Brigham Young University
BYU ScholarsArchive

Theses and Dissertations

2008-03-14

Event Related Potentials of Syntactic Language Processing in Two Children with Specific Language Impairment: A Case Study

Melissa Ann Willes
Brigham Young University - Provo

Follow this and additional works at: https://scholarsarchive.byu.edu/etd

Part of the Communication Sciences and Disorders Commons

BYU ScholarsArchive Citation
Willes, Melissa Ann, "Event Related Potentials of Syntactic Language Processing in Two Children with Specific Language Impairment: A Case Study" (2008). *Theses and Dissertations*. 1353.
https://scholarsarchive.byu.edu/etd/1353

This Thesis is brought to you for free and open access by BYU ScholarsArchive. It has been accepted for inclusion in Theses and Dissertations by an authorized administrator of BYU ScholarsArchive. For more information, please contact scholarsarchive@byu.edu, ellen_amatangelo@byu.edu.

EVENT RELATED POTENTIALS OF SYNTACTIC LANGUAGE PROCESSING IN TWO CHILDREN WITH SPECIFIC LANGUAGE IMPAIRMENT: A CASE STUDY

by

Melissa Ann Willes

A thesis submitted to the faculty of

Brigham Young University

in partial fulfillment of the requirements for the degree of

Master of Science

Department of Communication Disorders

Brigham Young University

April 2008

BRIGHAM YOUNG UNIVERSITY

GRADUATE COMMITTEE APPROVAL

of a thesis submitted by

Melissa Ann Willes

This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

Date	David L. McPherson, Chair
Date	Ron W. Channell, Committee Member
Date	Martin Fujiki, Committee Member

BRIGHAM YOUNG UNIVERSITY

As chair of the candidate's graduate committee, I have read the thesis of (Melissa Ann Willes) in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

______________________	______________________
Date	David L. McPherson Chair, Graduate Committee

Accepted for the Department

____
Ron W. Channell
Graduate Coordinator

Accepted for the College

____
K. Richard Young
Dean, David O. McKay School of Education

ABSTRACT

EVENT RELATED POTENTIALS OF SYNTACTIC LANGUGAGE PROCESSING IN TWO CHILDREN WITH SPECIFIC LANGUAGE IMPAIRMENT: A CASE STUDY

Melissa Ann Willes

Department of Communication Disorders

Master of Science

This study examined the electrophysiological activity of two children with Specific Language Impairment (SLI) and two aged-matched peers while listening to syntactically correct sentences versus syntactically incorrect sentences. The study specifically analyzed the N400 and P600 components. The N400 component is a negative wave occurring approximately 400 ms post-stimulus and is elicited by semantically incorrect stimuli. The P600 component is a positivity that occurs approximately 600 ms post-stimulus and reflects processing of syntactically incorrect stimuli. The participants in the study included a 7-year-old child and a 9-year-old child with SLI and two age-matched peers with typically developing language. Each participant listened to a series of syntactically correct and incorrect stimuli. The results of this study indicate that children

with SLI present with an N400 while listening to both syntactically correct and incorrect stimuli. This suggests that these participants have greater lexical and semantic processing demands while listening to sentence stimuli. The study also suggests that 7-year-olds have greater syntactic processing demands as seen by the presence of the P600 in both the correct and incorrect conditions. This was likely due to the complexity of the sentence stimuli which included irregular past tense and irregular plural forms. Further research is still needed in order to better understand the role of the N400 and P600 in children with SLI, which will provide useful information regarding the neurological basis for language impairments.

ACKNOWLEDGMENTS

I cannot adequately express the feelings of elation and joy that I feel upon completing this project. This study represents the culmination of the many years of hard work and sacrifice that I have dedicated to my schooling. Without the support and encouragement of my family, friends, and professors I would not have been able to complete this journey. First, I wish to sincerely thank the children and parents who participated in this study. Their willingness to assist me in this study is what propelled my research forward. Without their assistance, this study would not have been possible. I would also like to thank my family who has been a wonderful support to me throughout this process. Their love and faith in me provided constant encouragement to help me continue with this project. And to my dear friends, I truly cannot thank them enough for all of their support. I cannot imagine going through this process without their insights, humor, and tolerance for my many moments of stress. I must also thank all of my fellow graduate students. I will forever cherish the friendships that I formed during my graduate program. I also am especially grateful to Dr. McPherson. His kindness, patience, and willingness to teach me were my guide throughout this project. I am so grateful for his faith in my ability to succeed.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIXES

Introduction

Over the past two decades, our knowledge of the neurophysiological basis for language processing has been greatly extended through electrophysiological measures. Specifically, the use of event related potentials (ERPs) has improved theories of linguistic processing (Picton & Stuss, 1984).

ERPs are defined as minute voltage changes in the electrical activity produced by neurons in the brain which are recorded from various scalp locations (Featherston, Gross, Münte, & Clahsen, 2000). These changes are elicited by sensory, motor, or cognitive processes (Hahne & Friederici, 1999). The recording of this electrical activity helps researchers to better comprehend the brain's processing and computation of lexical stimuli. This information has been useful in understanding the brain's response to both visual and auditory stimuli as well as to unexpected and incorrect stimuli (Kutas & Hillyard 1980a, 1980b, 1980c, 1983; Osterhout & Holcomb, 1992, 1993).

ERP studies using lexical stimuli have focused on three long-latency ERP components. The N400 component, which is a negative wave occurring approximately 400 ms post-stimulus and is distributed over the centro-parietal regions over the scalp, is elicited by semantically related stimuli (Kutas & Hillyard 1980a, 1980b, 1980c, 1983). The early left anterior negativity (ELAN) occurs between 200 and 400 ms post-stimulus and is associated with primary syntactic processes (Freiderici, 1997). The P600 component is a late centro-parietal positivity with a midpoint at 600 ms and reflects secondary syntactic processes (Freiderici, 1997). These components have been more widely researched in adult participants; however, the ERP research that has been performed in child participants has been beneficial in understanding neurophysiological language development.

ERP research regarding children with typically developing language has shown that the N400 component is typically greater in amplitude, has a more delayed latency, and has a wider scalp distribution than in adults (Atchley et al., 2006; Freiderici & Hahne, 2001; Holcomb, Coffey, & Neville, 1992). This indicates that semantic anomalies place greater demand on children than on adults. The P600 component in children is typically greater in amplitude and has a more delayed latency than in adults (Atchley et al., 2006; Freiderici & Hahne, 2001). This indicates that children take additional time in processing syntactic violations.

Although the use of ERPs in children with specific language impairment (SLI) is limited, valuable information has been gained from these studies. Studies involving the use of tone and vowel stimuli show that children with SLI have age-inappropriate ERP waveforms in the N1-P2-N2 regions. This indicates that children with SLI have delayed maturation in the auditory cortex. Along with this conclusion, the results indicate that in at least a subset of children with SLI, the age-inappropriate ERP waveforms match those of a younger control group. This may support a maturational hypothesis, which proposes that the language of children with SLI is delayed due to delay in cortical development (Bishop & McArthur, 2005; McArthur & Bishop, 2004, 2005). Additional research has shown that children with SLI also have selective auditory deficits (Stevens, Sanders, & Neville, 2006).

The purpose of this study is to evaluate the N400 and P600 in children with SLI using stimuli that contain errors which are commonly produced by this population. The results of the children with SLI will be compared to age-matched peers in order to evaluate the development between the two populations. It is anticipated that this study will encourage further research into the use of long latency ERPs in understanding the neurophysiological basis for SLI.

Review of Literature

Event Related Potentials

ERPs reflect changes in electrical brain activity that are associated with a sensory, motor, or cognitive process (Hahne & Friederici, 1999). Friederici (1997) defined ERPs as “the electrical activity of the brain time-locked to the presentation of a given event averaged over several instances of the same event” (p. 65). The ERP measuring technique is based on the theory that certain cognitive processes are associated with specific brain activity that can be measured.

For the past two and a half decades ERPs have been instrumental in better understanding brain function associated with language processing. This physiological measure has enhanced researchers’ understanding of semantic (Kutas & Hillyard, 1980a, 1980b, 1980c, 1983) and syntactic (Osterhout & Holcomb, 1992, 1993**)** processing, language development in children (Holcomb et al., 1992), and abnormal language, such as in SLI (Neville, Coffey, Holcomb, & Tallal, 1993). The goal of current ERP research is to more fully identify the relationship between ERP components to specific aspects of linguistic processing.

ERP Measurement

There are four aspects that are analyzed when looking at linguistic cognitive processing: latency (time in milliseconds relative to the onset of a stimulus), polarity (positive or negative), amplitude (peak height), and topographic location (Friederici, 1997). These aspects are measured from electrodes placed on the scalp. The scalp-recorded ERP shows the postsynaptic activity that simultaneously occurs in many neurons. Multiple measures are taken and then averaged in order to differentiate the ERP components from the background electrical activity that is constantly produced by the brain (Friederici, 1997; Hillyard & Kutas, 1983; Picton & Stuss, 1984). The result of these measures is a waveform that consists of peaks, which are commonly called *components*. When labeling the components, either a P (positive) or an N (negative) is used followed by the latency in milliseconds, such as “P600,” which represents a positive peak that occurred 600 ms post-stimulus (Coulson, King, & Kutas, 1998).

Picton and Stuss (1984) explained four points that are necessary in understanding ERP studies of language:

1. Electrical activity recorded from the scalp can be generated from several sources, including physical movements of the facial structures involved with speech production (the eyes, scalp muscles, the skin, and the tongue). This can prove a challenge when examining linguistic processes because these factors may affect the ERP components.

2. When an ERP is generated, the brain has processed a change to some event. However, neural activity can occur without resulting in an ERP component.

3. Although an ERP occurs at a particular location on the scalp, it is difficult to determine the localization of language processes, because the generator is not consistently located where the amplitude of response is greatest.

4. ERP scalp recording can be generated by various sources with temporally and spatially overlapping fields. Each ERP peak that is recorded does not necessarily reflect a separate cerebral process. Therefore, it is advisable to replicate the recordings.

There are two common ERP subtypes: exogenous components, which are produced from physical stimuli and endogenous components, which are associated with perceptual and cognitive processes (Hillyard & Kutas, 1983). Exogenous components occur before approximately 80 ms post-stimulus and are referred to as stimulus-bound due to their sensitivity to physical parameters. The endogenous components are long latency components and are most affected by psychological state (Hillyard & Kutas, 1983; Picton & Stuss, 1984). Attention states affect endogenous ERP responses, especially those occurring after 150 ms post-stimulus (McPherson & Ballachanda, 2000).

There are four attentional states that may have an effect when evaluating ERP components. First, *selective* attention is required during an active discrimination (i.e., same-different) task. Second, *active* attention requires that the participant responds to the stimuli (i.e., button push). Third, *passive* attention requires the participant to be awake and alert, but not to necessarily be focusing on the stimuli. Fourth, an *ignore* attentional state requires the participant to be distracted from the stimuli (McPherson & Ballachanda, 2000). Since the type of attentional state has an effect on the ERP results, researchers must be careful in making comparisons across studies and in documenting the attentional state required during the research study.

Long Latency ERPs and Language

There are three long latency ERPs that are strongly associated with language processing: the N400, the ELAN, and the P600 (Friederici 1997). The N400 is a negative wave occurring approximately 400 ms post-stimulus and reflects lexical-semantic processing (Kutas & Hillyard, 1980a, 1980b, 1980c). The other two long-latency components reflect syntactic processing. The first is the ELAN, occurring between 200 and 400 ms (Freiderici, 1997) and the second syntactic component is the P600, a late centro-parietal positivity occurring at approximately 600 ms (Osterhout & Holcomb, 1992, 1993). Even though both of these components are related to syntactic violations, the ELAN is typically only associated with blatant syntactic violations, which disrupt the first-pass parsing, or word category violations (Freiderici, 1997); whereas the P600 is also associated with ambiguous or complex syntactic structures (Osterhout & Holcomb, 1992, 1993; van Herten, Kolk, & Chwilla, 2005).

N400 as a Function of Semantic Processing

Initial ERP studies done by Kutas and Hillyard (1980a, 1980b, 1980c, 1983) showed that the N400 was sensitive to the semantic aspect of language processing. These classic studies by Kutas and Hillyard examined the electrophysiological results of replacing a word within a sentence with a semantically inappropriate word. The sentences were presented visually. The researchers found that when a semantically inappropriate word was presented, an increased negative peak was seen at approximately 400 ms, with the amplitude greatest over the centro-parietal region of the right hemisphere. These results were consistent regardless of the position of the semantically anomalous word within the sentence.

Kutas and Hillyard (1980a, 1980b, 1980c) also found that the amplitude of the N400 increased as the expectancy of the target word decreased. Thus they concluded that the amplitude of the N400 is inversely related to the participant's expectancy to the substituted word, which they termed the cloze probability.

In addition to these findings, one of the three 1980 studies by Kutas and Hillyard (1980a) presented the final word of the sentence in an unusually large font. The researchers found that the results of the two types of violations were independent from each other. The semantic violation was accompanied by a large N400 component whereas the word presented in the unusually large font was accompanied by a late positive component.

Even though the previous research indicated that the N400 was exclusive to lexical-semantic processing, Polich (1985) challenged this view of the N400. In his study, he used two different types of stimuli: a list of words within a semantic category and a series of questions replicated from the Kutas and Hillyard study (1980c). Half of the categorical word list contained a final word that violated the semantic category and half of the question stimuli ended in a semantically incorrect word. The study consisted of two experiments. In the first experiment, the participants were required to read the sentences. The second experiment required the participants to press a button to indicate whether the stimuli did or did not end in a semantically appropriate word.

In the experiments with the correct and incorrect sentences, an N400 component was observed for the incongruous sentences. This is in accordance with the findings of Kutas and Hillyard (1980a, 1980b, 1980c, 1983). However, regarding the word series stimuli, a negative component occurring at 400 ms was produced by both the correct and incorrect stimuli. In addition to these findings, in the second experiment, a positive component was seen when participants categorized the stimuli as semantically correct or incorrect, which occurred in both sets of stimuli. This positive component was substantially increased in the sentences with the N400 (odd-ending sentences, odd-and normal-ending word series).

Polich (1985) concluded that the positive component must be the P300, which was thought to result from unexpected task-relevant stimuli requiring a motor response or a cognitive decision (Canseco-Gonzalez, 2000; Hillyard & Kutas, 1983). Polich also interpreted the N400 component as a delayed N200, which occurred during the decision of whether a stimulus was similar or dissimilar (Ritter, Simson, & Vaughn, 1983). He concluded that these results may reflect the brain's ability to comprehend complex relationships rather than the brain detecting semantic incongruities. Polich summarized his results by stating:

> It can also be argued that the different temporal scalp distributions reflect the operation of distinct processing mechanisms which generate different ERP components. However, given the consistent pattern of negative components observed over a variety of situations, it seems more parsimonious to assume that the nature of the processing tasks which invoke an N2 or N400 response—evaluation of stimulus similarity or dissimilarity—is the fundamental defining attribute of a "generic" N2 ERP response. (p. 318)

Typicality and semantic priming of the N400. Stuss, Picton, and Cerri (1988) examined the role of the N400 when participants decided how well a word fit into a particular category, known as the "typicality" of a word. They found that a word with a greater atypicality would elicit a larger N400 amplitude. An unexpected finding in the study was that the high frequency atypical words elicited a longer N400 than low frequency atypical words. The authors stated that the results indicate that the N400 is activated when a stimulus is complex, incorrect, or unanticipated. The authors also concluded that the results do not support the hypothesis that the N400 reflects lexical access because according to that hypothesis, low frequency words would require more time to access versus high frequency words, thus creating a longer N400 in low frequency words. However, after this study was conducted, the theory of the N400 reflecting lexical access was confirmed by Attias and Pratt (1992) who found that nonword stimuli elicited longer N400 latencies than meaningful stimuli.

Another finding in the Stuss et al. (1988) research was the presence of a later positive component (LPC). This component occurred around 745 ms and is distinctly different from the P300 in that it has a longer peak latency, a longer duration, and a more widely distributed scalp coverage. It was also found that the LPC was largest for high frequency words. The authors concluded that the LPC “varies with the frequency of a stimulus or perhaps how active the stimulus is in long-term memory” (p. 270).

In addition to the effects of typicality on the N400, the role of semantic priming on the N400 has also been evaluated. Semantic priming is the presentation of a word in a semantically appropriate context (Mitchell, Andrews, & Ward, 1993). Researchers have found that semantic priming increases the accuracy and speed of semantic processing, thus reducing the N400 amplitude (Bentin, Kutas, & Hillyard, 1993; Mitchell et al., 1993).

Radeau, Besson, Fonteneau, and Castro (1998) further investigated the role of semantic priming. They used ERPs in order to evaluate the effects of semantic, phonological, and repetition priming on words presented auditorily. They found that the N400 was smallest in words preceded by a semantic prime, intermediate when preceded by a phonological prime, and largest when preceded by an unrelated word.

Fujihara, Nageishi, Koyama, and Nakajima (1998) studied the effect that both semantic priming and typicality would have on the N400. These researchers presented categories with typical and atypical words. The typical words within a category were processed with greater accuracy and speed than the atypical words within the category. This was because the typical words within the category acted as semantic primes.

N400 summary. Research regarding the N400 component has found that the amplitude of the N400 varies with word frequency. The amplitude is smaller for high frequency words, function words, and words that have been semantically primed by a related word. On the other hand, the N400 amplitude is increased for content words and anomalous words. Even though the N400 is sometimes affected by other variables, it is typically accepted that the N400 is specifically associated with semantic processing.

Syntactic ERP Components—P600

The sensitivity of unique ERP responses to syntactic stimuli was first established by Osterhout and Holcomb (1992). In their experiment, they presented garden-path sentences to participants in order to evaluate the electrophysiological response to syntactic incongruities. Garden-path sentences contain words that are ambiguous within the syntactic structure of the sentence. For example, in the sentences *The broker persuaded the man to sell the stock* versus *The broker persuaded to sell the stock was sent to jail,* the first sentence is the syntactically preferred sentence, whereas the second sentence results in an ambiguous interpretation. When the syntactic representation is not preferred, the brain backtracks and reanalyzes the sentence. The researchers found that the electrophysiological component for the garden-path sentences was unique from the N400 component. The garden-path sentences elicited a widely distributed positive component with a midpoint at approximately 600 ms post-stimulus, giving it the name P600. The authors summarized their results by stating, “The P600 seems to act as an electrophysiological marker of the syntactic garden-path effect. Furthermore, the P600 effect is clearly distinct from the response typically observed following semantically inappropriate words" (p. 797).

