; Kutas & Federmeir, 2000). A key advantage to utilizing ERPs in the study of language comprehension is its ability to record brain activity in real time (Kutas & Federmeir, 2000). Due to the fast rate of language comprehension, the use of ERPs allows for the collection of data with temporal accuracy of a few milliseconds (Kaan, 2007). According to Kutas and Federmeir (2000) ERPs utilizing the N400 are useful in the study of language comprehension since it directly correlates to processing semantic information. After the presentation of a word or word-like stimuli, many neurons fire within the brain. This post synaptic activity is observed as a negative peak between 350-650 ms. This is known as the N400 component (D'Arcy et al., 2003; Kutas & Federmeir, 2000).

D'Arcy et al. (2003) used ERPs to assess language comprehension of individuals who suffered a stroke. The authors wanted to determine whether assessing language comprehension utilizing electrophysiological data (i.e., ERPs) correlated with behavioral assessment measures of language comprehension. The participants were asked to complete a battery of tests while the examiners observed ERPs. D'Arcy et al. (2003) found that behavioral assessment measures correlated with data from the ERPs. These findings suggest that the use of ERPs is an efficient method to assess the degree of language comprehension in individuals with aphasia, specifically those with physical impairments that greatly limit the effectiveness of behavioral assessment instruments.

The temporal resolution of ERPs is an advantage in the study of auditory comprehension since it allows for the collection of data with temporal accuracy of a few milliseconds. This is in line with the fast rate of processing evident in language comprehension. Additionally, research has found that the utilization of the N400 ERP component is an accurate indicator of language comprehension. Therefore, the use of ERPs is an ideal method for analyzing language comprehension.

Purpose of the Study

There is limited research to support that temporal aspects, such as insertion of pauses in spoken messages, can improve auditory comprehension of individuals with aphasia. In addition, this research is limited to behavioral analysis. Therefore, the purpose of the current study is to examine electrophysiological data in addition to behavioral data to determine the effects of pauses inserted within spoken messages using data previously collected but not yet analyzed. Specifically, this study seeks to determine if there is a difference between an individual with aphasia and an individual with no brain damage for each pause time 1) in average correct response rate, 2) in behavioral reaction time, 3) in amplitude of the N400 ERP component, 4) in latency of the N400 ERP component, and 5) in brain location engagement relative to electrode placement.

Chapter 3: Methods

Design of Study

The current study utilized existing data to perform a secondary data analysis. Data sets obtained during previous research were analyzed to examine the effects of pauses inserted within spoken messages in an individual with aphasia and an individual with no brain damage. The independent variables were the pause times (i.e., 1, 2, and 3 second) and the dependent variables were the correct response rate, behavioral reaction time, amplitude and latency of the N400 ERP component, and brain location of cortical activity.

Data Source

The existing data were collected during a previous study that had approval from the University of Texas at El Paso (UTEP) Institutional Review Board (IRB). Although data were collected, it was not analyzed. Use of data for the current study was exempt from full IRB review per Category 4 as outlined in the IRB Exemption Request Application form issued by the UTEP IRB Office. Dr. Patricia Lara, the owner of the existing data granted permission to utilize and analyze this data for the current study. One advantage of secondary data analysis is that it may alleviate the risk of attrition and demands placed on participants. This is especially relevant since collection of ERP data requires participants to sit for long periods of time and avoid extraneous movements since this can disrupt the signal of interest.

The existing data consisted of EEG recordings stored in a password protected computer in the Voice, Brain, and Language Lab at UTEP. Utilization of the existing data did not require transfer of data to another storage format. This ensured the integrity of the existing data (Doolan, Winters, & Nouredini, 2017).

Existing data were collected from one individual diagnosed with Wernicke's aphasia and one individual with no brain damage. The individual with aphasia was a female who was 64 years old and 14 years post stroke at the time of data collection. The individual with no brain damage was a male who was 54 years old at the time of data collection. Participants could not be age matched due to limited existing data. During the original study, participants responded to spoken messages using a modified version of the Revised Token Test (RTT) (McNeil & Prescott, 1978) while cortical activation was recorded using EEG. The RTT is a behavioral assessment instrument that assesses mild comprehension deficits in individuals with aphasia. Comprehension deficits are examined by having individuals respond to auditory commands to touch and manipulate objects of different sizes (i.e., little or big), shapes (i.e., square or circle), and colors (i.e., green, blue, white, black, or red). The modified version of the RTT allowed for auditory stimuli to be presented through computer speakers and visual stimuli to be presented on a computer monitor. Spoken messages that increased in length and grammatical complexity were presented as auditory stimuli. An example of a spoken message was “Touch the big red circle and the little blue square.” Participants were presented with a visual display on a computer monitor that provided eight different token arrangements per trial as shown in Figure 3.1. Participants were instructed to listen to the spoken message and respond by touching the visual choice that matched the spoken message on a touch screen monitor.

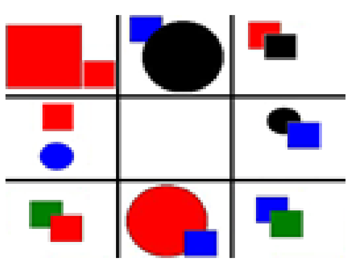

Figure 3.1. Example of visual stimuli of token arrangement.

The existing electrophysiological data were recorded from the participants' scalp using 64 electrodes placed according to the International 10-20 EEG Electrode placement system (Jasper, 1958). Electrophysiological data were recorded from the electrodes using ActiveTwo from Bio Semi.

Electrophysiological Data Analysis

In the secondary data analysis for the current study, existing EEG recordings were filtered and analyzed using Brain Vision Analyzer. During the data filtering and analysis, data were first converted to a sampling rate of 512 Hz. Brain Vision Analyzer was also used to filter artifacts before the averaging of data. Artifacts are defined as extraneous noise or electrical disturbances that interfere with the response to the stimuli. The EEG data were filtered with a range of 0.1 Hz for the low cut off and 30 Hz for the high cut off. A notch filter was set at 60 Hz and was used to filter noise from electrical power lines. The most common artifacts result from eye movements and blinking. During the original study, reference electrodes were placed on the mastoids of the participants to eliminate these artifacts.

Stimulus markers were established as S1, S2, and S3 in the original study. S1 marked the presentation of the visual stimuli informing participants that the experimental task was about to begin. S2 marked presentation of the auditory stimuli (i.e., the spoken message). S3 marked the participant's response to the visual presentation of choices. An example of each stimulus marker is outlined in Figure 3.2.

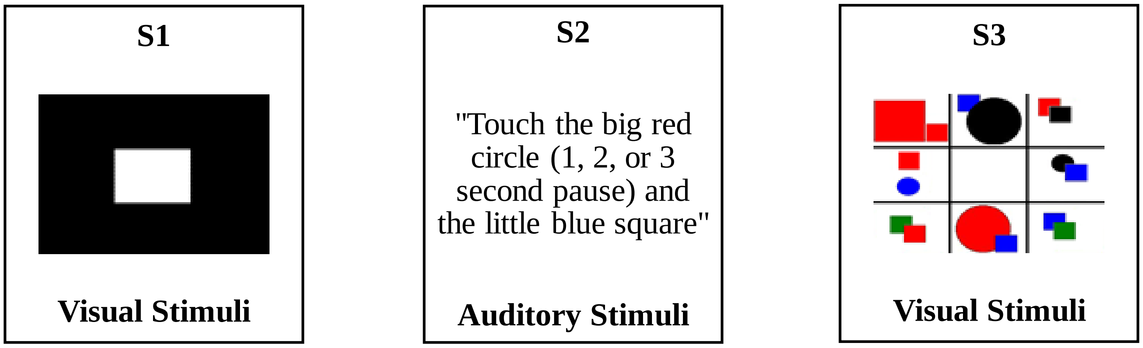

Figure 3.2. Example of stimulus markers that were segmented.

For the secondary data analysis, data were segmented using Brain Vision Analyzer to allow for the data to be separated into smaller segments (i.e., S1, S2, and S3) that could be analyzed individually. The signal of interest was determined by dividing the EEG raw data into different segments based on these stimulus markers. The signal of interest is known as the ERP component.

Once the data were averaged, visual inspection of the ERP wave form allowed for the determination of amplitude and latency values. Amplitude of the N400 ERP component was identified as the most negative deflected peak between 350-650 ms (D'Arcy et al., 2003). Latency of the N400 ERP component was determined at the point in time that this negative deflection occurred.

Visual Inspection of Data

Visual inspection of the behavioral and electrophysiological data was used to examine the effects of a 1, 2, or 3 second pause time in the participant with aphasia and the participant with no brain damage to determine each participant's 1) average correct response rate, 2) behavioral reaction time, 3) amplitude of the N400 ERP component, 4) latency of the N400 ERP component, and 5) brain location engagement relative to electrode placement.

Visual inspection of Cortical Activation Maps

Topographic maps of cortical activation allowed for spatial analysis. The cortical activation maps were visually inspected to localize brain activity of the participant with aphasia and the participant with no brain damage in response to the pauses inserted within the spoken messages. Cortical activity was derived from the central electrode (i.e., Cz) and analyzed relative to electrode placement.

Chapter 4: Results

The purpose of the current study was to determine the effects of pauses of different durations inserted in spoken messages in an individual with aphasia and an individual with no brain damage by examining behavioral and electrophysiological data from an existing data set. Behavioral data consisted of correct response rate and behavioral reaction time. Both correct response rate and behavioral reaction time were collected using SuperLab. SuperLab is a stimulus presentation software used in ERP research. Average correct response rate was determined by calculating the percentage of correct responses. Behavioral reaction time was determined by calculating the amount of time elapsed from the presentation of the auditory stimuli to the participant's motor response on the touch screen monitor. Electrophysiological data consisted of the amplitude measured in microvolts and latency measured in milliseconds of the N400 ERP component.

Behavioral Results

The participant with aphasia had an average correct response rate of 85.6% and an average behavioral reaction time of 7,945.08 ms for the 1 second pause. The participant with no brain damage had an average correct response rate of 91.9% and an average behavioral reaction time of 8,027.37 ms for the 1 second pause.

The participant with aphasia had an average correct response rate of 86.1% and an average behavioral reaction time of 8,465.68 ms for the 2 second pause. The participant with no brain damage had an average correct response rate of 91.8% and a behavioral reaction time of 7,078.72 ms for the 2 second pause.