Visual versus auditory modality. In order to evaluate the effects of auditory stimuli on the P600 component, Osterhout and Holcomb (1993) replicated their previous study (1992) using auditory stimuli versus visual stimuli. The researchers found that in the auditory modality as in the visual modality, the P600 was elicited by the garden-path sentences. However, the P600 elicited by auditory stimuli had an earlier onset than in the visual stimuli. Also, in the auditory study, the P600 was more restricted to the posterior portion of the brain than in the visual modality. In spite of these differences, the similarity between the two modalities suggests that auditory and visual language processing occurs using the same strategies (Osterhout & Holcomb, 1993).

Hagoort and Brown (2000) also compared the P600 across the auditory and visual modalities. They found that the P600 components between the two modalities were very similar. Unlike the results of Osterhout and Holcomb (1993), they found that the onset of the P600 across modalities was almost identical. However, their results concurred with Osterhout and Holcomb in that the auditory modality had a more posterior distribution.

P600 as a member of the P300 family. There has been debate on whether the P600 component is part of the P300 family, which is associated with unexpected, task-relevant stimuli (Ruchkin, Johnson, Conoune, Ritter, & Hammer, 1990). Osterhoust and Holcomb (1993) gave three reasons why the P600 could be related to the P300 component. First, if participants anticipated a grammatical structure, then "'perceived ungrammaticality' might act as an 'unexpected event'" (p. 432) and thus elicit a P300 component. Second, the syntactically incorrect words in the stimuli provided participants with knowledge of the outcome of the current trial. Ruchkin et al. found that the P300 amplitude is affected by the extent of information that is given through the stimulus. Therefore, when the participants were able to predict the outcome of the trial as in the Osterhout and Holcomb study, the P300 would be increased. Third, the modality-related differences seen in the Osterhout and Holcomb studies were similar to results in a study eliciting the P300 in both the visual and auditory modalities (Johnson, 1989).

Gunter, Stowe, and Mulder (1997) also concluded that the P600 is a member of the P300 family. They found that both the P600 and P300 were elicited in an experiment with a syntactic violation at the end of a sentence. They concluded that these components appear to be elicited by unexpected, task-relevant stimuli. Coulson et al. (1998) also came to the same conclusion regarding the P600. In an experiment with syntactically incorrect sentences, they found that the scalp distribution for the P600 and P300 were almost identical. They also found an interaction between grammaticality and probability on the amplitude of the components.

Recently, the belief that the P600 is part of the P300 family has been challenged (Frisch, Kotz, Cramon, & Friederici, 2003). In an experiment with aphasic patients, half of who had lesions in the basal ganglia and half with temporal-parietal lesions, researchers presented syntactically correct and incorrect sentences. A P300 was elicited in all participants with the incorrect sentences; however, only the group with temporal-parietal lesions showed a P600 to the incorrect sentences. The authors concluded that the basal ganglia plays a role in the generation of the P600, but not in the P300. This would be evidence that the two components are unique. The authors summarized their results by stating, “The finding that the generation of the P600 is dependent on brain structures which do not play a role in eliciting a P300 response is evidence for the assumption that we deal with two different components" (p. 339).

Specificity of the P600. There has been debate regarding the specificity of the P600 to syntactic anomalies. While some researchers have concluded that the P600 is specific to the syntactic processing of language (Osterhout & Mobley, 1995), other researchers have challenged this specific view of the P600 (Kolk, Chwilla, van Herten, & Oor, 2003; Munte, Heinze, Matzke, Wieringa, & Johannes, 1998; van Herten, Kolk, & Chwilla, 2005). A possible reason why previous studies evaluating syntactic and semantic violations did not elicit a P600 (e.g., Kutas & Hillyard, 1983; Osterhout & Mobley, 1995) is that these studies were flawed by either presenting 30 or fewer trials per condition, not using enough participants, or failing to assess the epoch containing P600.

Munte et al. (1998) conducted a study comparing sentences which were presented visually with either a morphosyntactic error (e.g. *The witch used her broom's to fly to the forest*), semantic error (e.g. *The witch used her dream to fly to the forest*), or an orthographic error (e.g. *The witch used her broome to fly to the forest*). The morphosyntactic, semantic, and orthographic errors all elicited similar waves at approximately 600 ms post-stimulus. This finding indicates that the P600 is sensitive to linguistic errors other than just syntactic anomalies.

Kolk et al. (2003) also studied the specificity of the P600 and concluded that the P600 is not just elicited by syntactic anomalies. In the study, sentences with syntactic anomalies concerning subject-verb agreement and semantic anomalies were presented to participants. Two types of semantic anomalies were presented: semantic reversal anomalies (e.g. *The cat that fled from the mice ran through the room*) and restriction violations that modified the noun (e.g. *The trees that stood in the park were all remarkable*). The researchers found that the semantic reversal anomalies elicited a P600 component with similar centro-parietal scalp distribution as in the syntactic anomalies. Also, the N400 was absent during semantic reversal anomalies, but not during the restriction violations.

Kolk et al. (2003) explained the results of their study by comparing their results to the garden-path sentence study of Osterhout and Holcomb (1992). As was found in that study, the P600 was elicited when the participants had to reanalyze the sentence because their first interpretation did not fit the syntactic structure of the sentence. Kolk et al. stated that in the case of their current study, a reanalysis would not take place, because that would confirm a mismatch. Instead, they proposed that the brain “reattends” (p. 31) to the unexpected stimuli in order to check the truthfulness of the stimuli. They also proposed that the absence of the N400 is related to the presence of the P600. When the brain does not believe that the sentence has been processed correctly, than there would be no need for the brain to integrate what has been read, thus resulting in no N400 component.

The results of Kolk et al. (2003) were confirmed in a study by van Herten et al. (2005). They also used semantic reversal anomalies and compared them with the electrophysiological results of syntactic anomalies and found that “the latency, duration, and scalp distribution of the P600 effects did not differ between the two conditions” (p. 251). Combined, the results of these studies challenge the view of the P600 as only being elicited by syntactic anomalies. Instead, it appears that the P600 is elicited during "reprocessing" (Kolk et al., 2003, p. 252) and when an individual encounters unexpected stimuli (Kolk et al., 2003; van Herten et al., 2005).

Role of the ELAN in Syntactic Processing

In addition to a positive ERP component being elicited near 600 ms when encountering syntactic anomalies, the ELAN is also evoked during syntactic violations. The ELAN has been elicited for phrase structure, verb agreement, and verb subcategorization violations in addition to word-category errors. It is also distinct from the N400 component in that it has a more frontal distribution and smaller amplitude than the N400 (Canseco-Gonazalez, 2000). Also, the ELAN is typically only seen with outright syntactic violations that affect the first-pass parsing processes (Friederici, 1997).

A Temporal Model of Language Processing

Friederici (1995) proposed a model of temporal language processing that assesses how syntactic and semantic processes interact over time. She used a series of four experiments in order to formulate her model. In the first experiment, she used three types of visually presented stimuli: (a) sentences with a subcategorization violation (e.g. *The president is being fallen*), (b) sentences with semantic anomalies (e.g. *The president is being spiced*), and (c) correct sentences. ERPs of both the syntactic and semantic violations elicited an N400 component. However, the topography between the two sets of stimuli differed. In the semantic violation, the ERP was broadly distributed over the left and right hemispheres whereas in the syntactic violation the ERP component had a left anterior distribution. Freiderici concluded that "The *temporal domain* around 400 ms was taken to reflect the time window at which the full information of a lexical entry is available . . . as well as syntactic aspects" (p. 265). Freiderici also concluded that the different topography represented the individual brain systems and areas involved with semantic and syntactic lexical processing.

The second experiment (Friederici, 1995) involved early syntactic parsing processes assumed to be founded on word category information. Stimuli consisted of four sets of sentences that were presented auditorily: (a) correct sentences, (b) sentences with a restriction violation (e.g. *The cloud is being buried*), (c) sentences with a morphological error (e.g. *The parquet is being polish*), and (d) sentences with a phrase structure violation (e.g. *The friend is being in the visited*). Both the semantic and morphological conditions produced a negativity around 400 ms. However, in the morphological condition, the negativity peaked slightly earlier and was less prominent in the posterior sites than the semantic condition. Also, the negativity elicited by the morphological error was followed by a distributed positivity in the posterior regions. In the phrase structure violation, an early negativity at the frontal electrodes peaking at approximately 200 ms was elicited. Friederici inferred from these results that different brain systems are activated for lexical-semantic information versus local phrasal information and that the anterior parts of the left hemispheres specifically support early syntactic processes that are involved with structure building and maintenance.

The third experiment conducted by Friederici (1995) investigated the processing of phrase structure violations along with the processing of phrase structure preferences. The data from the phrase structure violation was the same as the ELAN in the previous experiment. However, the negativity that was elicited during the phrase structure preference condition began approximately at 400 ms post-stimulus, which suggests a negativity that represents processes different from the ELAN. Freiderici concluded that this left anterior negativity around 400 ms may represent syntactic processes that reflect lexical information versus word category information. She also proposed that these two different left anterior negativities may reflect the brain's hierarchical access to different syntactic information, with syntactic word category information being accessed prior to argument structure information.

The final experiment by Freiderici (1995) focused on the late positivity component (P600) and its role in syntactic reanalysis. Freiderici presented sentences with relative clauses and that were structurally ambiguous until the last word of the sentence. The last word of the sentence made it clear whether the clause was a subject relative clause or an object relative clause. The positivity elicited by the ambiguous sentences occurred at 345 ms. This differs from previous studies that also investigated the reanalysis of sentences (Osterhout & Holcomb, 1992, 1993). However, the distribution of the positivities is similar between the studies. Friederici hypothesized that this difference in latency may reflect the complexity of processing between the two studies. In the Osterhout and Holcomb studies, the parser needs to reanalyze the hierarchical representation in order to comprehend the sentence; whereas in the study by Freiderici, the parser only needs to reanalyze the subject noun phrase and the object noun phrase to fit the relative pronoun. These results suggest that the parser considers only the least complex structure when presented with syntactically ambiguous sentences.

Although more research is needed in order to fully understand the temporal aspects of language processing, Friederici (1995) proposed a comprehensive and well supported theory. Friederici summarized her results regarding the neurophysiological model of language processing with the following outline:

> Four different language-related ERP components manifest in three different time windows: first, an early negativity around 200 ms at the left anterior sites associated with the processing of local phrase structure information; second, two negativities with different distributions around 400 ms, (a) the N400 elicited by semantic anomalies widely distributed over the posterior areas and (b) a more localized negativity in the same time window with left anterior maxima associated with the processing of lexically bound syntactic information, such as subcategorization information; and third, a late positivity which is widely distributed centrally and over the posterior parts of both hemispheres and which seems to correlate with processes of structural reanalysis. (p. 276)

Even though this is an extensive model for temporal language processing, it does not reflect the brain's response to temporal violations during language comprehension. Further research was needed in order to understand the neurophysiological effects of temporal disruptions of language.

Besson, Faita, Czernasty, and Kutas (1997) evaluated the effects of temporal disruptions on ERP recording using both auditory and visual stimuli. Half of the presented sentences were familiar (i.e., proverbs or idoms) and half of the sentences were unfamiliar. Also, half of the sentences in both the auditory and visual modality contained a 600 ms delay between the final two words of the sentence.

Consistent with previous studies (Kutas & Hillyard, 1980a, 1980b), Besson et al. (1997) found an increased N400 for the unfamiliar sentences versus familiar sentences in both modalities. However, the ERP recordings of the 600 ms pause between the two final words of the sentence differed in the two modalities. In the visual modality, this pause elicited a Contingent Negative Variation (CNV), which is a broad negative potential; whereas in the auditory modality the pause elicited an emitted potential. This emitted potential was identical to that found in a musical experiment where the final two notes of a musical phrase were separated by a 600 ms delay (Besson & Faita, 1995; Besson, Faita, & Requin, 1994). This suggests that the brain processes music and spoken language similarly, whereas the brain processing for reading is unique. The results of this study indicate that the brain is very sensitive to temporal violations in spoken sentences. These results may also be beneficial in the research of how rhythm and prosody affect language comprehension.

ERP Components in Children

Few studies have been performed regarding the semantic and syntactic language processing of children. The studies that have been performed demonstrate that children with typically developing language detect both syntactic and semantic anomalies in language and that as children become older, their processing of language more closely resembles the language processing of adults (Atchley et al., 2001; Freiderici & Hahne, 2001; Hahne, Eckstein, & Friederici, 2004; Holcomb et al., 1992).

N400 Component in Children

Holcomb et al. (1992) performed one of the most comprehensive ERP studies regarding how semantic language processing is affected by development. Holcomb et al. examined 130 participants between the ages of 5 and 26 years in order to evaluate the effects of age development on semantic processing as reflected by the N400 component. Each participant listened to 40 correct sentences and 40 semantically anomalous sentences. After listening to each sentence, the participants pressed a button in order to determine if the sentence was correct or incorrect. In addition to this measure, ERPs were also measured in order to detect the participants' brain activity during the stimuli.

Both the child and adult participants exhibited a peaked N400 component to the semantically anomalous sentences. However, unlike the adult participants, the participants aged 5 to 14 years also showed a N400 component to all sentence types, including the control sentences, although the peak for the anomalous sentences was greater. Also, the N400 showed a significant decrease in both latency and amplitude from ages 5 to 16 years, after which these aspects stabilized. In addition to these differences between the age groups, the five youngest groups (5 to 14 years) also showed waveforms that were most negative in the anterior temporal and frontal regions whereas the four oldest groups (17 to 26 years) showed the greatest negativity in the posterior regions. Holcomb et al. (1992) speculated that the large anterior negativity found in the child participants may indicate a second ERP component that is only seen in children.

Additional studies regarding the N400 component in children have shown similar results as Holcomb et al. (1992). Friederici and Hahne (2001) found that German children ages 6 to 9 years had a longer N400 peak latency than adults. They also found that the N400 in children had a greater scalp distribution which covered the central, parietal, and frontal areas. In addition to this, Hahne, Eckstein, and Friederici (2004) also found that children are capable of detecting correct versus incorrect semantic sentences as shown through ERPs. They found that children ages 10 to 13 produced an N400 component similar to adults and that children ages 7 to 8 produced N400 components that were slightly delayed from adults. Unlike Holcomb et al. (1992), these researchers did not find a decrease in the N400 amplitude. Also in the 6-year-olds, it was found that there was a small N400 effect. This is most likely because even in the correct sentences, the 6-year-olds presented with an elevated N400. This indicates that for this age group, the task places large semantic demands on the participants, but even more demands when presented with the incorrect stimuli (Hahne, et al.).

Atchley et al. (2006) also completed a study in order to evaluate the N400 in children. There were 14 participants between the ages of 8.5 and 13 years and 15 adult participants. Stimuli consisted of semantically correct sentences paired with a matching, incorrect sentence (e.g., *Where does a boy like to play?* and *Where does a chair like to play?).*

Atchley et al. (2006) found that both children and adults had a significant N400 when presented with semantic incongruities. However, the adults and children differed in scalp location, latency, and amplitude when presented with these semantic violations. The researchers found that when presented with semantically incorrect sentences, the children had a peak latency of approximately 75 ms greater than the adults. Also, the child participants processed the information in the frontal regions of the brains; whereas the adult participants processed the information in the parietal and centro-parietal regions. In addition to these differences, the child participants also had a larger N400 component than the adults.

P600 and the ELAN Components in Children

Studies regarding the syntactic violations and language processing of children show that the P600 component is greater in amplitude and has a greater latency delay than adults. Friederici and Hahne (2001) found that when children ages 6 to 9 years were presented with grammatically correct sentences (e.g. *The fish was caught*) versus grammatically incorrect sentences (e.g. *The fish was in the caught*), the children exhibited a delayed P600 component which extended beyond the adult P600 component. Also, the children ages 8.2 to 9.2 years showed an ELAN between 150 and 350 ms like the adults. However, the children ages 6.1 to 7.8 years had an ELAN that was delayed in comparison to the adults. Because the ELAN represents the initial structure building of the sentence whereas the P600 reflects the secondary stage of reanalyzing and repairing the sentence, Freiderici and Hahne suggested that “children at the age of 8.7 years perform the first-pass parsing routines reflected by the ELAN similar to adults, but need more time for secondary processes including a possible repair of the sentences indicated by the latency differences in the P600” (p. 240–241). They stated that these findings suggest that children require greater time in order to process the ungrammatical sentences than the adults and that children’s parsing routines become more adult-like around the age of 8 years.

Hahne et al. (2004) also found that children’s ERP components show a difference between grammatical and ungrammatical sentences. In this study, the researchers presented passive sentences to children in various age groups. Like Friederici and Hahne (2001) they found that children between the ages of 7 and 13 years had a P600 component similar to that found in adults. However, unlike the previous study, they found that between the ages of 7 and 10 the participants did not exhibit an ELAN component. This was not seen until 13 years of age. Instead of an ELAN component, the participants exhibited a sustained anterior negativity. The researchers stated that the presence of the sustained anterior negativity in combination with the P600 indicates that the participants did recognize the presence of a syntactic violation. Also, in the 6-year-olds an ELAN was not observed and a late posterior positivity between 1250 and 1500 ms that was similar to the P600 was observed. This indicates that in these participants, the passive tense is not fully established.

Atchley et al. (2006) also studied the P600 component in children by presenting three grammatical conditions: verb drop violations, agreement violations, and correct syntactic sentences. They found that both the child and adult participants showed a significant P600 when presented with syntactically incorrect sentences. The results between children and adults regarding verb drop violations and agreement violations differed. In the verb drop violations, no significant differences were found between the two groups regarding amplitude, latency, and scalp location. However, in response to the agreement violations, the child participants had a longer P600 duration and a greater P600 amplitude than the adults.

Summary of ERP Components in Children

The ERP research regarding children with typically developing language indicates that the N400 component is typically greater in amplitude, has a more delayed latency, and has a wider scalp distribution than in adults. The P600 component is typically greater in amplitude and has a more delayed latency than adults.

ERP Research in Children with Specific Language Impairment

It has long been established that ERPs are an effective component in better understanding language disorders. Picton and Stuss (1984) stated “There are two different reasons for studying the event-related potentials of patients with language disorders. The first aims at describing the pathology using neurophysiological measures; the second aims at understanding the neurophysiology using the different kinds of pathology as experimental tools” (p. 336). Therefore, event related potentials in individuals with language impairment can help in understanding the physiology of the impairment and may also be used as a tool in diagnosing the impairment.

Unfortunately, only limited research has been performed regarding the N400 and P600 components of children with SLI. The ERP studies that have been performed regarding children with SLI clearly demonstrate that this population detects syntactic and semantic anomalies differently than children with typically developing language (Neville et al., 1993; Sabisch, Hahne, Glass, Suchodoletz, & Friederici, 2006). In addition to this research, substantial research using ERPs has been performed regarding the auditory processing deficits and auditory attention in children with SLI (Bishop & McArthur, 2005; McArthur & Bishop, 2004, 2005; Ors et al., 2002; Stevens et al., 2006). This research proves very useful in better understanding the neurophysiological aspects to SLI.