The participant with aphasia had an average correct response rate of 89.8% and a behavioral reaction time of 11,705.41 ms for the 3 second pause time. The participant with no brain damage had an average correct response rate of 93.7% and a behavioral reaction time of 11,391.32 ms for the 3 second pause.

The 3 second pause time resulted in the highest correct response rate and longest behavioral reaction time for both participants. For the participant with aphasia, both correct response rate and behavioral reaction time increased as the duration of the pause time increased. However, for the participant with no brain damage, the correct response rate remained the same for the 1 and 2 second pause time but increased with the 3 second pause. Additionally, behavioral reaction time was shortest for the 2 second pause time and longest at the 3 second pause time for the participant with no brain damage. Behavioral results for the participant with aphasia and the participant with no brain damage are shown in Table 4.1.

Table 4.1

Behavioral Data

Individual with Aphasia			**Individual with No Brain Damage**		
Pause Time	**Correct Response Rate**	**Behavioral Reaction Time**	**Pause Time**	**Correct Response Rate**	**Behavioral Reaction Time**
1 second	85.6%	7,945.08 ms	1 second	91.9%	8,027.37 ms
2 second	86.1%	8,465.68 ms	2 second	91.8%	7,078.72 ms
3 second	89.8%	11,705.41 ms	3 second	93.7%	11,391.32 ms

Behavioral results for both participants are illustrated in Figure 4.1. and Figure 4.2.

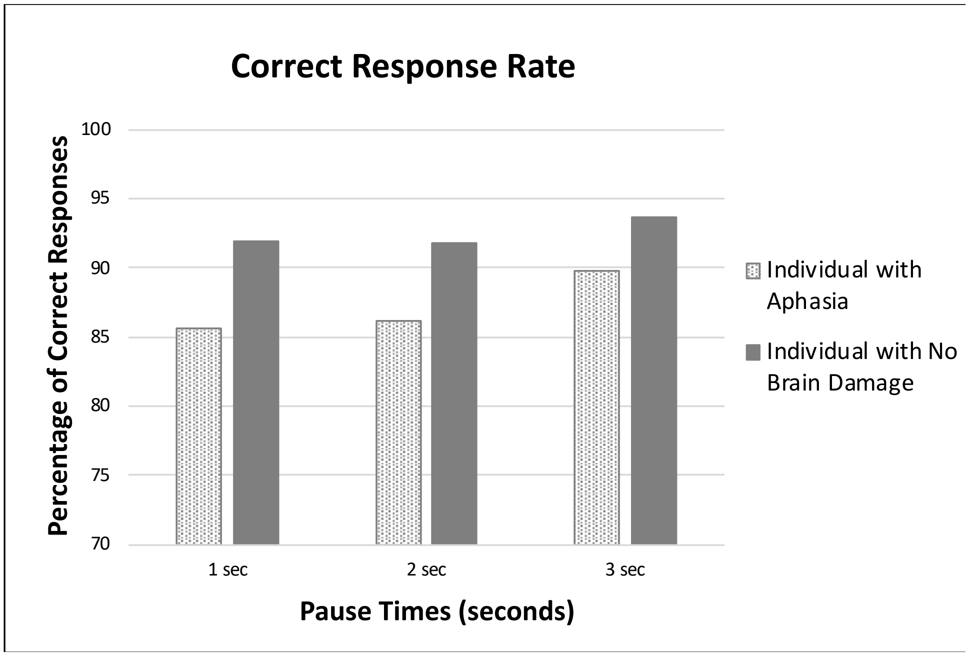

Figure 4.1. Participant's correct response rate for each pause time.

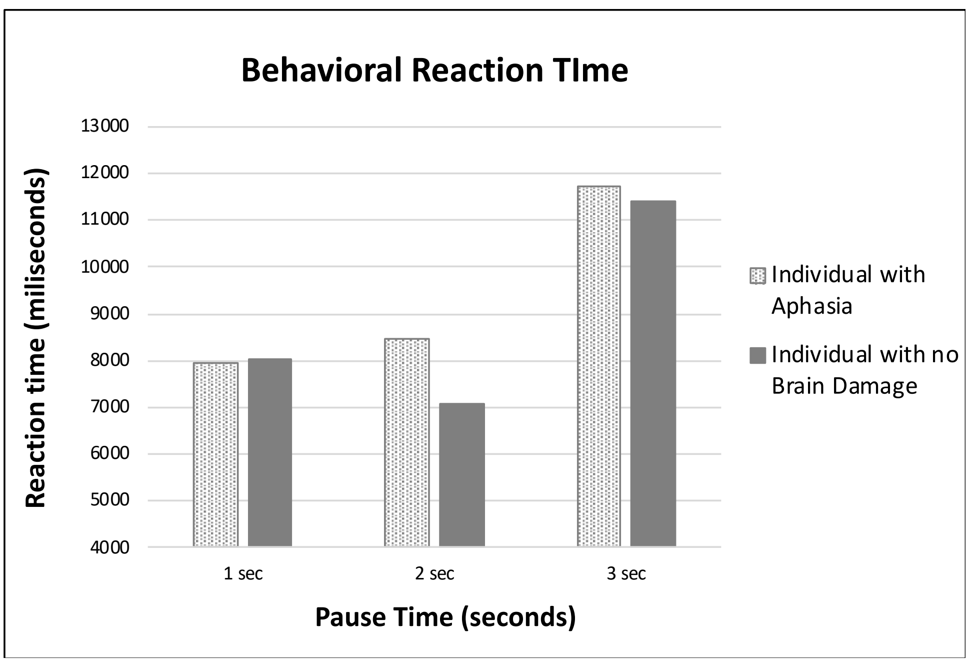

Figure 4.2. Participant's behavioral reaction time for each pause time.

Electrophysiological Results

Amplitude and latency of the N400 were determined by visual inspection of ERP waveforms. Amplitude was identified as the most negative deflected peak between 350-650 ms. Latency was determined at the point in time that this negative deflection occurred.

There was no negative deflection between 350-650 ms for the participant with aphasia for the 1 second pause time. Absence of an N400 indicates that participant had delays in auditory comprehension. The participant with no brain damage displayed an N400 at an amplitude of -6.156 mv and a latency of 551 ms for the 1 second pause.

The participant with aphasia displayed an N400 at an amplitude of -2.482 mv and a latency of 398 ms for the 2 second pause time. The participant with no brain damage displayed an N400 at an amplitude of -1.269 mv and a latency of 588 ms for the 2 second pause.

The participant with aphasia displayed an N400 at an amplitude of -1.826 mv and a latency of 418 ms for the 3 second pause. The participant with no brain damage displayed an N400 at an amplitude of -0.725 mv and a latency of 609 ms for the 3 second pause.

For both participants, as pause times increased the amplitude of the N400 was less negative (i.e., less cortical activity) indicating a reduced effort to comprehend the spoken message. Although both participants followed the same pattern, it is important to note that the participant with aphasia had greater amplitudes for the N400 (i.e., more cortical activity) than the participant with no brain damage. Latency of the N400 also increased as pause times increased for both participants. Electrophysiological results for the participant with aphasia and the participant with no brain damage are shown in Table 4.2.

Table 4.2

Electrophysiological Data

Individual with Aphasia			Individual with No Brain Damage		
Pause Time	**Amplitude of N400**	**Latency of N400**	**Pause Time**	**Amplitude of N400**	**Latency of N400**
1 second	No N400 detected	No N400 detected	1 second	-6.156 mv	551 ms
2 second	-2.482 mv	398 ms	2 second	-1.269 mv	588 ms
3 second	-1.826 mv	418 ms	3 second	-0.725 mv	609 ms

ERP waveforms for each pause time are shown in Figure 4.3., Figure 4.4., and Figure 4.5.

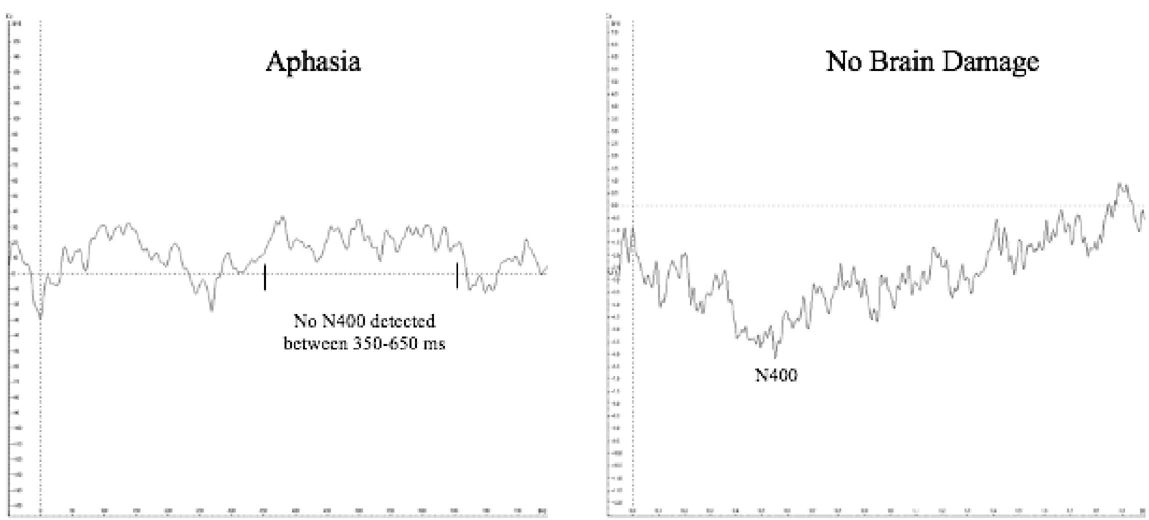

Figure 4.3. ERP waveforms for 1 second pause time.