Specific Language Impairment and Auditory Processing

Auditory processing is studied using the ERP components N1, P2, and N2. The N1 originates in the primary auditory cortex, the posterior-superior temporal plane, and non-specific frontal regions (Pang & Taylor, 2000). The P2 may result from activity in the mesencephalic reticular activating system (Ponton, Eggermont, Kwong, & Don, 2000). The N2 may reflect activity in the superior temporal gyrus and medial temporal lobes (O’Donnell et al., 1993).

McArthur and Bishop (2004) evaluated the cortical responses to auditory stimuli consisting of single tones and tone pair stimuli in children and young adults with SLI versus age-matched controls. They found that a subgroup of children with SLI performed poorly on the behavioral task of discriminating between different frequencies. However, they also found that the majority of children with SLI did not show age-appropriate waveforms on the N1-P2-N2 components during the frequency discrimination task, regardless if they performed correctly on the behavioral task. The authors suggested that this may indicate delayed maturation of the auditory cortex in individuals with SLI along with impaired processing in the supra-temporal and frontal regions of the brain.

McArthur and Bishop (2004) also suggested that the results of the study may reflect the recent finding that the maturation of the auditory systems continues into adolescence (Ponton et al., 2000). McArthur and Bishop hypothesized that children with SLI are approximately 4 years delayed in cognitive maturation. According to Thompson, Cranford, and Hoyer (1999), auditory frequency discrimination does not achieve adult-like status until 8 years of age in typically developing children. Therefore, McArthur and Bishop determined that a child between the ages 10 and 11 would exhibit a similar behavioral response to a frequency discrimination task as a 6- to 7-year old child would. However, a 14- to 15-year-old child would have similar behavioral results to a typically developing 10- to 11-year-old child, which would resemble adult responses. McArthur and Bishop speculated that even though the participants with SLI aged 14 and older were able to perform correctly on a behavioral task, their auditory neurodevelopment had not reached the level of their peers, as seen in that they did not have age-appropriate ERP waveforms.

Bishop and McArthur (2005) performed a follow-up study 18 months later using a subset of participants from the McArthur and Bishop study (2004) along with new participants. There were three purposes of this study: (a) To examine whether the participants who had poor frequency discrimination abilities in the McArthur and Bishop study would improve within 18 months due to maturation, (b) To replicate the abnormal ERP results of children with SLI as seen in the McArthur and Bishop study, and (c) To evaluate whether the waveforms of children with SLI resemble waveforms of typically developing peers, which would support a maturational hypothesis. This hypothesis suggests that children with SLI are delayed in their cortical development.

In response to these questions, Bishop & McArthur (2005) first found that two of the SLI participants who had behavioral scores close to threshold had normalized within the 18 months and that two of the participants with SLI had showed improvement in their behavioral responses. Regarding the second question, the authors also replicated the results from the previous study in that a majority of SLI participants had age-inappropriate ERP waveforms in the N1-P2-N2 region. Regarding the third question, the results of the study indicated that a maturational hypothesis is appropriate for at least a subset of children with SLI. However, the authors cautioned that the study was small and that further research is needed.

Similar findings were replicated by McArthur and Bishop (2005) in a study in which they presented pure tone and vowel stimuli in children with SLI. They found that only the young participants with SLI (ages 14.5 or younger) had inappropriate behavioral responses to a frequency discrimination task. However, they found that both the young and old participants with SLI had age-inappropriate ERP waveforms in the N1-P2 areas when presented with pure tones and vowels. These findings replicated the previous findings by McArthur and Bishop (2004). The authors stated that the results of the study are consistent with an auditory maturational account of SLI. However, they cautioned that other interpretations are also appropriate and that further research regarding the maturational hypothesis needs to be performed. They suggested that future research should compare ERPs at different electrode sites and include larger groups of individuals with SLI.

Auditory Attention in Children with SLI

Stevens et al. (2006) performed an ERP study in order to evaluate the selective auditory attention abilities in children with SLI. The stimuli consisted of two narrative stories that were played simultaneously. The stories differed in three aspects: location (left/right speaker), narration voice (male/female), and content. The children were instructed to attend to one of the two stories and small pictures related to the attended story were displayed on a monitor. Within the stories was embedded a linguistic probe (i.e., the syllable /ba/) and a nonlinguistic probe (a broad spectrum buzz). Four probe types were tested: linguistic/nonlinguistic by attention/unattended.

The results of the study showed that children with typically developing language showed amplification by 100 ms of the sensorineural response to the attended stimuli versus the unattended stimuli. However, the children with SLI processed both the attended and unattended stimuli identically. This is a significant consideration for the present study because attentional states affect ERP components (McPherson & Ballachanda, 2000). Therefore, if children with SLI have selective auditory attention deficits, the participants in the present study may not be able to attend to the presented stimuli.

The N400 Component in Children with SLI

Limited research has been done regarding the ERP components in children with SLI when presented with lexical stimuli. The research that has been conducted has focused on the N400 component. Neville et al. (1993) studied the N400 component in children with language impairments and reading disorders. They visually presented sentences with semantic incongruities to the participants. They found that the children with language impairments and reading impairments presented with a larger N400 component than the control group. The authors stated that these findings suggest that the syntactic processing difficulties in children with language impairments and reading impairments led to the children using increased effort in an attempt to understand the semantically anomalous words in the provided context.

Sabisch, Hahne, Glass, Suchodoletz, and Friederici (2006) also studied the N400 in children with SLI when presented sentences with semantic anomalies. They found that the ERPs of the control group showed an N400 peak followed by a late positivity, whereas the group with SLI did not show an N400 peak, but did show a late and broadly distributed positivity. The children with SLI had a large N400 amplitude for the correct sentences, which contributes to why they did not show an additional N400 effect for the incorrect stimuli. The researchers suggested that these results show that children with SLI have either a weaker lexical-semantic understanding of verbs or problems with integrating lexical-semantic meaning. These results differed from the previous results of Neville et al. (1993). This may be due to the fact that Neville et al. used a visual presentation whereas Sabisch et al. used an auditory presentation. A visual presentation may be harder for a child to process versus an auditory presentation (Holcomb, et al. 1992), which may have affected the results of the two studies.

Present Study

There is still much research that can be done regarding the language processing of children with SLI. The current study evaluates the electrophysiological response elicited by syntactic errors in plurality, past tense, and irregular verb forms presented to children with SLI. The comparison of ERP components regarding latency, amplitude, polarity, and topographical distribution between children with normal and disordered language will increase our understanding of the cognitive language processing of children with SLI, specifically their language processing to syntactic errors that are commonly made in this population.

Method

Participants

The sample consisted of two children with SLI and two typically developing children matched for gender and chronological age, for a total of 4 participants. The participants with SLI are referred to as SLI-1 and SLI-2 and the corresponding age-matched control participants are referred to as CP-1 and CP-2. The children were between the ages of 7 and 9 years old and all participants were male. Each group is described as follows.

The participants with SLI met the following criteria:

1. No known history of neuropsychiatric disorders.
2. Normal hearing as demonstrated with pure-tone thresholds of ≤ 15 dB HL at 250, 500, 1000, 2000, 4000, and 8000 Hz and normal tympanograms (tympanometric peak pressure between -65 and 20 daPa, acoustic static admittance of .3–1.5 mmhos; Hanks & Rose, 1993; Northern, 1991).
3. Evidence of a language disorder as determined by a score of at least 1.5 standard deviation below the mean on the Clinical Evaluation of Language Fundamentals-4 (CELF-4) in addition to enrollment in speech language pathology services.
4. No evidence of a cognitive impairment as determined by a standard score of at least 85 on the Universal Nonverbal Intelligence Test (UNIT).

For each child with SLI, an age and gender-matched peer with typical language development was selected. The peers met the following criteria:

1. Chronological age within 6 months of the child with a language disorder.
2. No known history of neuropsychiatric disorders.
3. Normal hearing as demonstrated with pure-tone thresholds of ≤ 15 dB HL at 250, 500, 1000, 2000, 4000, and 8000 Hz and normal tympanograms (tympanometric peak pressure between -65 and 20 daPa, acoustic static admittance of .3–1.5 mmhos; Hanks & Rose, 1993; Northern, 1991).
4. No evidence of language delay or disorder as determined by a “passing” score on the CELF-4.
5. No evidence of a cognitive impairment as determined by a standard score of at least 85 on the UNIT.

Instrumentation

An electrode cap (Electrocap International) was used to place silver-silver chloride electrodes over the scalp at 32 electrode positions according to the 10-20 International System (Jasper, 1958). Electrode impedances were kept below 3000 ohms. Eye movements were monitored by placing electrodes on the outer cantha on one eye and above the supra-orbital foramen of the opposite eye. During post-hoc averaging trials containing eye movement were rejected.

Hearing screenings were performed using a Grason-Stadler model GSI-10 audiometer. A Grason-Stadler model GSI-33 impedance bridge was used to perform tympanograms. A NeuroScan computer using Scan 4.0 software was used to collect the event-related potentials. The raw electrical potentials were filtered between DC and 300 Hz. A 2100 ms sample was taken from the onset of the second to last word of each sentence. An interstimulus interval of 1.5 seconds was used between stimuli. The GSI-10 audiometer was used to present stimuli through insert phones. Each participant was seated comfortably in a reclining chair in a sound treated test room. The ambient noise did not exceed ANSI S3.1-1991 maximum permissible levels for air conduction testing with ears uncovered and all electronic equipment operating.

Sentences were recorded using a Larson Davis Laboratories 1.27cm model 2541 microphone attached to a Larson David Laboratories model 900 microphone at a 0º azimuth. The microphone preamplifier was attached to a Larson Davis Laboratories model 2200 preamplifier power supply. Speech was digitized at 44.1 kHz using a 24-bit quantization and stored on a hard disk for later editing. SADiE disk editor was used to edit the digital recordings and write them to a CD by dithering from 24-bit to 16-bit.

Stimuli

Sentences were presented binaurally to each participant through headphones at 65 dB HL in a sound-attenuated chamber using the GSI-10 audiometer. Sentences were taken from the Houghton Mifflin English Textbooks. One hundred thirteen sentences were used to create the stimuli. Two versions of each sentence was used. One version of the sentence contained no syntactic error, and the alternate version contained one of the following syntactic errors: a plural noun syntactic error, a past tense *–ed* verb syntactic error, a past tense irregular verb syntactic error, or a third person verb syntactic error. The syntactic errors were relative to the participants' regional dialect. All syntactic errors occurred in the final word of the sentence. The correct and incorrect versions of the same sentence were randomized and never occurred consecutively. Each participant listened to two sets of randomized sentences and received a five-minute break between each set. Four randomized versions of the 216 sentences were constructed to prevent bias. Each

SLI participant and aged-matched control participant listened to the same versions of the sentences. CP-1 and SLI-1 each listened to a total of sentences 190 sentences. CP-2 and SLI-2 listened to a total of 164 sentences. Examples of the sentences are listed below (see Appendix C for the complete set):

No Syntactic Errors

1. The sleeves covered both hands.
2. The girl laughed.
3. The plane flew.
4. The mother smiles.

Four Types of Syntactic Error

1. The sleeves covered both *hand* (plurality error).
2. The girl *laugh* (past tense regular verb error or omission of auxiliary “be” followed by progressive –ing).
3. The plane *flied* (past tense irregular verb error).
4. The mother *smile* (third person verb error).

Analysis

The N400 was identified as a negativity occurring between 437 and 448 ms over the frontal and central-frontal region (Atchley et al., 2006) for both age groups. The P600 was identified as a positivity peaking between 674 and 724 ms over the central-parietal and parietal sites (Atchley et al.) for the 9-year-old age group and as a posterior positivity occurring between 600 and 1500 ms (Hahne et al., 2004) for the 7-year-old age group. The latency of both the N400 and P600 was defined as that time interval in the waveform where maximum amplitude measured from the pre-stimulus baseline. Amplitude of the N400 was identified as the peak amplitude measured from the pre-stimulus baseline. The amplitude of the P600 was measured from the positive peak (P600) to the baseline of the waveform. Thirty-two scalp locations were recorded and scalp electrode FC4 was discarded on all participants due to a bad recording.

An epoch of 2100 ms was sampled beginning 100 ms before the end of the stimulus presentation and ending 2000 ms after the stimulus presentation. The recordings from each participant were averaged separately resulting in two distribution maps per participant for each condition. In addition, a *t*-score map was computed for each participant between the two conditions. Also, a *t*-score map was computed between each SLI participant and corresponding control participant for each condition. A *t*-score of ±1.83 is significant at the 0.05 level. Group statistics could not be completed due to the small sample size. Also, group statistics could not be performed because within the time window of ages assessed, differences in the amplitude and latency due to maturation would be expected.

Results

Control Participant 1 – (CP-1)

Case history. At the time of testing, CP-1 was age 9:8 and had recently finished the third grade. CP-1 had no history of neurological disorders. He was living at home with both parents and English was the only language spoken in the home. CP-1 came from a middle socioeconomic income family.

Language and IQ assessment. CP-1 received a standard score of 108 on the CELF-4, placing him in the 70th percentile and a standard score of 113 on the UNIT, placing him in the 81st percentile (Table 1).

Time analysis maps. Figure 1 shows the scalp distribution for CP-1 while listening to the syntactically correct sentences. A negativity is seen starting at approximately 251 ms over the frontal and left frontal-temporal regions. This negativity dissipates by approximately 335 ms. A positivity is also seen beginning at approximately 251 ms over a small area of the left temporal region. The positivity begins to spread at approximately 335 ms over the left temporal-occipital and right frontal regions. At approximately 419 ms the positivity is widespread throughout all regions of the brain except the occipital region. At about 503 ms the positivity dissipates except for a slight positivity over the right parietal region that subsides by approximately 587 ms when a slight positivity is seen over the left frontal region, which begins to enlarge over the left frontal region at approximately 671 ms. Also, at approximately 671 ms a positivity is seen over the occipital region. This positivity dissipates around 755 ms. Beginning at 755 ms a negativity is seen over the parietal and frontal-temporal regions, with increased activity over the right frontal-temporal region versus the left frontal-temporal region. There is also a slight positivity between 755 and 839 ms over the small areas of the frontal and left temporal-occipital regions. The negativity at approximately 755 ms begins to dissipate at approximately 839 ms and is limited to the right posterior-temporal and left and right frontal-temporal regions, with an increase of activity over the right versus the left frontal-temporal region. The negativity fully subsides by approximately 1006 ms. A positivity is seen at approximately 1090 ms over the frontal-temporal, parietal, and temporal-parietal regions, with an increase of activity over the right hemisphere. This positivity subsides by 1174 ms; although small areas of positivity are seen over the frontal and occipital regions, with an increase in positivity on the left side, between 1258 and 1342 ms. At approximately 1845 ms a negativity is seen over the right frontal-temporal region. The negativity begins to spread at approximately 1929 ms over

Table 1

CP-1's Assessment Scores

Clinical Evaluation of Language Fundamentals-4

	Core Language	Receptive Language	Expressive Language
Concepts and Following Directions	9	9	
Recalling Sentences	11		11
Formulated Sentences	14		14
Word Classes-Receptive	11	11	
Word Classes-Expressive	11		11
Word Classes-Total	11		
Standard Score	108		
Percentile Rank	70		

Universal Nonverbal Intelligence Test

	Standard Score	Percentile
Full Scale IQ	113	81

Note: Scores of the Clinical Evaluation of Language Fundamentals-4 are standard scores: *M* = 100, *SD* = 15; subtest scores: *M* = 10, *SD* = 3. Scores of the Universal Nonverbal Intelligence Test are standard scores: *M* = 100, *SD* = 15.

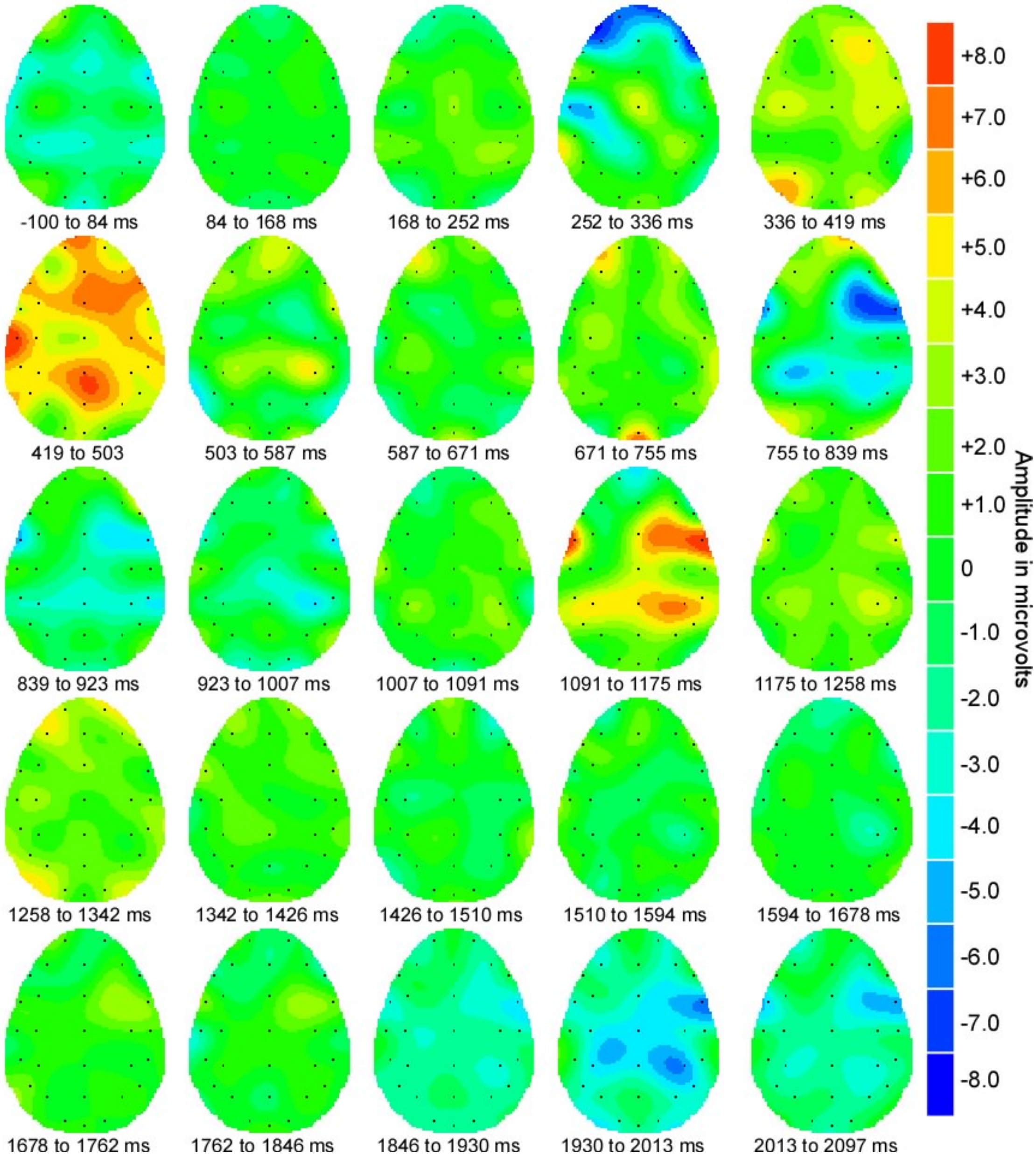

Figure 1.