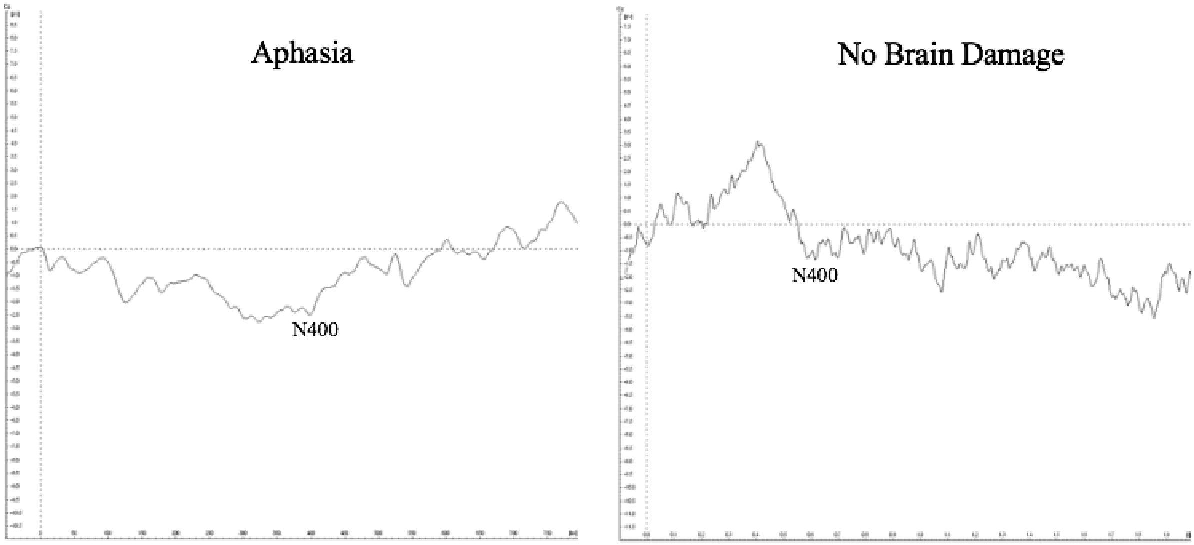

Figure 4.4. ERP waveforms for 2 second pause time.

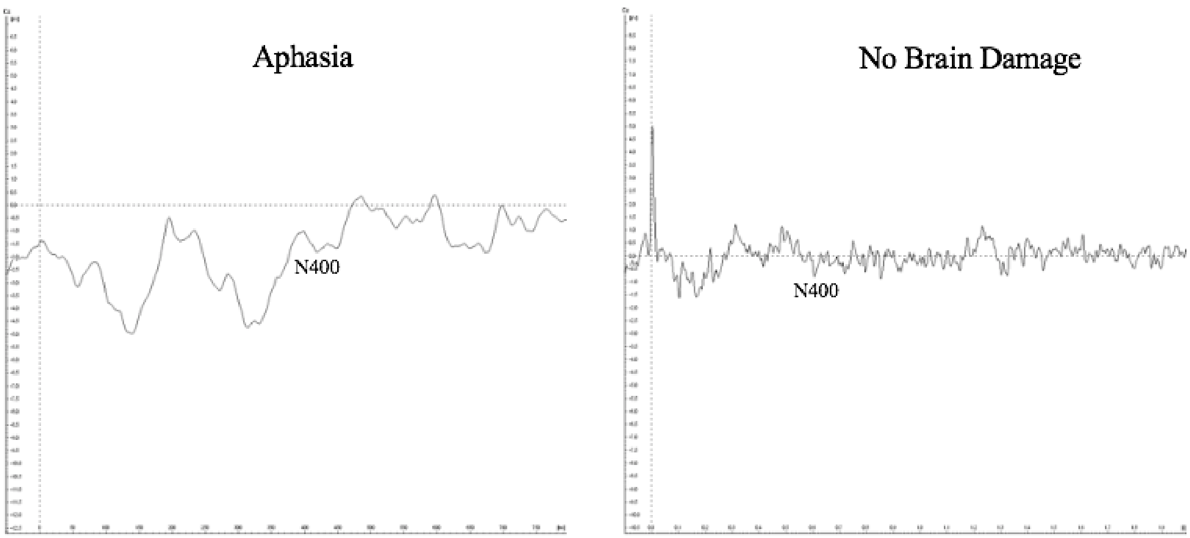

Figure 4.5. ERP waveform for 3 second pause time.

Electrophysiological results for both participants are illustrated in Figure 4.6. and 4.7.

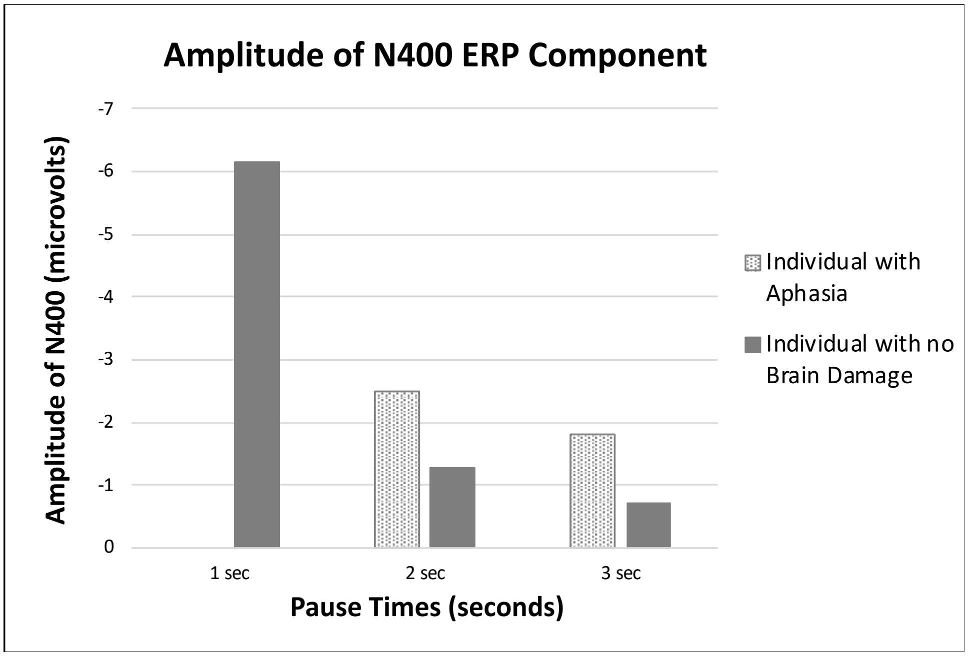

Figure 4.6. Participant's amplitude of N400 ERP component for each pause time.

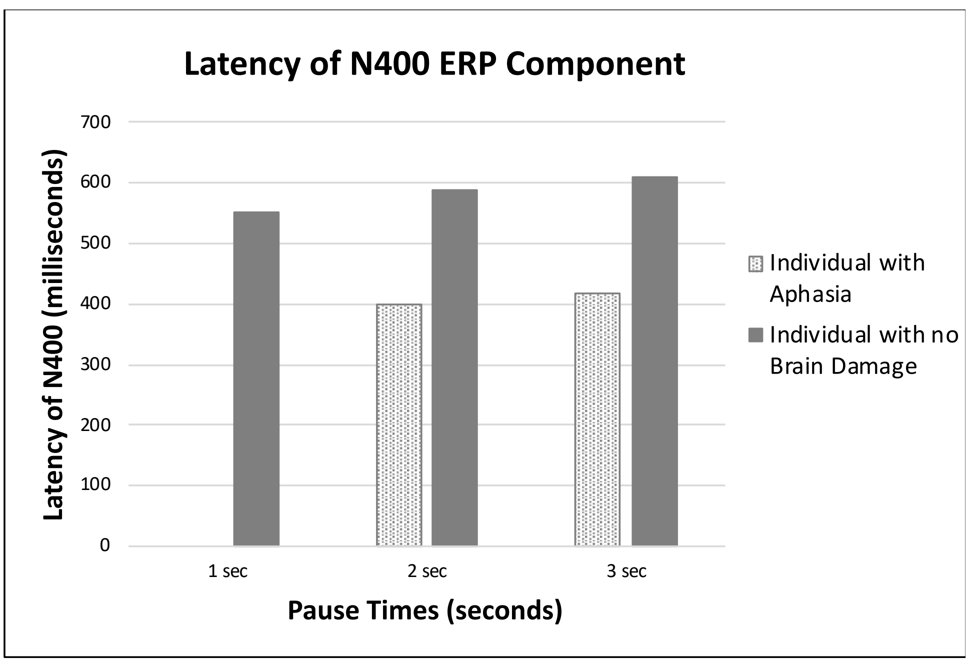

Figure 4.7. Participant's latency of N400 ERP component for each pause time.

Cortical Activation Maps

Visual inspection of cortical activation in the form of topographic maps was performed in order to determine cortical brain activity relative to electrode placement. Cortical activation maps not only allow for the visual inspection of areas of the brain engaged during a particular task, but also the level of activation. Areas of blue indicate negative activation, areas of yellow indicate moderate levels of activation, and areas of red indicate high levels of activation. Topographic maps of cortical activity were generated for both participants' N400 ERP component at each pause time. Since the participant with aphasia did not have an N400 for the 1 second pause, a topographic map of cortical activity was generated over a 350-650 ms time frame.

Both participants' topographic maps of cortical activity displayed various levels of activation throughout the brain for each pause time. The participant with aphasia showed decreased areas and levels of activation as the pause times increased. Specifically, the participant with aphasia showed negative activation for the 1 second pause, high levels of activation for the 2 second pause, and minimal activation for the 3 second pause. Negative activation for the 1 second pause suggests that the participant with aphasia may have had difficulty comprehending the spoken messages within the 350-650 ms range. The participant with no brain damage did not show the same pattern as the participant with aphasia. The areas and levels of activation remained somewhat consistent across all pause times. Additionally, the participant with no brain damage showed more concentrated areas of activation than the participant with aphasia. Both participants' topographic maps of cortical activation are shown in Figure 4.8., Figure 4.9., and Figure 4.10.