Scalp distribution of CP-1 while listening to the syntactically correct sentences.

the parietal, occipital, and right frontal-temporal regions. By approximately 2097 ms the negativity subsides over the frontal-temporal regions, with an increased negativity over the right region.

Figure 2 shows the scalp distribution for CP-1 while listening to the syntactically incorrect sentences. Beginning at approximately 167 ms, a negativity is seen in the frontal, frontal-temporal, and left temporal-occipital regions. By approximately 251 ms a positivity is seen over the temporal-occipital regions, with increased activity over the left region. By approximately 335 ms all activity subsides. A slight positivity is also seen between 419 and 503 ms over small areas of the frontal and left frontal-temporal regions. An N400 pattern is observed at approximately 503 ms over the central-frontal, right frontal, and right frontal-temporal regions and continues until approximately 671 ms. Also, at 503 ms a negativity is seen over the temporal-occipital regions. This negativity remains steady on the left side until approximately 671 ms when it subsides. The negativity on the right side remains steady until approximately 755 ms when it begins to dissipate and by approximately 839 ms all negativity subsides. Between 671 and 755 ms there is a P600 over the parietal regions. Additional positivity is seen over the occipital and posterior temporal regions between 755 and 1174 ms. Between 1258 and 1342 ms a negativity is seen over the left frontal region. All activity subsides until approximately 1678 ms with a negativity over small areas of the frontal-temporal regions. The negativity begins to spread at approximately 1761 ms over the right frontal-temporal and parietal regions and dissipates by approximately 1845 ms. Between 1761 and 1845 ms there is also a slight positivity over the right frontal and left temporal-occipital regions. A

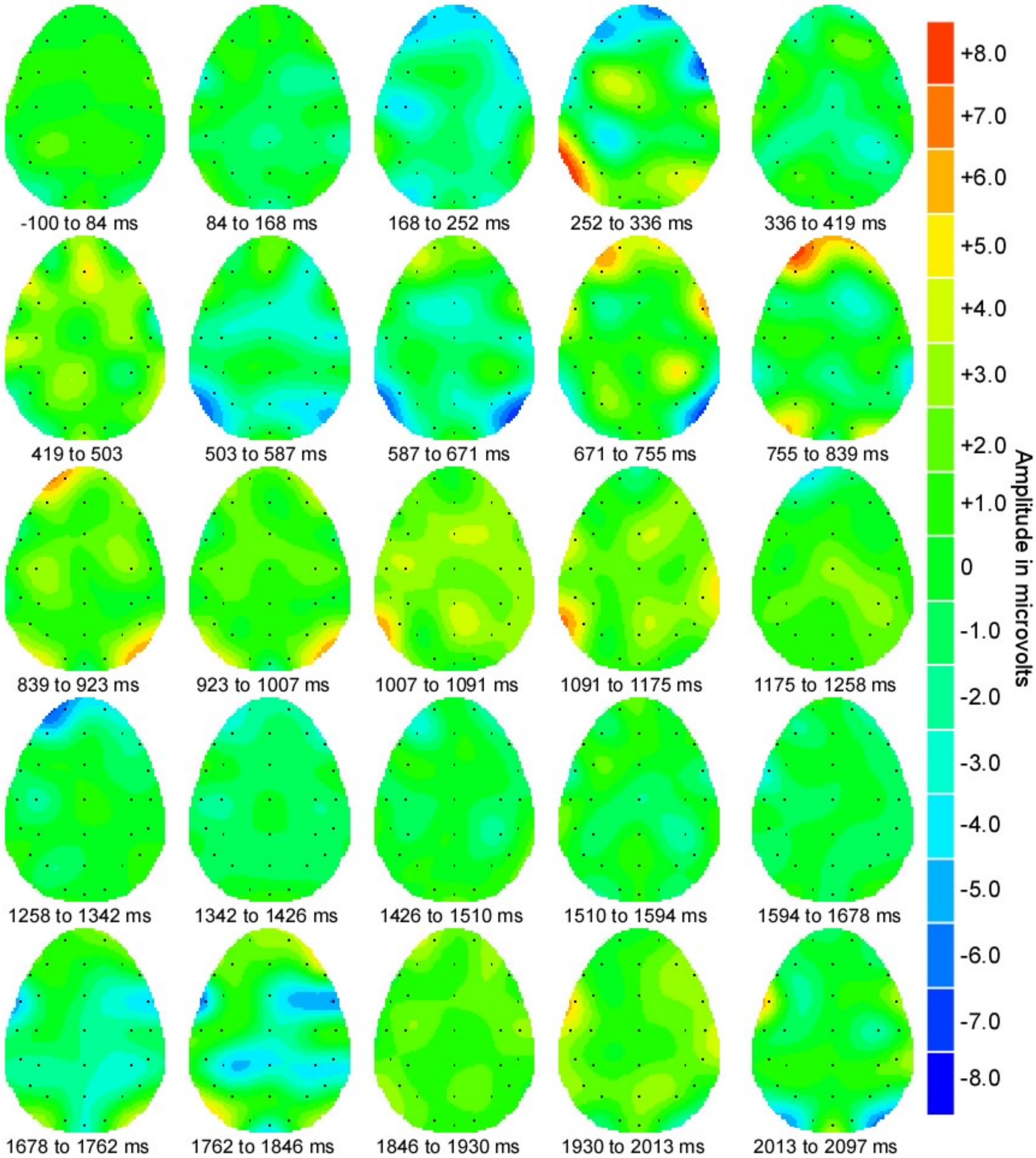

Figure 2.

Scalp distribution of CP-1 while listening to the syntactically incorrect sentences.

positivity is again seen starting at approximately 1929 ms over the left frontal-temporal region which remains steady to approximately 2097 ms. A negativity is seen over the occipital regions between 2013 and 2097 ms.

t-score map. Figure 3 shows the t-score map of CP-1 between the correct and incorrect sentences. Significant differences are seen between the two conditions throughout the epoch. At approximately 83 ms, differences are seen in the temporal-occipital, parietal, and left frontal regions. Between 83 and 167 ms differences are seen over the occipital and right frontal regions. At approximately 335 ms and continuing to 671 ms differences are seen over the temporal-occipital regions. Between 335 and 419 ms differences are seen over the parietal regions. Differences over the temporal-occipital regions are again seen between 755 and 1174 ms. At approximately 922 to 1006 ms differences are seen over the left posterior-temporal, posterior-parietal, frontal-temporal, and left frontal regions. Between 1090 and 1174 ms differences are also seen over the parietal region. At approximately 1258 to 1342 ms differences are seen over the left frontal and left occipital regions. Differences over the occipital regions are seen between 1342 and 1510 ms. Widespread differences are seen starting at 1678 ms over the frontal-temporal, parietal, posterior-parietal, and temporal-occipital regions. These differences diminish over the parietal and right frontal-temporal regions by approximately 1761 ms and dissipate by approximately 1845 ms.

Specific Language Impairment Participant 1 – (SLI-1)

Case history. At the time of the assessment, SLI-1 was 9:8 old and enrolled in the third grade. SLI-1 had attended the same school for four years. He was living at home with both parents and had two younger siblings. The father was employed full time and

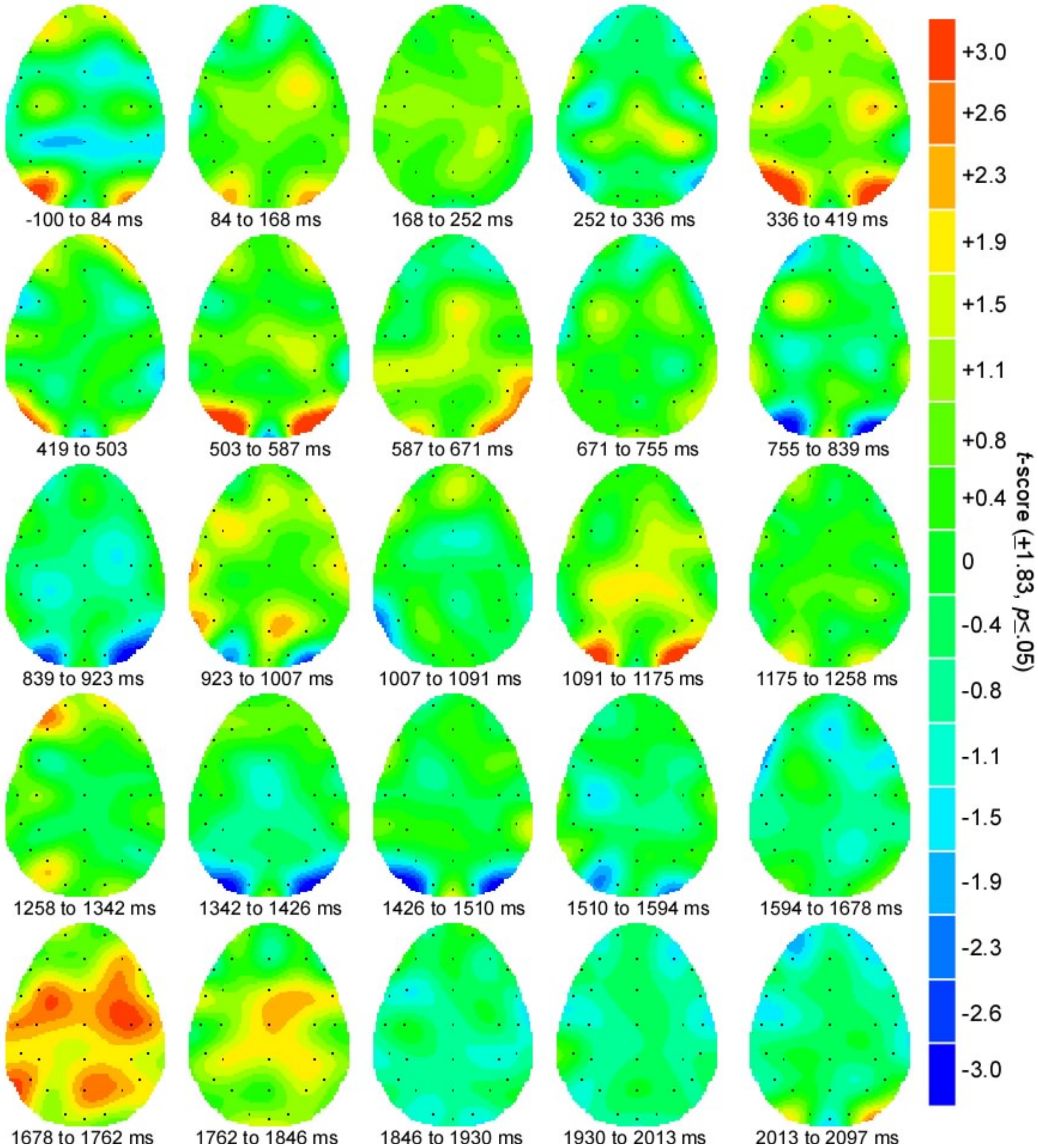

Figure 3.

t-score map showing the differences between the syntactically correct and syntactically incorrect sentences in CP-1. A *t*-score of ±1.83 is significant at the 0.05 level.

the mother part time. SLI-1 came from a middle socioeconomic income family. English was the only language spoken in the home.

SLI-1 was identified with having a language delay when he was 3:6. Prior to being identified, his mother became concerned regarding his speech and language development shortly before he turned 2:0. She reports that he developed sounds appropriately and that he spoke his first words around 1:0, but that he demonstrated difficulty developing vocabulary and sentence structure. At the time, the pediatrician was not concerned regarding SLI-1's speech and language development because he had a history of normal physical development. When SLI-1 was 3:6 he was evaluated by a private speech therapist who identified him as being very delayed in speech and language development. Since that time, SLI-1 has been enrolled in speech and language services. He is currently receiving speech therapy through the public school system. His current goals in speech therapy focus on forming grammatical structures, such as irregular verbs and plural nouns, and forming correct sentence structures. SLI-1 is currently enrolled in a mainstream classroom and is enrolled in resource for reading and language. SLI-1 does not present with any other academic difficulties.

Language and IQ assessment. In the current language evaluation, SLI-1's language is notably delayed. He received a core language score of 69 on the CELF-4, placing him in the 2nd percentile. On the UNIT, a nonverbal IQ test, SLI-1 received a standard score of 90, placing him in the 25th percentile (Table 2).

Time analysis maps. Figure 4 shows the scalp distribution of SLI-1 while listening to the syntactically correct sentences. The scalp distribution shows positive potentials

Table 2

SLI-1's Assessment Scores

Clinical Evaluation of Language Fundamentals-4

	Core Language	Receptive Language	Expressive Language
Concepts and Following Directions	5	5	
Recalling Sentences	6		6
Formulated Sentences	4		4
Word Classes-Receptive	4	4	
Word Classes-Expressive	5		5
Word Classes-Total	4		
Standard Score	69		
Percentile Rank	2		

Universal Nonverbal Intelligence Test

	Standard Score	Percentile
Full Scale IQ	90	25

Note: Scores of the Clinical Evaluation of Language Fundamentals-4 are standard scores: *M* = 100, *SD* = 15; subtest scores: *M* = 10, *SD* = 3. Scores of the Universal Nonverbal Intelligence Test are standard scores: *M* = 100, *SD* = 15.

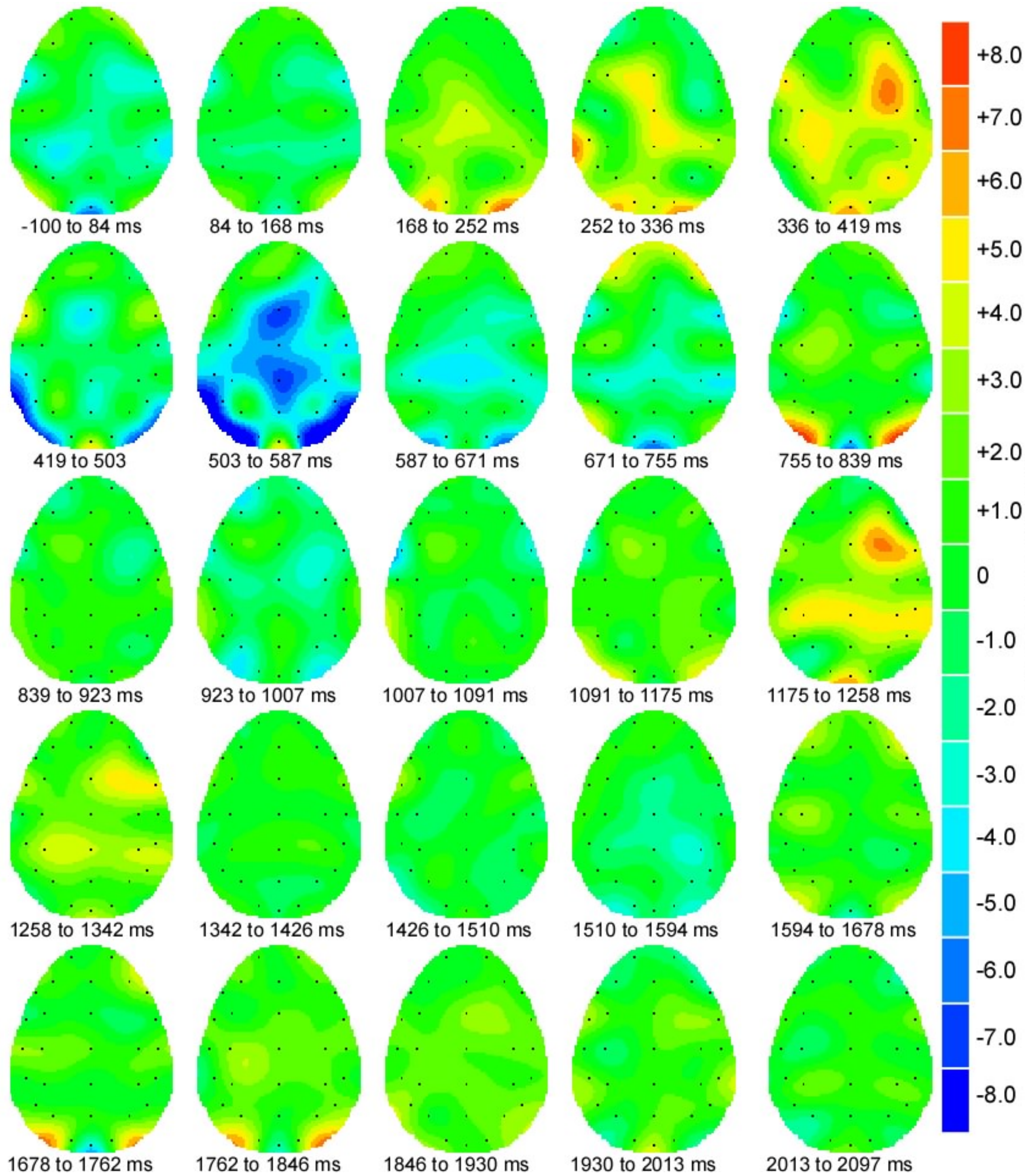

Figure 4.

Scalp distribution of SLI-1 while listening to the syntactically correct sentences.

starting at 160 ms over the vertex region with a steadily increasing positivity over the occipital regions, peaking at approximately 420 ms. The positivity spreads over the right frontal-temporal region and left parietal region by approximately 335 ms and dissipates around 420 ms. An N400 pattern is observed beginning at approximately 503 ms with a negativity over the central-frontal region which continues until approximately 587 ms. There is also a negativity over the posterior-parietal and occipital regions at approximately 419 ms until approximately 839 ms. Following this activity, a positivity is seen over the temporal-occipital region at approximately 671 ms and dissipates by approximately 839 ms. Between 1174 and 1342 ms a positivity is seen over the temporal regions, with pronounced activity over the right temporal region. At approximately 1679 ms a positivity over the right and left temporal-occipital regions is seen, which dissipates around 1845 ms.