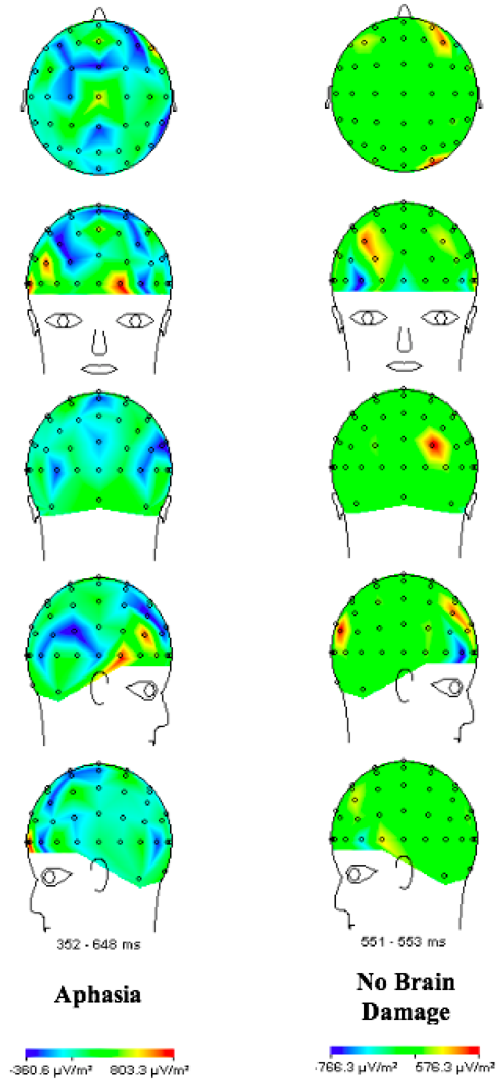

Figure 4.8. Topographic maps of cortical activation for 1 second pause time.

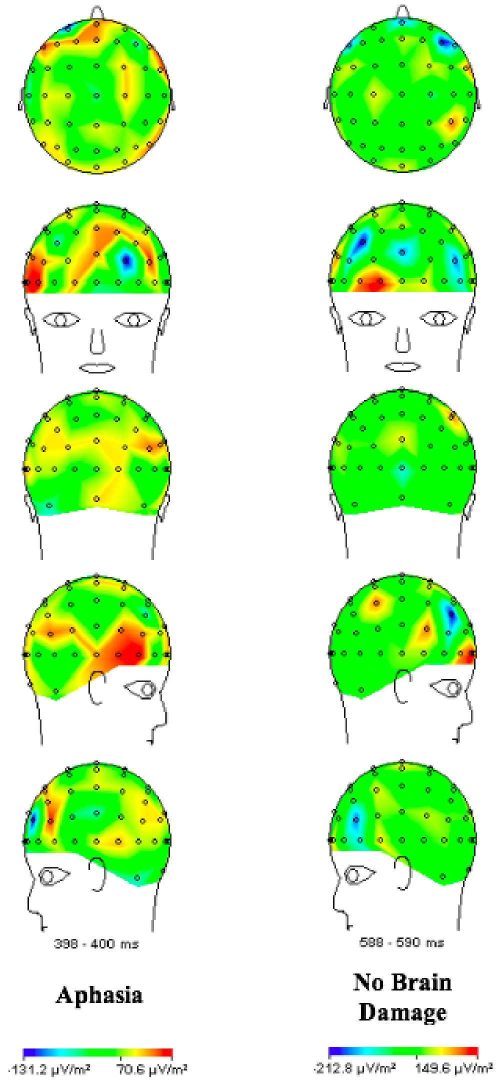

Figure 4.9. Topographic maps of cortical activation for 2 second pause time.

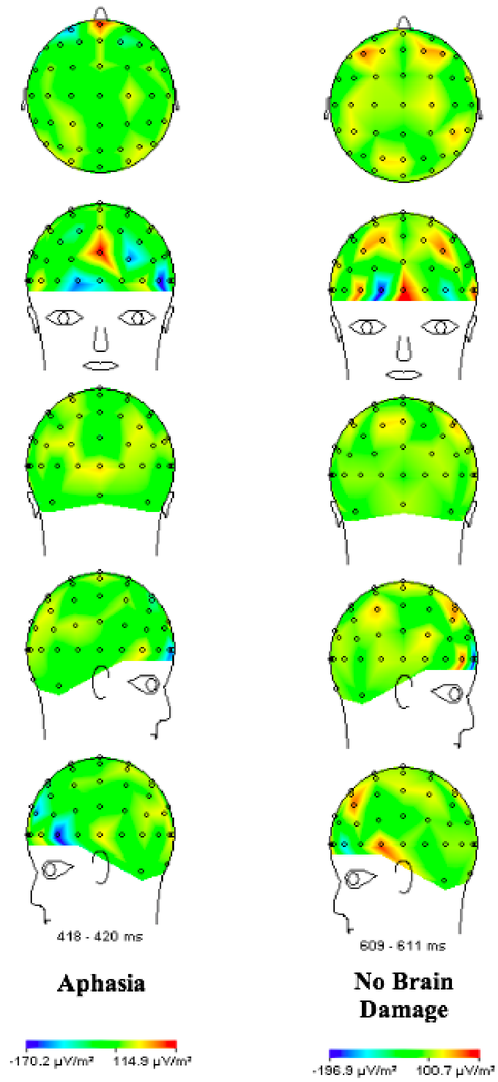

Figure 4.10. Topographic maps of cortical activation for 3 second pause time.

Chapter 5: Discussion

The current study utilized secondary data analysis to determine the effects that pauses of different durations inserted within spoken messages have on comprehension. The existing data consisted of behavioral and electrophysiological data that were collected during a previous study but was not analyzed. A 64 year old female with aphasia and a 54 year old male with no brain damage responded to auditory stimuli with pauses of different durations inserted within spoken messages of increasing in length and complexity.

Specifically, the current study sought to determine if there is a difference in behavioral and electrophysiologic performance between an individual with aphasia and an individual with no brain damage for each pause time 1) in average correct response rate, 2) in behavioral reaction time, 3) in amplitude of the N400 ERP component, 4) in latency of the N400 ERP component, and 5) in brain location engagement relative to electrode placement.