Figure 5 shows the scalp distribution of SLI-1 while listening to the syntactically incorrect sentences. A positivity is seen starting at approximately 167 ms over the right frontal-temporal region and temporal-parietal regions with a steadily increasing positivity in the central-frontal, right occipital, temporal, temporal-occipital, and right parietal regions at approximately 250 ms. The activity begins to decrease by approximately 335 ms and dissipates by approximately 420 ms. Following the positivity, an N400 is seen beginning at approximately 503 ms with a negativity over the central-frontal region which spreads over the right frontal-temporal region at approximately 587 ms and subsides by approximately 671 ms. A positivity is seen starting at approximately 670 ms over the left and right occipital regions and continues until approximately 755 ms. A positivity is again seen over the posterior-temporal and central-parietal regions and

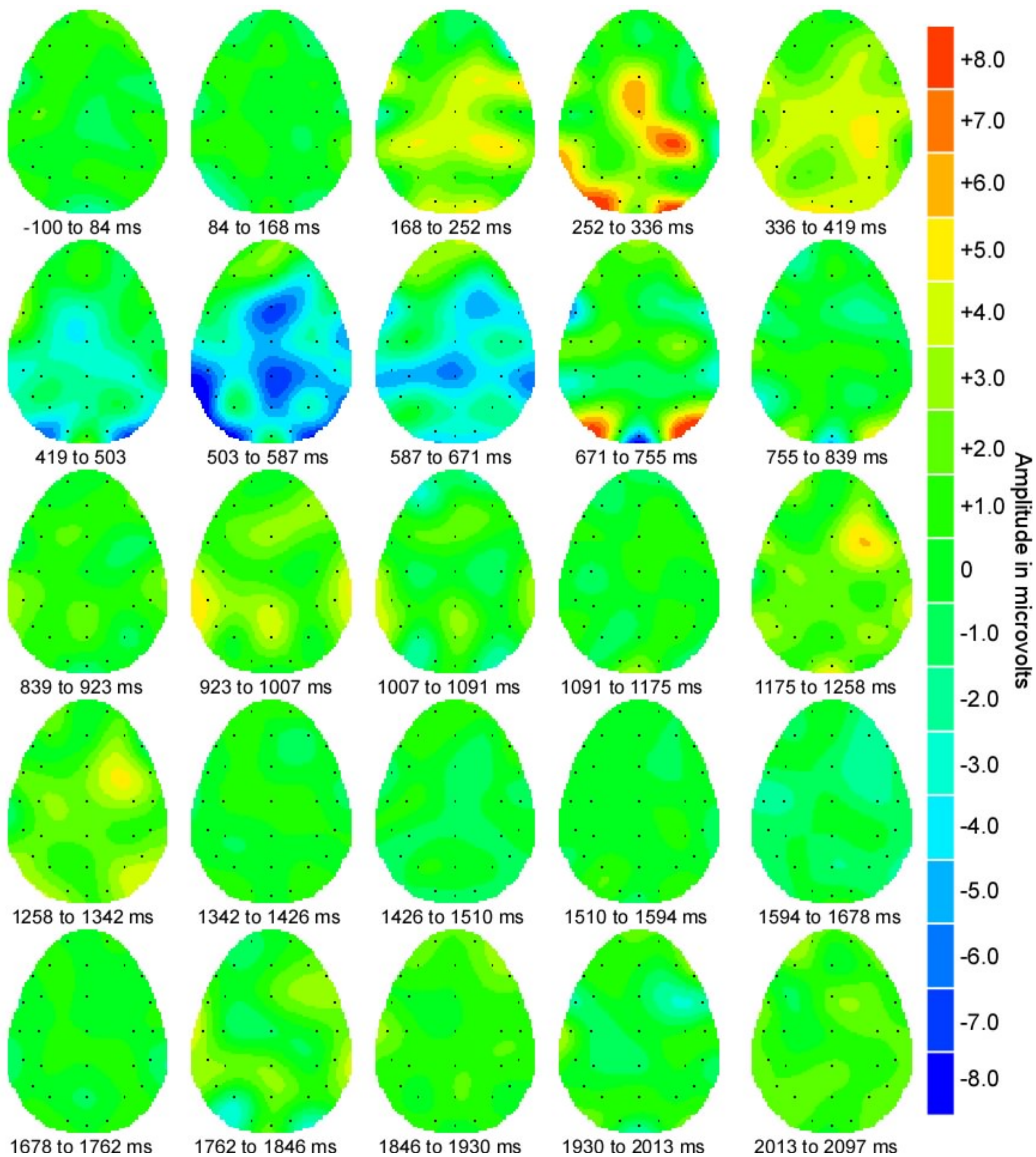

Figure 5.

Scalp distribution of SLI-1 while listening to the syntactically incorrect sentences.

continues until approximately 1006 ms. This is followed by a positivity between 1170 ms and 1342 ms in the right frontal-temporal and right temporal-occipital regions.

t-score map. Figure 6 shows the t-score map of SLI-1 between the correct and incorrect sentences. Minimal significant differences are seen between the two conditions. Beginning at approximately 83 ms, a difference between the two conditions can be seen over a small section of the left temporal-occipital region. Between 167 and 251 ms differences can be seen over a small portion of the central-frontal region. Between 251 and 419 ms differences can be seen over a minimal part of right posterior-parietal region and between 335 and 419 ms differences can be seen over a small portion of the central-frontal region. Between 671 and 755 ms differences can be seen over the left and right occipital regions. Differences between the two controls are also seen over the left temporal-occipital and left and right frontal regions between 755 and 839 ms. Differences are seen over the left and right frontal and left and right occipital regions between 922 and 1091 ms. Starting at 1090 ms and continuing to 1174 ms significant differences are seen over the left frontal region. At approximately 1258 ms differences are seen over the posterior-temporal region which spread at approximately 1342 ms over the right frontal and left posterior-temporal region at 1342 ms. Following this activity, differences are seen over the central-frontal region at approximately 1426 ms which spread over the left and right frontal regions, left frontal-temporal, and left and right occipital regions at approximately 1510 ms. At approximately 1594 ms the differences are limited to the central and right frontal region and left frontal-temporal region. The differences begin to subside at approximately 1678 ms and are limited to the central-frontal region. Between 1761 and 1845 ms the differences increase and are seen over the central-frontal and left

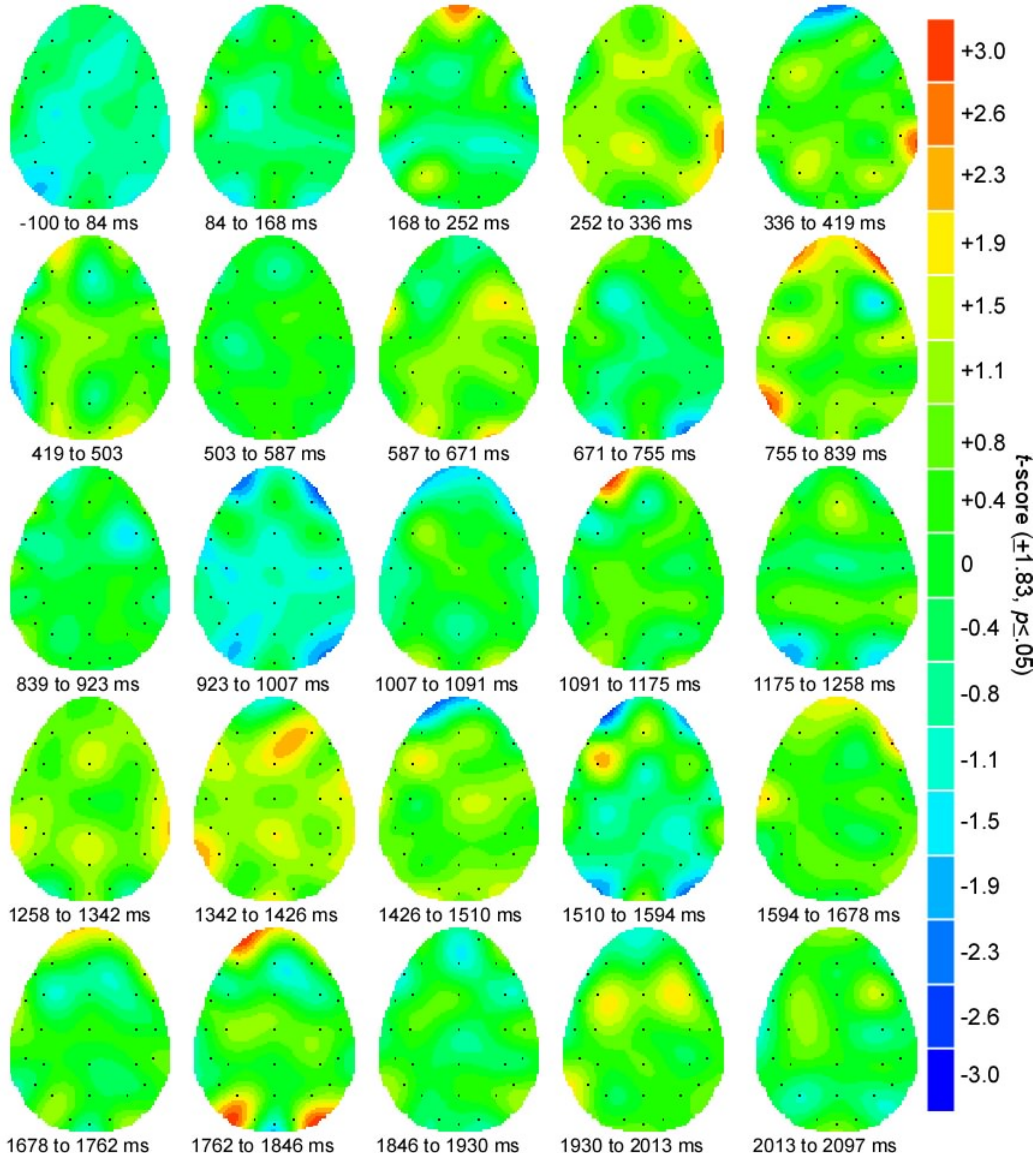

Figure 6.

t-score map showing the differences between the syntactically correct and syntactically incorrect sentences in SLI-1. A *t*-score of ±1.83 is significant at the 0.05 level.

and right occipital regions. At 1929 ms and continuing to 2013 ms differences are seen over the left and right anterior-central regions.

Differences between CP-1 and SLI-1

t-score map. Figure 7 shows the t-score results between CP-1 and SLI-1 while listening to the syntactically correct sentences. Significant differences are seen beginning at approximately 83 ms over the occipital and left frontal regions. Beginning at 167 ms differences over the occipital and frontal regions are again seen and begin to spread over the frontal, temporal, temporal-occipital, and parietal regions at approximately 251 ms. By approximately 335 ms the differences begin to subside and are seen over the left parietal, right temporal, and occipital regions. At approximately 419 ms significant differences are seen over the temporal, temporal-occipital, frontal, and parietal regions. These differences continue until approximately 503 ms until they are limited over the occipital region. At approximately 587 ms significant differences are seen over the frontal, frontal-temporal, and left temporal-occipital regions. By approximately 671 ms the differences have dissipated and are seen only over the central-frontal region. At approximately 755 ms and continuing to approximately 839 ms widespread significant differences are seen over the frontal, frontal-temporal, parietal, parietal-occipital, and temporal-occipital regions and dissipate by approximately 1426 ms. Between 1426 and 1510 ms a significant difference is seen over the right frontal-temporal region. Beginning at approximately 1594 and continuing to approximately 1678 ms significant differences can be seen over the central-frontal and right frontal regions. At approximately 1761 ms significant differences are seen over the occipital regions that steadily increase to a peak

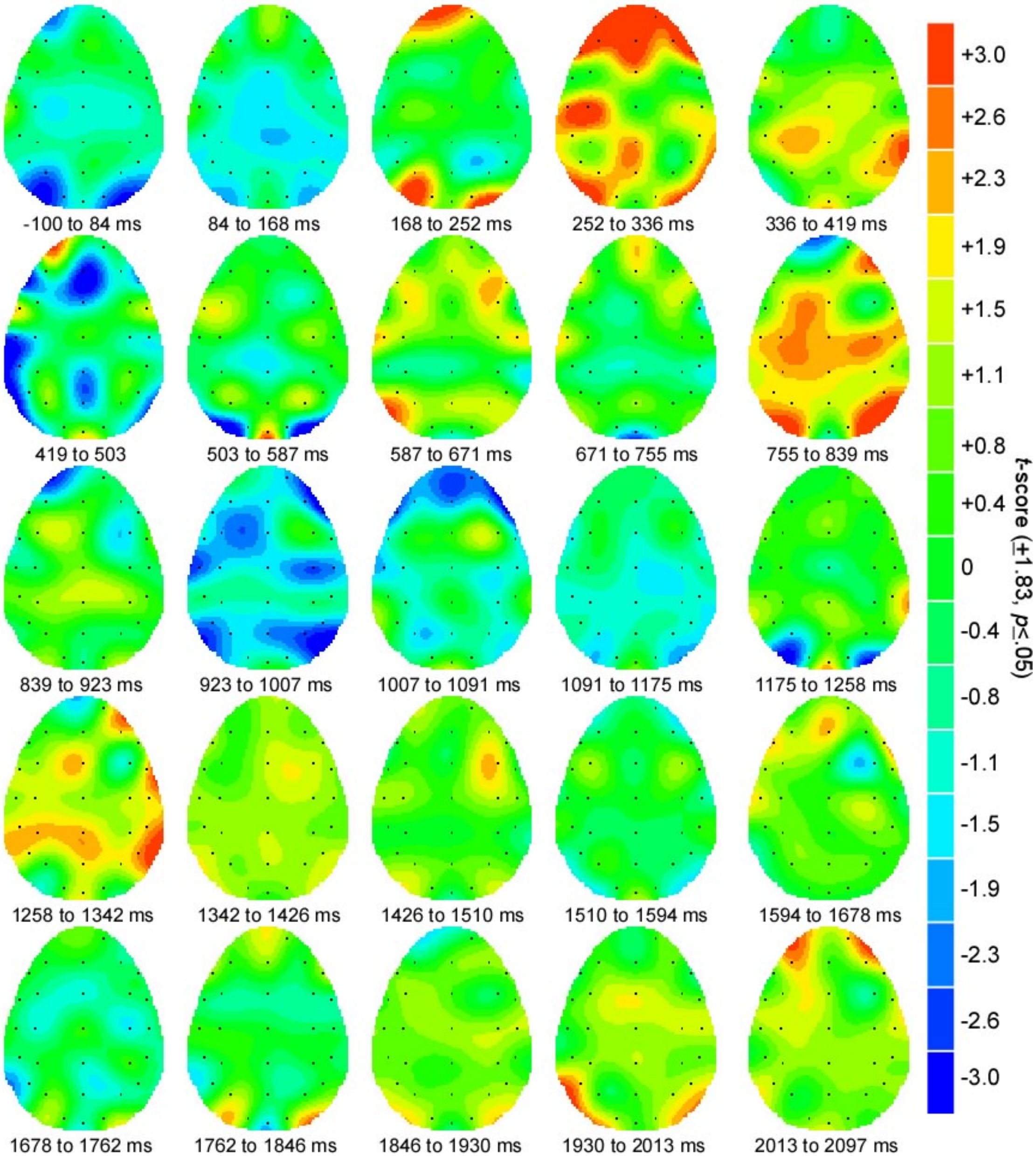

Figure 7.

t-score map showing the differences between CP-1 and SLI-1 while listening to the syntactically correct sentences. A *t*-score of ±1.83 is significant at the 0.05 level.

at approximately 1929 ms. Between 2013 and 2097 ms significant differences are seen over the frontal region.

Figure 8 shows the *t*-score results between CP-1 and SLI-1 while listening to the syntactically incorrect sentences. Beginning at approximately 167 ms significant differences are seen over the occipital and parietal regions. At approximately 251 ms the significant differences spread over the frontal, frontal-temporal, and parietal regions. Significant differences are seen over the right frontal, parietal, and temporal-occipital regions between 335 and 419 ms when the activity spreads over the central-frontal, left frontal-temporal, parietal, and right temporal-occipital regions. The differences diminish by approximately 503 ms. Starting at approximately 587 ms significant differences are again seen over the temporal-occipital regions and right frontal region. The differences increase over the occipital region at approximately 671 ms. At approximately 755 ms and continuing to approximately 839 ms the activity spreads over the frontal, left frontal-temporal, left temporal, parietal, and right temporal-occipital regions where significant differences are seen. Between 1006 and 1090 ms there are significant differences over the occipital region. At approximately 1258 ms and continuing to 1342 ms significant differences are seen over the frontal region. Between 1426 and 1510 ms significant differences are seen over the occipital region. At approximately 1678 ms significant differences are seen over the left frontal-temporal, temporal, parietal, and parietal-occipital regions. By approximately 1761 ms the differences dissipate and are seen only over the left parietal region until approximately 1845 ms. Between 1845 and 1929 ms and 2013 and 2097 ms significant differences are seen over the occipital region.

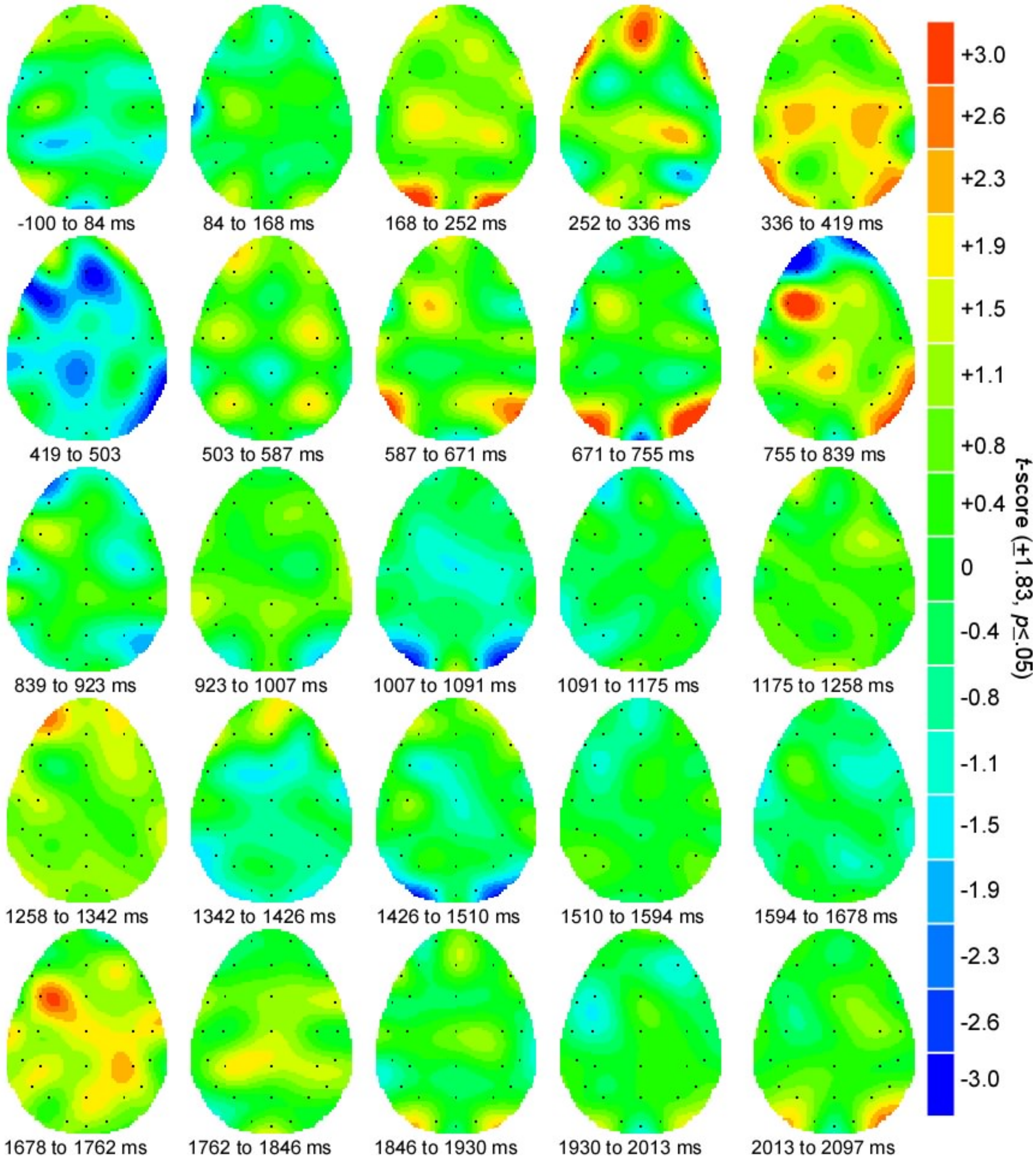

Figure 8.

t-score map showing the differences between CP-1 and SLI-1 while listening to the syntactically incorrect sentences. A *t*-score of ±1.83 is significant at the 0.05 level.

N400 and P600 comparison. CP-1 and SLI-1 exhibit differences in the P600 and N400 across the two conditions. CP-1 does not exhibit a P600 or an N400 during the syntactically correct sentences (Figure 1). This is in contrast to SLI-1 who does present with an N400 at approximately 503 ms and continues until approximately 587 ms over the central-frontal region. SLI-1 also presents with a posterior positivity in the occipital region between 671 and 755 ms (Figure 4).

During the syntactically incorrect sentences, CP-1 does not present with an N400 (Figure 2). However, SLI-1 presents with an N400 at approximately 419 ms over the central-frontal region, which lasts until approximately 671 ms (Figure 5). A P600 is seen in CP-1 between 671 and 755 ms over the parietal regions. SLI-1 does not present with a P600. Instead, SLI-1 presents with a posterior positivity in the occipital region between 671 and 755 ms.

Control Participant 2 – (CP-2)

Case history. At the time of testing, CP-2 was age 7:8 and had recently completed the first grade. CP-2 had no history of neurological disorders. CP-2 was living at home with both parents and English was the only language spoken in the home. CP-2 came from a middle socioeconomic income family.

Language and IQ assessment. In the current language assessment, CP-2 was within typical language development. CP-2 received a standard score of 100 on the CELF-4, placing him in the 50th percentile and a standard score of 95 on the UNIT, placing him in the 37th percentile (Table 3).

Time analysis maps. Figure 9 shows the scalp distribution of CP-2 while listening to the syntactically correct sentences. Beginning at approximately 251 ms a widespread negativity is seen over the frontal, frontal-temporal, parietal, and right temporal-occipital

Table 3

CP-2's Assessment Scores

Clinical Evaluation of Language Fundamentals-4

	Core Language	Receptive Language	Expressive Language
Concepts and Following Directions	10	10	
Word Structure	10		10
Recalling Sentences	10		10
Formulated Sentences	11		11
Standard Score	100		
Percentile Rank	50		

Universal Nonverbal Intelligence Test

	Standard Score	Percentile
Full Scale IQ	95	37

Note: Scores of the Clinical Evaluation of Language Fundamentals-4 are standard scores: M = 100, SD = 15; subtest scores: M = 10, SD = 3. Scores of the Universal Nonverbal Intelligence Test are standard scores: M = 100, SD = 15.

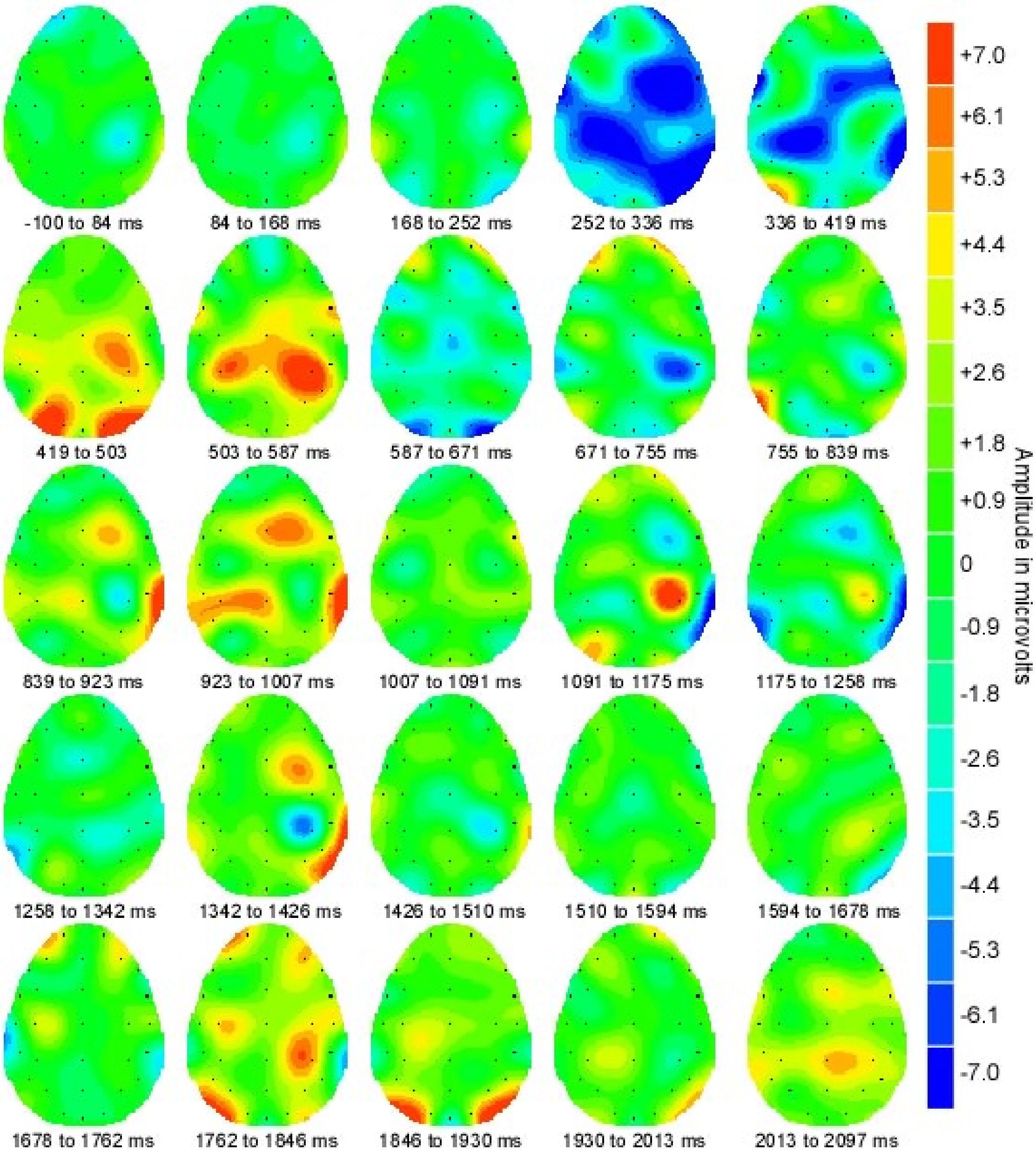

Figure 9.

Scalp distribution of CP-2 while listening to the syntactically correct sentences.

regions. This negativity begins to subside at approximately 225 ms and is seen over the right frontal-temporal, parietal, and right temporal-occipital regions and dissipates by approximately 419 ms. Following this activity, a slight positivity is seen over the left temporal-occipital regions at approximately 335 ms which begins to spread over the left and right temporal-occipital regions and right temporal-parietal region at approximately 419 ms. The positivity peaks at approximately 503 ms over the parietal region and dissipates by approximately 587 ms. A negativity is seen between 587 and 671 ms over the left and right frontal-temporal and frontal-central regions. In addition to this negativity, there is negative activity over the occipital region, which then spreads over the right posterior-parietal region between 587 and 671 ms. Following this activity, a P600 is seen over the central-posterior region between 839 and 1007 ms. Also, beginning at approximately 839 ms a positivity over the right frontal-temporal and central-frontal regions is seen. This activity increases and spreads to peak over the right frontal-temporal, left temporal-parietal, and right temporal-occipital regions at approximately 922 ms and dissipates by approximately 1006 ms. Following this activity, a positivity is seen over the right parietal region with a negativity over the right temporal-occipital region at approximately 1090 ms. The positivity dissipates by approximately 1174 ms with the negativity spreading over the left posterior-temporal region at approximately 1174 ms and dissipating at approximately 1258 ms. Between 1342 and 1426 ms a positivity is seen over the right temporal-occipital and right frontal regions. Beginning at approximately 1678 ms a slight positivity is seen over the frontal regions. The activity increases and spreads over the right temporal-parietal, left temporal-occipital, and frontal regions at approximately 1761 ms. This positivity peaks at approximately 1845 ms over the occipital region and dissipates at approximately 1929 ms.

Figure 10 shows the scalp distribution of CP-2 while listening to the syntactically incorrect sentences. Beginning at approximately 251 ms a negativity is seen over right frontal-temporal, left parietal, and right temporal-parietal regions. This negativity peaks at approximately 335 ms and dissipates by approximately 419 ms. At approximately 335 ms a strong positivity is seen over the occipital region which spreads to a peak at approximately 503 ms over the frontal-temporal, parietal, temporal-parietal, and temporal-occipital regions. This positivity begins to subside at approximately 587 ms and dissipates by approximately 671 ms. At approximately 587 ms a negativity is seen over the frontal regions and peaks over the central-frontal and frontal-temporal regions at approximately 839 ms. During this activity, a P600 is also seen at approximately 587 ms over the central-posterior regions which lasts until approximately 923 ms. At approximately 839 ms a slight positivity is present over the left occipital region which spreads over the right occipital region by approximately 922 ms. By approximately 1006 ms all activity has dissipated. Between 1090 and 1174 ms a slight positivity is seen over the temporal, central-occipital, and right frontal regions. Between 1174 and 1258 ms a slight negativity is seen over the left posterior-temporal region. Beginning at approximately 1342 ms a negativity over the right temporal region is seen with a positivity over the right posterior-temporal region. The positivity comes to peak at approximately 1426 ms and spreads over the left parietal, right frontal-temporal, and right temporal and occipital regions, with a negativity also seen over the right parietal region. The positivity begins to subside at approximately 1510 ms over the right frontal-temporal

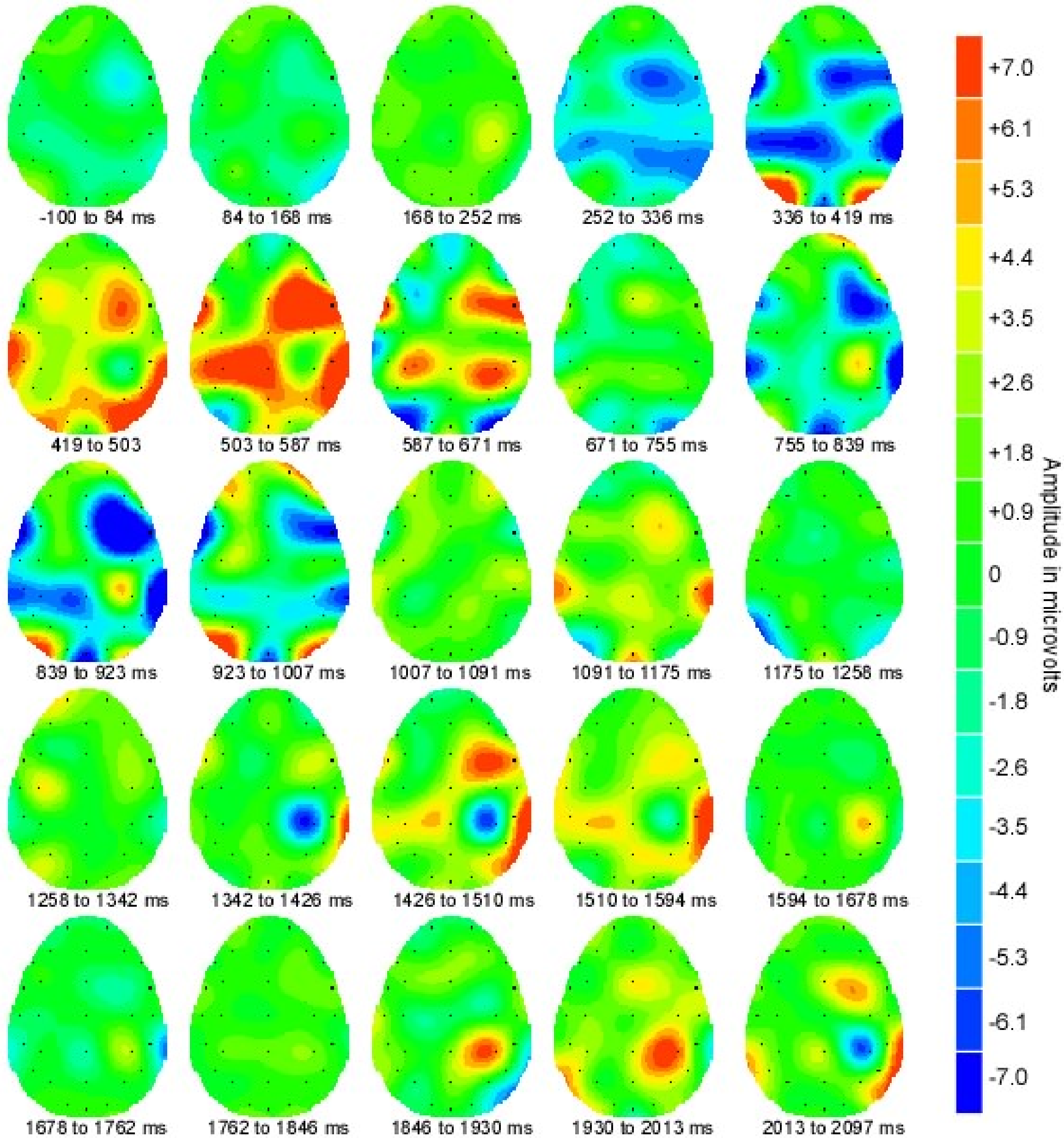

Figure 10.

Scalp distribution of CP-2 while listening to the syntactically incorrect sentences.

and left parietal regions; however the positivity remains strong over the right posterior-temporal region. By approximately 1678 ms the positivity dissipates. At approximately 1845 ms a positivity is seen over the right parietal region which spreads over the left posterior-temporal and right-frontal region by approximately 1929 ms. The positivity over the right-frontal region begins to increase at approximately 2013 ms and a positivity over the right posterior-temporal region is also seen. Also at approximately 2013 ms a negativity is seen over the right parietal region.

t-score map. Figure 11 shows the t-score results of CP-2 between the correct and incorrect sentences. At approximately 167 to 251 ms significant differences are seen over the frontal region and between 251 and 335 ms significant differences are seen over the right temporal-occipital region. At approximately 419 to 503 ms significant differences are seen over the left occipital and right posterior-temporal regions. The significant differences begin to increase between 503 and 587 ms over the left occipital and posterior-temporal regions. Between 587 and 671 ms the significant differences are seen over the frontal region and continue over the left occipital and right posterior-temporal regions. Starting at approximately 671 ms the significant differences spread over the frontal region and are also seen over the left temporal-parietal, left parietal-occipital, and right occipital regions. These differences at approximately 755 ms spread further over the temporal, posterior parietal, frontal, and frontal-temporal regions. The significant differences continue to increase and peak between 933 and 1006 ms over the frontal, frontal-temporal, temporal, parietal, and occipital regions. Beginning at approximately 1006 ms the significant differences begin to decrease and are seen over the frontal, temporal, right parietal, and occipital regions which dissipate at approximately 1174 ms.

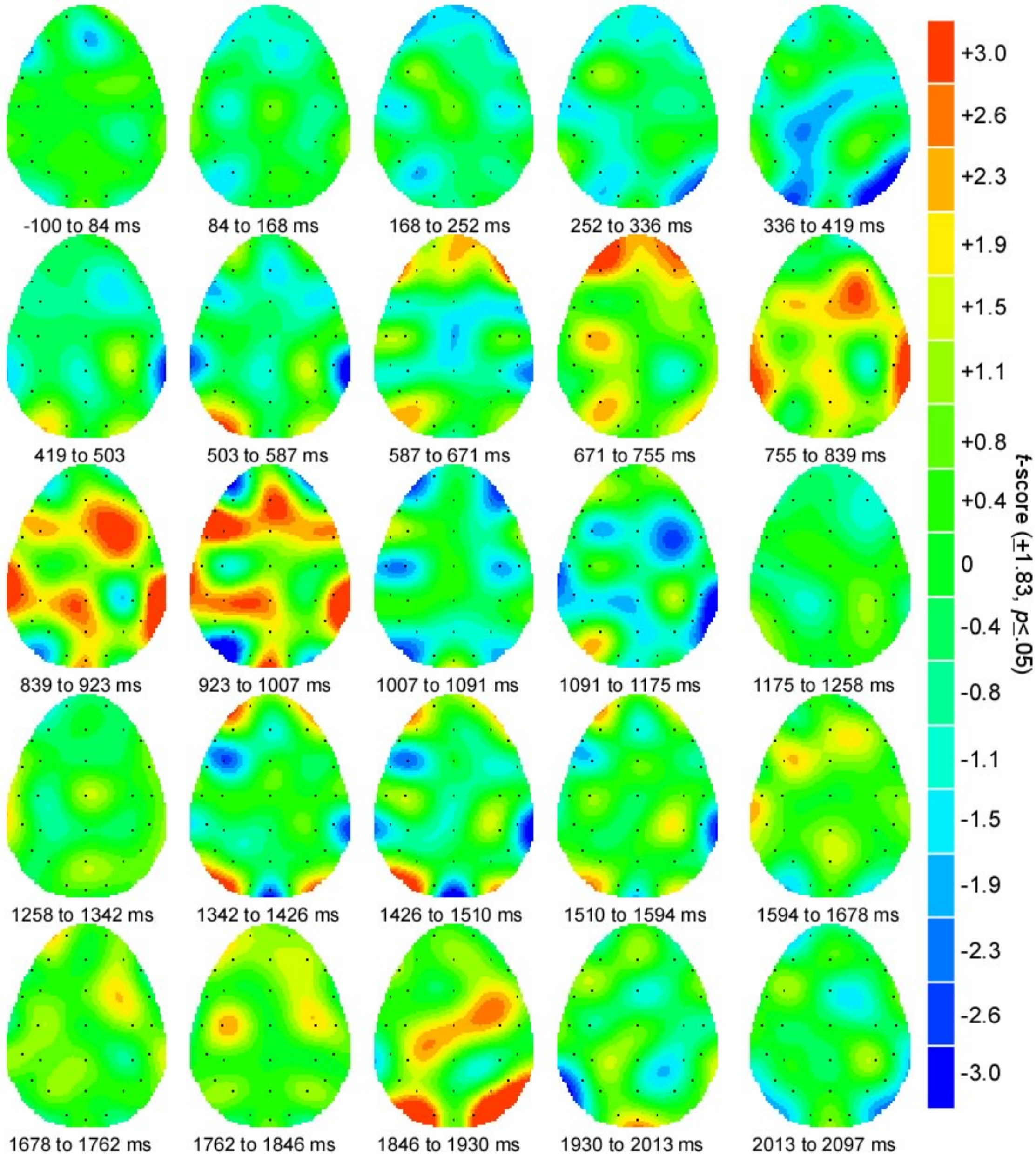

Figure 11.

t-score map showing the differences between the syntactically correct and syntactically incorrect sentences in CP-2. A *t*-score of ±1.83 is significant at the 0.05 level.