The results of the secondary data analysis suggest that increased pause times inserted in spoken messages can improve auditory comprehension in individuals with aphasia. These results are evident in both the behavioral data and the electrophysiological data. The behavioral data indicated that the 3 second pause time resulted in the highest correct response rate and longest behavioral reaction time for both participants. This suggests that a longer pause time inserted in a spoken message can allow for increased processing time and better comprehension as evidenced by the increase in correct response rate. For the participant with no brain damage, an increase in correct response rate (i.e., comprehension) was noted only for the 3 second pause. However, for the participant with aphasia each pause time allowed for an increase in correct response rate (i.e., better comprehension) demonstrating that although a longer pause time yields better comprehension, any pause time may be beneficial when communicating with an individual with aphasia. This finding is consistent with previous research that suggests that increased pause times allow for increased processing time and improved auditory comprehension in individuals with aphasia (Blumstein et al., 1985; Liles & Brookshire, 1975; Salvatore, 1976).

Electrophysiological data suggest that longer pause times may result in decreased cortical activation. Both participants demonstrated less cortical activity as pause times increased indicating less effort to comprehend the spoken message. Specifically, the 3 second pause resulted in less cortical activity than the 1 and 2 second pause times for both participants. However, the topographic map of cortical activity in the participant with no brain damage showed localized activity in the left temporal lobe indicating that they were using the language areas of the brain to process the information presented. The topographic map of cortical activity for the participant with aphasia, on the other hand, showed diffused cortical activation in the left temporal area and frontal lobe. This suggests that the individual with aphasia recruited more areas of the brain to process the information presented. Furthermore, latency also increased as pause time increased, indicating longer time required to process the spoken messages. This could have been attributed to difficulty with working memory as research has shown that working memory declines as part of the normal aging process (Klencklen, Banta, Lavenex, & Lavenex, 2017). Additionally, cognitive impairments were not accounted for during the previous study, therefore deficits in this domain could have contributed to the results for both participants. Although it took both participants longer to process the spoken message, percentage of correct response rate continued to be over 80% for both participants suggesting that providing additional time to process information is beneficial for individuals with aphasia as well as individuals with no brain damage.

Individual evaluation of behavioral data and electrophysiological data suggests that a 3 second pause time was most beneficial for both participants in the study. Behavioral results demonstrated that the 3 second pause time allowed the highest correct response rate while the electrophysiological data demonstrated the least amount of cortical activity. The participant with aphasia displayed decreased areas and levels of activation as pause times increased. However, the participant with no brain damage did not display this same pattern, rather cortical activity remained somewhat consistent across pause times, though with more localization in the left temporal area. The combination of behavioral results and electrophysiological results provide compelling evidence that a 3 second pause time was most beneficial for both participants in this study, especially for the participant with aphasia.

A key finding in the current study is the similarity of performance in the participant with aphasia and the participant with no brain damage. This similarity can suggest that the participant with aphasia is accessing their semantic network in the same manner as the participant with no brain damage. This suggests that the differences in performance can be attributed to a delayed access rather than a complete loss of the semantic network in this particular individual with aphasia. This finding is consistent with previous research that suggests that auditory comprehension deficits in individuals with aphasia result from a delayed access to the semantic network rather than a complete loss of the semantic network (McNeil & Kimelman, 1986; Milberg & Blumstein, 1981; Robson et al., 2012).

Clinical Implications

The results of the current study revealed that inserting pause times into spoken messages was beneficial for the particular individual with aphasia in the study. Additionally, there is previous research to support that inserting pauses into spoken messages can result in better auditory comprehension in individuals with aphasia. Therefore, communication partners should implement pauses when speaking to individuals with aphasia. This strategy should be disseminated to communication partners within the individual's environment. Friends and family members can implement this strategy to improve the individual's comprehension of day-to-day conversations and interactions. Additionally, this strategy can be used by healthcare professionals when communicating with individuals with aphasia since information and treatment are delivered auditorily. Communication partners implementing this strategy can assist in improving auditory comprehension in individuals with aphasia.

Limitations

Although the results of the current study suggest that increased pause times inserted in spoken message allow for an increase in auditory comprehension, there are limitations to this study. One limitation is the small sample size. The study required a diagnosis of aphasia limiting the availability of participants at the time the previous study was conducted. Additionally, the experimental task required participants to have the physical ability to respond by utilizing their arm and hand to point to the correct response, further limiting the availability of participants. Therefore, existing data for individuals with aphasia were limited to only one participant. Another limitation of the small sample size is that it did not allow for statistical analysis to be performed. Since the study was performed using a secondary data analysis, certain variables such as age, gender, severity, and onset of aphasia could not be controlled for. Another limitation to consider is the modality used for the task instructions. Instructions explaining the experimental task were presented auditorily. Therefore, performance on the experimental task may be affected by the auditory comprehension deficits evident in aphasia.

While the results of the current study are beneficial and suggest the use of pauses can increase auditory comprehension, the findings of the current study cannot be generalized to the population. Results should be interpreted with caution. Future research should continue to utilize electrophysiological methods in addition to behavioral methods when examining the effects of pause times in individuals with aphasia. Additionally, larger sample sizes should be used.

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Vita

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