Significant differences are again seen beginning at approximately 1342 ms over the frontal, left temporal, and occipital regions. These differences remain steady until approximately 1510 ms and begin to subside by approximately 1594 ms over the left frontal, right temporal, and left occipital regions. Beginning at approximately 1594 ms significant differences are seen over the left frontal and left temporal regions. At approximately 1678 ms these differences move over the right frontal-temporal and left frontal region. Significant differences are seen over the right and left parietal regions at approximately 1761 to 1845 ms. At approximately 1845 ms the significant differences peak over the occipital, temporal-occipital, parietal, and right temporal-parietal regions. The differences begin to subside at approximately 1929 ms over the left temporal-occipital and occipital regions. By approximately 2013 ms all significant differences dissipate.

Specific Language Impairment Participant 2 – (SLI-2)

Case history. At the time of the assessment, SLI-2 was age 7:9 and had recently completed the first grade. SLI-2 had attended the same school for two years and was enrolled in a mainstream classroom. He was living at home with both parents and had five older siblings. The father was employed full time and the mother part time. SLI-2 came from a middle socioeconomic income family. English was the only language spoken in the home.

SLI-2 was identified with having a language delay at approximately 2:0. His mother became concerned with his language development at this age because SLI-2 would use motions and gestures in order to communicate his needs instead of verbally communicating. His mother reported that at this age, he had a few words such as mom, dad, no, go, and his brothers and sisters' names. He could also put together two-word combinations. However, he demonstrated difficulty with word retrieval and relied on gestures in order to communicate. His mother also reported that his comprehension of spoken language was typical. Also, SLI-2 had a history of typical physical development. His mother reported that he was able to sit, crawl and walk at that appropriate ages. He was evaluated by a local early intervention agency and diagnosed with a language disorder. He received speech therapy services through the early intervention agency for one year, after which he was enrolled in a transitional preschool where he received speech therapy services.

Once SLI-2 entered kindergarten, he began receiving speech therapy services through the school. SLI-2's current IEP goals in therapy are to improve comprehension, increase vocabulary, form grammatically correct sentences and clearly articulate words within a sentence. SLI-2 is enrolled in a mainstream classroom and demonstrates difficulty in reading; however, he is not receiving resource services.

SLI-2 also has one older sister who has a history of speech language difficulties. His sister demonstrates difficulties with word retrieval and has previously received language services until the fifth grade.

Language and IQ assessment. In the current language evaluation, SLI-2's language is notably delayed. He received a core language score of 72 on the CELF-4, placing him in the 3rd percentile. On the UNIT, a nonverbal IQ test, SLI-2 received a standard score of 85, placing him in the 16th percentile (Table 4).

Time analysis maps. Figure 12 shows the scalp distribution of SLI-2 while listening to the syntactically correct sentences. Starting at approximately 83 ms, a slight positivity is seen over the frontal-temporal region which steadily increases over the left

Table 4

SLI-2's Assessment Scores

Clinical Evaluation of Language Fundamentals-4

	Core Language	Receptive Language	Expressive Language
Concepts and Following Directions	3	3	
Word Structure	8		8
Recalling Sentences	3		3
Formulated Sentences	7		7
Standard Score	72		
Percentile Rank	3		

Universal Nonverbal Intelligence Test

	Standard Score	Percentile
Full Scale IQ	85	16

Note: Scores of the Clinical Evaluation of Language Fundamentals-4 are standard scores: *M* = 100, *SD* = 15; subtest scores: *M* = 10, *SD* = 3. Scores of the Universal Nonverbal Intelligence Test are standard scores: *M* = 100, *SD* = 15.

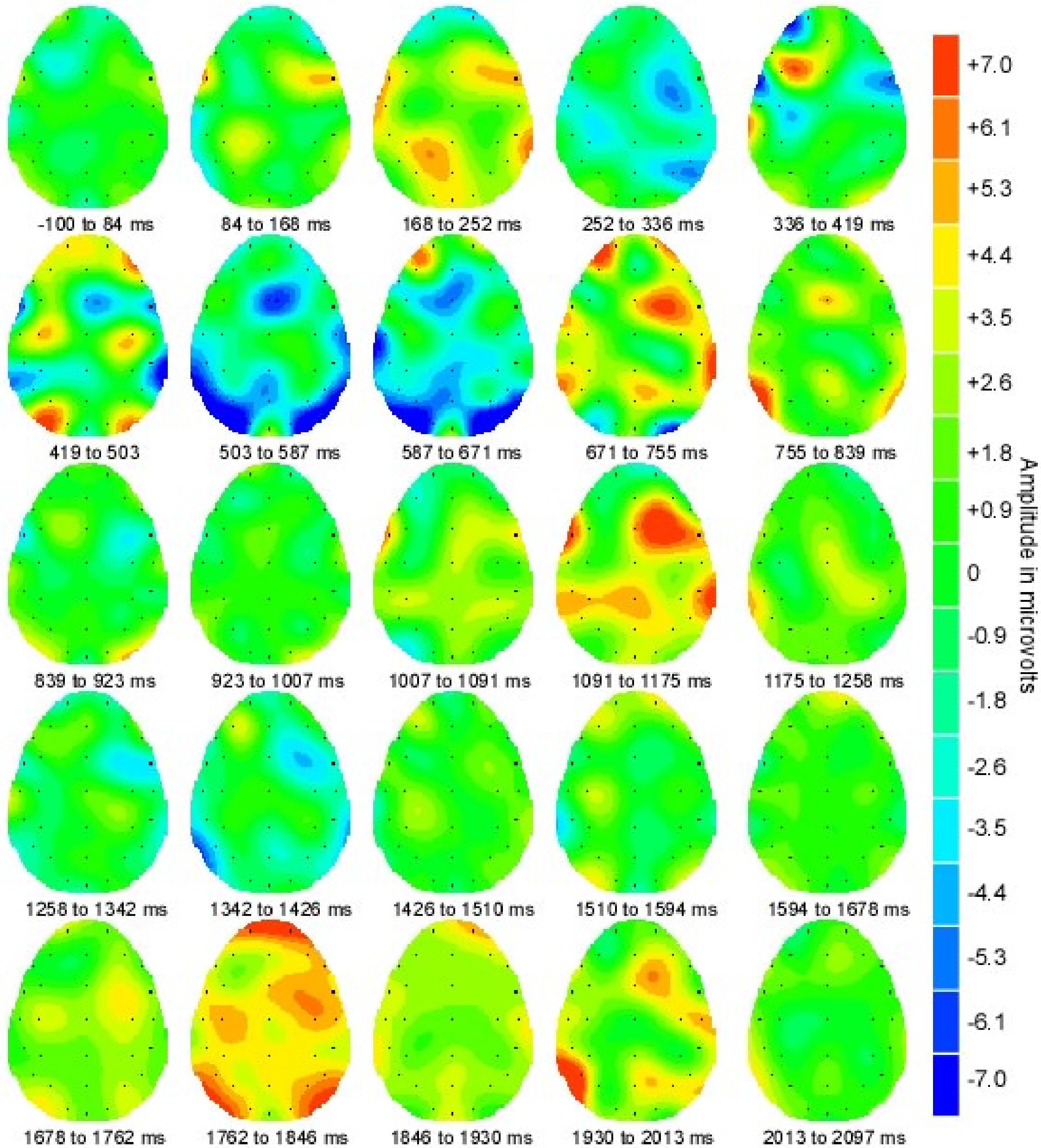

Figure 12.

Scalp distribution of SLI-2 while listening to the syntactically correct sentences.

parietal, left temporal, right frontal-temporal, and right temporal-parietal regions peaking at approximately 250 ms. A negativity is seen over the right frontal-temporal and right temporal-occipital regions between 250 and 335 ms. The activity then reduces to the frontal portion of the brain starting around 335 ms with a negativity over the left frontal and left and right frontal-temporal regions. The activity spreads starting at approximately 419 ms with a negativity over the posterior-temporal regions and a positivity over the occipital and left and right central regions. Also at approximately 419 ms a N400 is seen over the frontal-central region and remains steady until approximately 671 ms. The negativity subsides, except for a slight negativity over the occipital regions which dissipates by approximately 755 ms. Also, a slight positivity is seen in the frontal region beginning around 580 ms. The positivity begins to spread at approximately 671 ms over the frontal regions and temporal-frontal regions and a P600 is also seen over the posterior-parietal region between 671 and 839 ms. The positivity begins to dissipate around 839 ms except for a positivity over the temporal-occipital regions and central frontal region. The positivity continues until approximately 1258 ms. Between 1342 ms and 1426 ms a slight negativity is seen over the posterior temporal regions and right temporal-parietal regions. A minimal positivity is seen starting at approximately 1426 ms over the left frontal region and left parietal region which spreads over the right frontal-temporal region and left occipital region at approximately 1678 ms. The positivity peaks and spreads over the vertex, central-frontal region, right frontal-temporal region, left parietal region, and the temporal-occipital regions at approximately 1761 ms. This activity begins to subside at approximately 1845 ms except for slight activity in the right frontal region, temporal regions, and occipital region. The positivity again increases over the right frontal regions, right frontal-temporal region, left temporal-occipital region, and right parietal-occipital region at approximately 1929 ms and begins to subside at approximately 2013 ms.

Figure 13 shows the scalp distribution for SLI-2 while listening to the syntactically incorrect sentences. Beginning at approximately 83 ms a positivity is seen over the frontal-temporal areas and the right temporal-parietal area. This positivity dissipates by approximately 100 ms. A negativity over the left and right occipital regions is also seen starting at approximately 83 ms which steadily increases spreading over the left and right frontal regions, parietal regions, and temporal-occipital regions by approximately 167 ms. This activity continues to spread at approximately 251 ms over the right frontal-temporal region, right frontal region, left frontal-temporal region, posterior-parietal region, and right temporal-parietal region. This negativity begins to dissipate by 335 ms and is limited over the frontal-temporal regions. However, starting at approximately 335 ms a positivity is seen over the right and left temporal-occipital regions and left frontal region. The positivity increases over the frontal regions, left frontal-temporal region, parietal regions, and temporal-occipital region at approximately 419 ms and dissipates by approximately 503 ms. In addition to this positivity, an N400 is seen over central-frontal regions between 419 and 587 ms. This negativity continues to spread over the central- frontal region, right temporal region, left frontal-temporal region, left temporal-parietal region, and posterior parietal region at approximately 503 ms. At approximately 587 ms the negativity continues to spread over the occipital regions, left temporal region, and left frontal region and dissipates by approximately 671 ms. At approximately 671 ms to 839 ms a P600 is seen over the central-parietal region. In

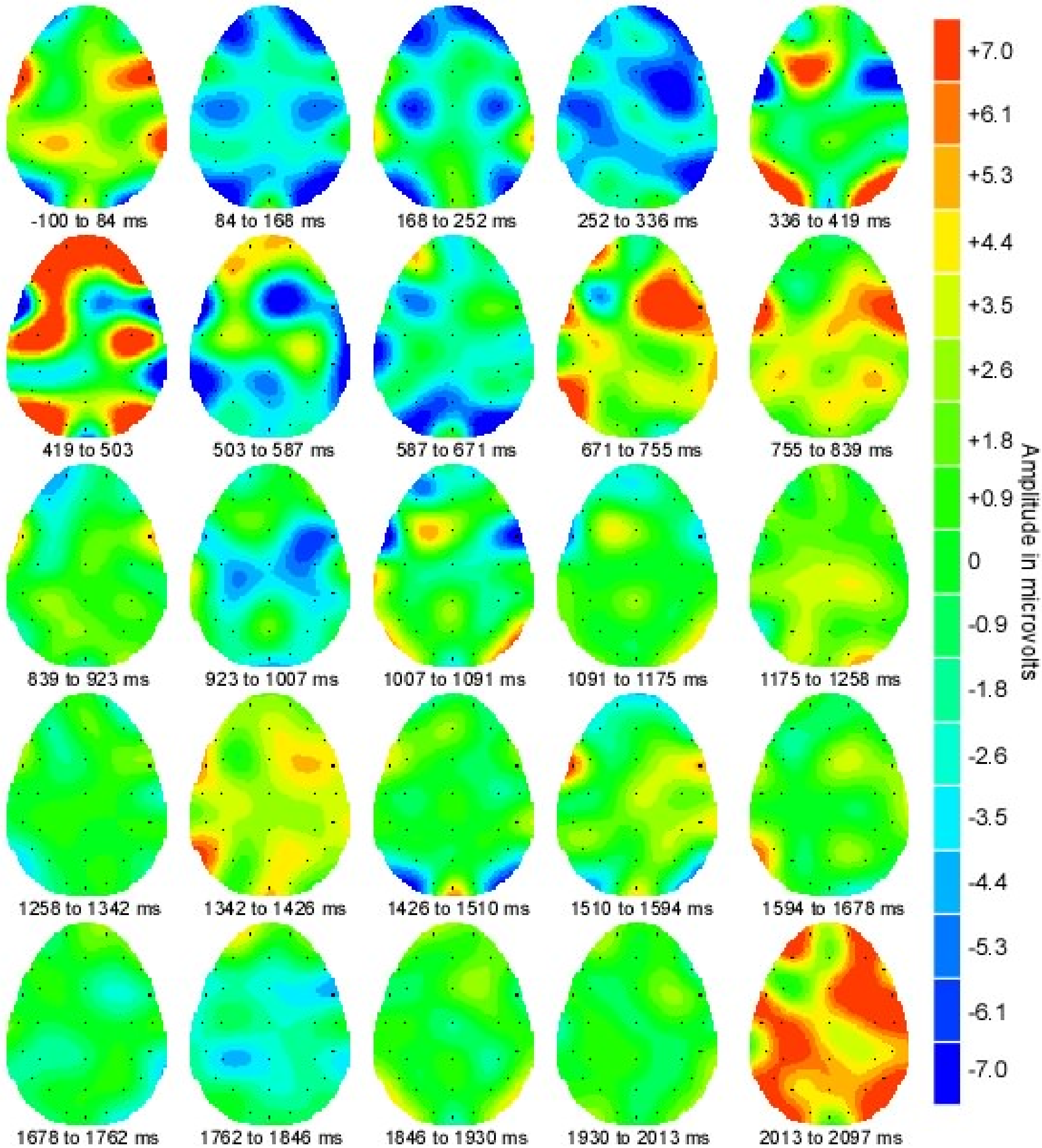

Figure 13.

Scalp distribution of SLI-2 while listening to the syntactically incorrect sentences.

addition to this positivity, a positivity over the left and right frontal-temporal regions is seen. Starting at approximately 922 ms, there is a negativity over the right frontal-temporal region and left parietal region. The negativity decreases and spreads over the frontal-temporal regions and left frontal region between 1006 and 1090 ms. Also during this time, there is a slight positivity over the left frontal region and right occipital region. Beginning at 1342 ms there is a positivity over the left posterior temporal region, right frontal-temporal region, occipital region, and slight activity over the left frontal-temporal region. The positivity dissipates by approximately 1426 ms. However, a negativity over the left and right occipital region is seen between 1426 and 1510 ms. Starting at approximately 2013 ms there is a widespread positivity over the temporal-occipital region, frontal-temporal region, frontal region, and left parietal region.

t-score map. Figure 14 shows the t-score results of SLI-2 between the correct and incorrect sentences. Significant differences are seen starting at approximately 83 ms over the central-frontal, frontal-temporal, posterior-parietal, posterior-temporal, occipital, and left frontal regions. The differences begin to dissipate at approximately 83 to 167 ms and are seen over the right temporal-occipital, left frontal, and left posterior-temporal regions. An increase in activity is seen between 167 and 251 ms with differences over the frontal-temporal, central-temporal, left temporal, parietal, parietal-occipital, and right temporal-occipital regions. The differences begin to diminish at approximately 251 ms and are seen over the right temporal-occipital region and over small portions of the right frontal, central-frontal, left temporal, and posterior-parietal regions. By approximately 419 ms, differences are seen only over the left temporal region. Differences are again seen starting at approximately 503 ms over the occipital and left frontal-temporal regions and between

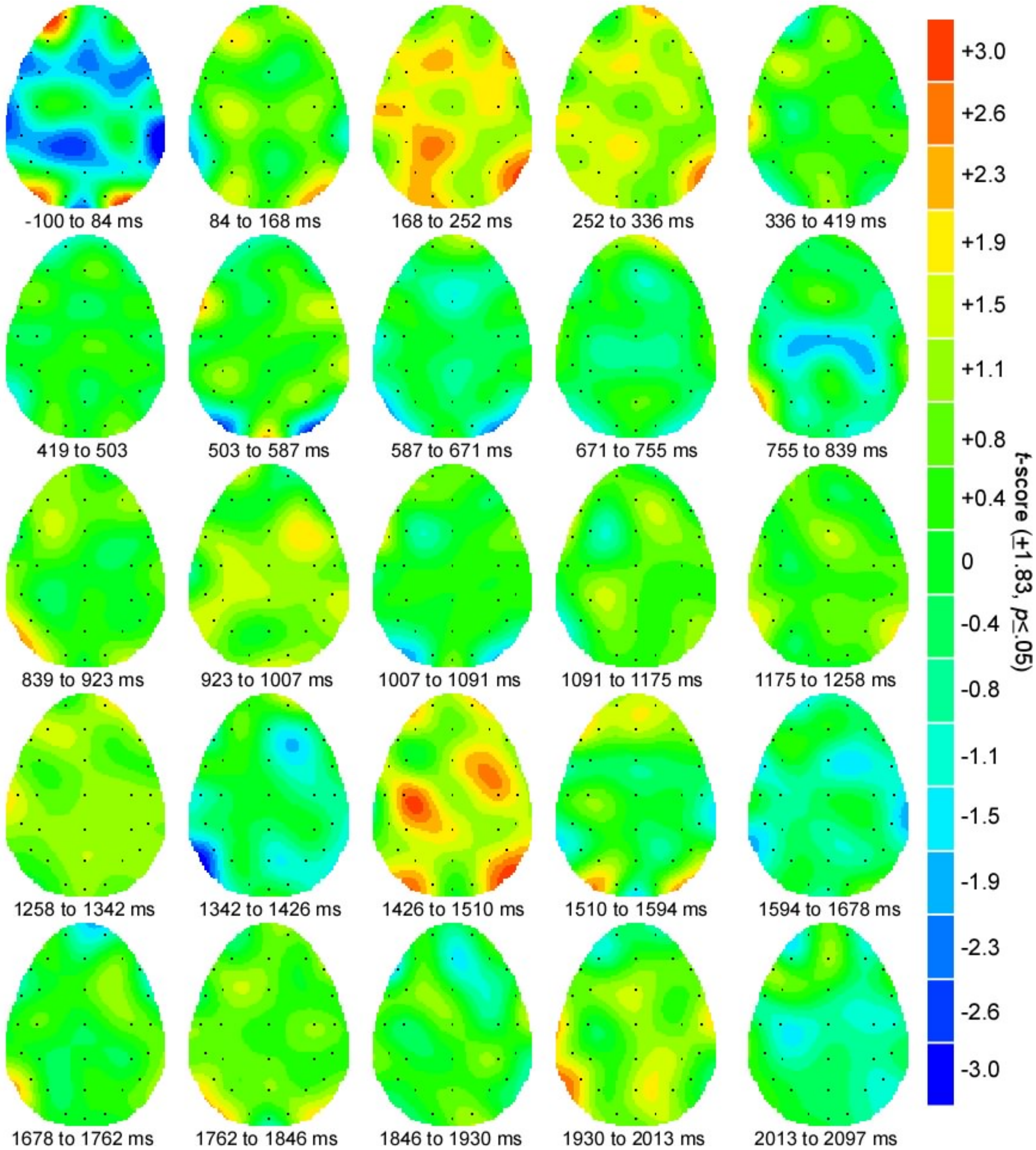

Figure 14.

t-score map showing the differences between the syntactically correct and syntactically incorrect sentences in SLI-2. A *t*-score of ±1.83 is significant at the 0.05 level.

587 and 671 ms differences are only seen over a small portion of the temporal-occipital regions. At approximately 755 to 839 ms, differences are seen over the parietal region and a small section of the left temporal-occipital region. By approximately 839 ms the differences over the left temporal-occipital region spread over the left temporal-occipital region. Between 922 and 1006 ms a difference is seen over the right frontal region. At approximately 1258 to 1342 ms, a difference is seen over a small section of the left frontal-temporal region. Between 1342 and 1426 ms differences are seen over the occipital and right frontal regions. Between 1426 and 1510 ms widespread differences are seen over the left and right frontal, right frontal-temporal, left parietal, and parietal-occipital regions. At approximately 1510 ms the differences begin to subside and are seen only over small portions of the left and right occipital regions. Between 1594 and 1845 ms differences are seen over small sections of the parietal and parietal-occipital regions and between 1929 and 2013 ms differences are seen over the left posterior-temporal and parietal-occipital regions.

Differences between CP-2 and SLI-2

t-score map. Figure 15 shows the t-score results between CP-2 and SLI-2 while listening to the syntactically correct sentences. At approximately 83 ms a significant difference is seen over the frontal region, which spreads over the frontal-temporal, temporal-occipital, and parietal-occipital regions at approximately 167 ms. These differences begin to subside at approximately 251 ms and are seen only over the occipital, right temporal-occipital, left parietal, left posterior-central, and a small area of the right frontal region. At approximately 335 ms the differences spread over the left frontal-temporal, left temporal, left parietal, and right posterior-temporal regions. The significant differences come to a peak at approximately 503 ms over the occipital,

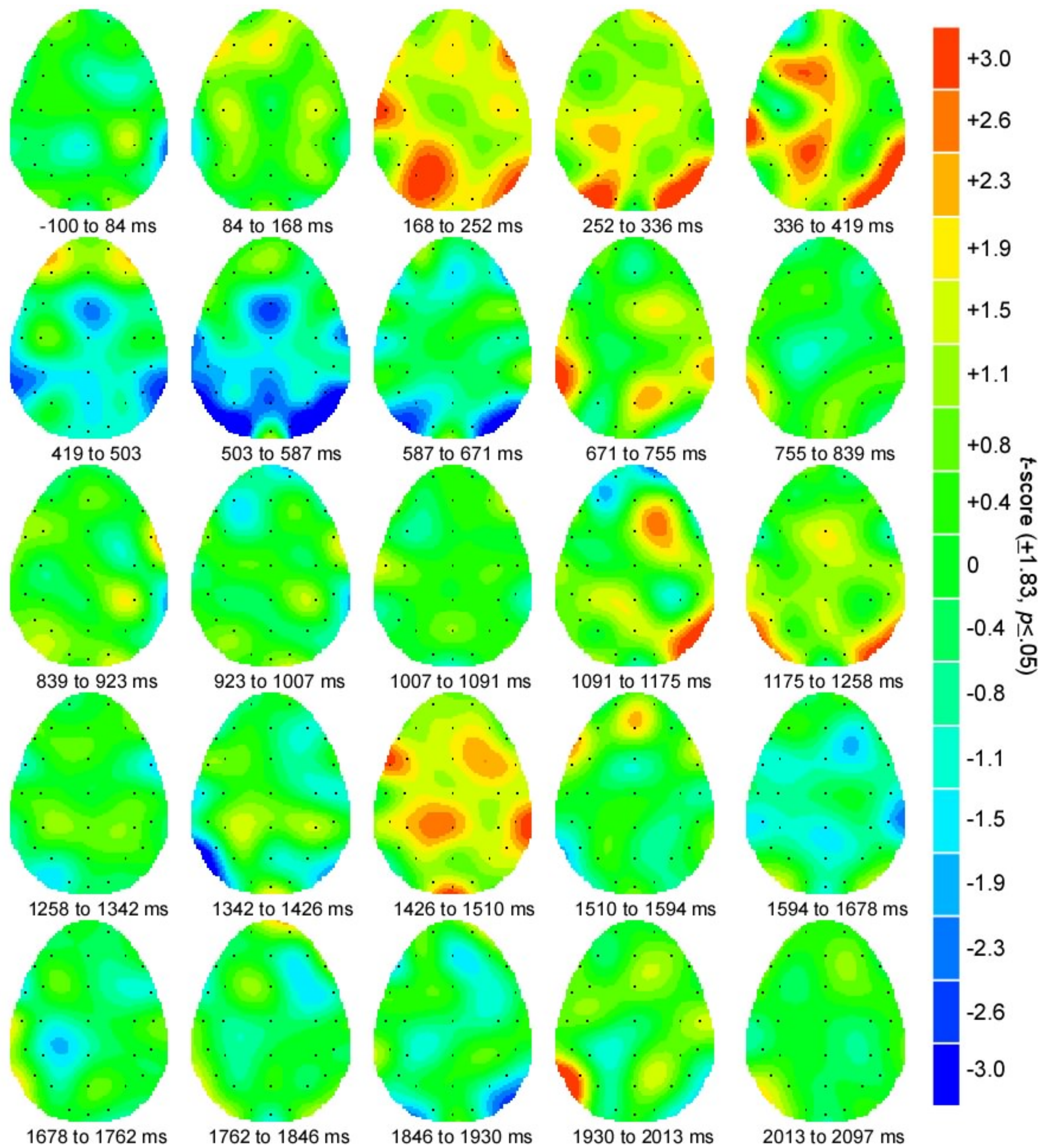

Figure 15.

t-score map showing the differences between CP-2 and SLI-2 while listening to the syntactically correct sentences. A *t*-score of ±1.83 is significant at the 0.05 level.

temporal-occipital, parietal, parietal-occipital, and frontal-temporal regions. At approximately 587 ms the differences begin to subside and are seen over the occipital region. The differences spread over the temporal and posterior-parietal regions by approximately 671 ms and by approximately 755 ms the differences are seen only over the left posterior-temporal region. Between 1090 and 1174 ms significant differences are seen over the right temporal-occipital and frontal regions. Following this, a significant difference is seen over the temporal-occipital regions until approximately 1258 ms. At approximately 1342 ms differences are seen over the temporal-occipital region and by 1426 ms the differences are widespread over the frontal-temporal, left posterior-central, central-occipital, and right temporal-parietal regions. These differences dissipate by approximately 1510 ms and are limited over the central and left temporal-frontal regions. Between 1594 and 1678 ms there is a significant difference over the right temporal region. At approximately 1845 ms differences are seen over the left and right occipital regions and by 1929 the activity is limited to the left occipital region.

Figure 16 shows the *t*-score results between CP-2 and SLI-2 while listening to the syntactically incorrect sentences. At approximately 83 ms differences are seen over the posterior-central, frontal-temporal, left frontal, occipital, and parietal regions. The differences begin to subside and are limited to the left and right occipital and left frontal regions by approximately 83 ms and by 167 ms the differences dissipate. At approximately 419 ms differences are seen over the vertex, frontal, temporal-frontal, posterior-central, and parietal regions. These differences spread to a peak over the vertex, left frontal, frontal-temporal, parietal, central-occipital, and posterior-central regions at approximately 503 ms. Between 587 and 671 ms the differences dissipate and are limited

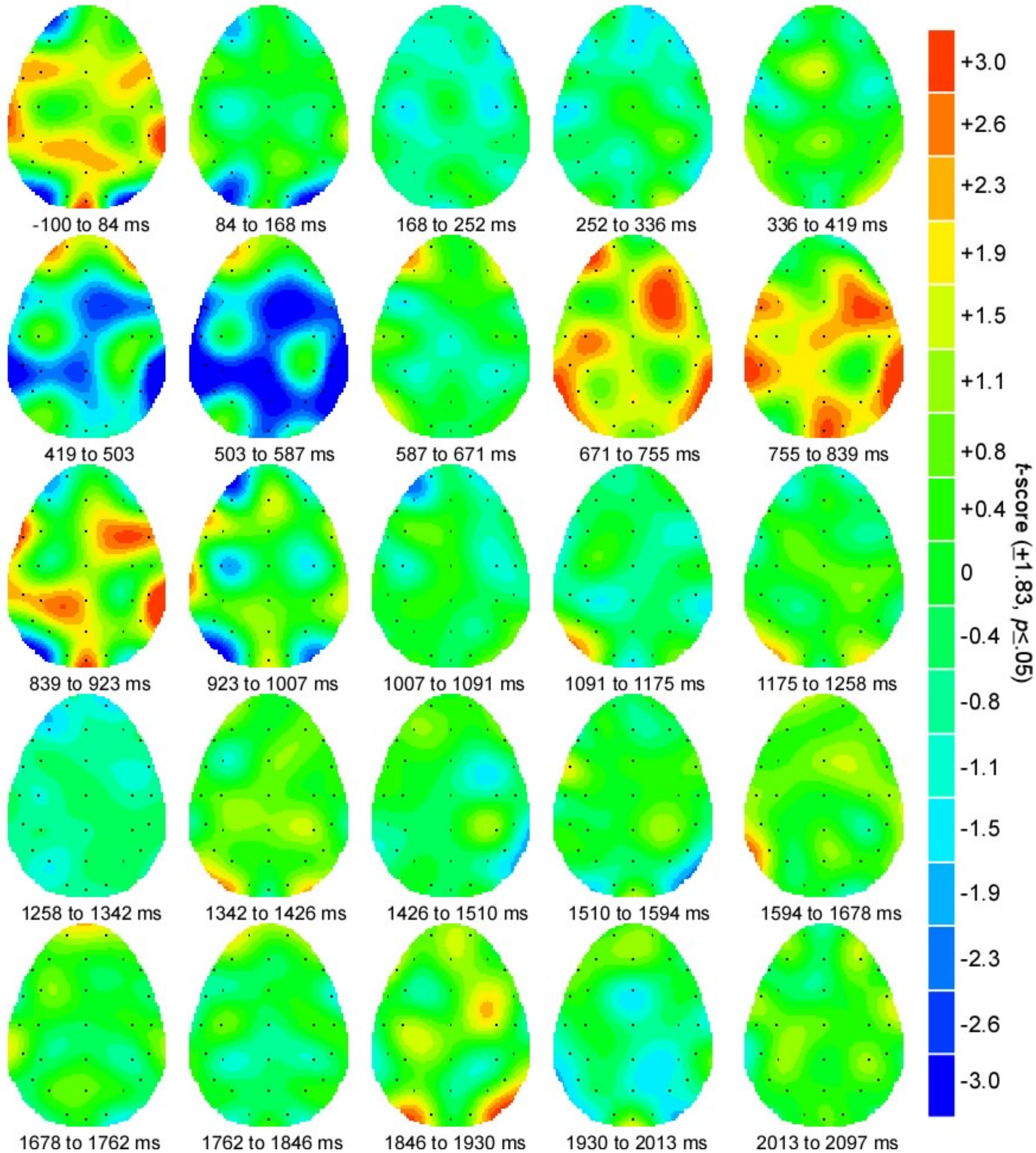

Figure 16.

t-score map showing the differences between CP-2 and SLI-2 while listening to the syntactically incorrect sentences. A *t*-score of ±1.83 is significant at the 0.05 level.

to a small area of the left frontal region. By 671 ms the differences spread over the left and right frontal, right frontal-temporal, posterior-temporal, and left and right occipital regions. At approximately 755 ms the differences spread further over the vertex, central-occipital, parietal, frontal-temporal, right frontal, and temporal regions. The differences begin to subside at approximately 839 ms and are seen over the left frontal, frontal-temporal, right anterior-central, posterior-temporal, left posterior-central, and central-occipital regions. At approximately 922 ms the differences have continued to subside and are limited to the left and right occipital, left frontal, and left temporal- occipital regions. By 1006 ms the differences are seen over the left frontal region and between 1090 and 1258 ms the differences are limited to the left occipital region. Between 1342 and 1426 ms the differences are seen over the left and right occipital regions. At approximately 1594 ms significant differences are seen over the left temporal-occipital region. Between 1678 and 1761 ms differences are seen over the central-frontal region and between 1845 and 1929 ms differences are seen over the left and right occipital and right anterior-central region.

N400 and P600 comparison. CP-2 and SLI-2 exhibit differences in the N400 and P600 while listening to the two conditions. During the syntactically correct sentences, CP-2 does not present with an N400 (Figure 9). On the other hand, SLI-2 does present with an N400 over the frontal-central region between 419 and 671 ms (Figure 12). Both participants also present with a P600 during the syntactically correct sentences. CP-2 presents with a delayed P600 between 839 and 1007 ms over the central-parietal region (Figure 9). The P600 seen in SLI-2 begins earlier at approximately 671 ms and is seen until approximately 839 ms (Figure 12). The P600 seen in SLI-2 is of greater amplitude than the P600 seen in CP-2.

During the syntactically incorrect sentences, CP-2 and SLI-2 again present with differences between the N400 and P600. In CP-2 an N400 is not present during the syntactically incorrect condition (Figure 10). On the other hand, an N400 is seen in SLI-2 at approximately 419 ms over the central-frontal regions. The N400 peaks at approximately 587 ms and dissipates by 755 ms (Figure 13). A P600 is also seen in both participants. In CP-2 a P600 is observed at approximately 587 ms over the central-parietal regions. The P600 continues until approximately 671 (Figure 10). In SLI-2 the P600 is seen between 671 and 839 ms over the central-parietal regions.

Discussion

This study examined the brain electrical activity of two children with SLI and two typically developing age-matched peers while listening to sentences with syntactic errors versus syntactically correct sentences. The results illustrate how children with SLI process language differently than age-matched peers. Specifically, the N400 and P600 were analyzed in each condition across participants and the results were compared to determine differences between the two groups.

CP-1 and SLI-1 Scalp Distribution Comparison

The N400 and P600 results of CP-1 during both conditions are congruent with that seen in previous studies (Atchley et al., 2005; Friederici & Hahne, 2001; Hahne et al., 2004). During the syntactically correct sentences, CP-1 did not demonstrate an N400 or P600 (Figure 1). However, during the syntactically incorrect sentences, CP-1 presented with a P600 between 670 and 755 ms over the left and right parietal region (Figure 2). Again, this is consistent with previous studies. Hahne et al. (2004) found a posterior positivity after 600 ms in a group of 10-year-olds and Atchley et al. (2005) also found that children demonstrated a P600 over parietal and centro-parietal sites between 674 and 724 ms while listening to syntactic violations. The P600 indicates that CP-1 recognized the presence of the syntactic errors within the sentences.

The results of SLI-1 during the syntactically correct condition are contrary to that seen in studies of children with typically developing language. SLI-1 presented with an N400 during both the syntactically correct (Figure 3) and incorrect (Figure 4) condition. However, SLI-1 did not present with a P600 during either condition. An N400 is typically present with semantic violations (Atchley et al., 2006; Freiderici & Hahne, 2001; Holcomb, Coffey, & Neville, 1992); whereas a P600 is present with syntactic violations (Atchley et al., 2006; Freiderici & Hahne, 2001). SLI-1 presented with an N400 instead of a P600 during both conditions, which indicates that SLI-1 required additional cognitive processing in order to comprehend both types of sentences. However, the presence of an N400 versus a P600 indicates that SLI-1 was processing the semantic structure of the sentences instead of the syntactic structure. SLI-1 presented with word finding difficulties as well as syntactic errors on the CELF-4. The presence of the N400 but not a P600 may suggest that the semantic and lexical difficulties in SLI-1 dominate the cognitive processing of SLI-1 and that syntactic processing does not occur.

Also, the N400 seen in SLI-1 during the syntactically incorrect sentences was similar in both location, amplitude, and latency as seen during the control condition. This similarity across the two conditions is similar to a finding of Sabisch et al. (2006) that a group of 8-year-old SLI participants presented with a large N400 amplitude during both semantically correct and semantically incorrect sentences. In this study, the researchers hypothesized that because children with SLI have a weaker representation of verbs that they may also have increased difficulty with lexical and verbal integration into sentences, thus creating an N400 amplitude during both sets of stimuli. The presence of the N400 during both sets of sentences reflects the increase in neuronal activity while processing the semantic structure of both correct and incorrect syntactic sentences.

CP-2 and SLI-2 Scalp Distribution Comparison

CP-2 presented with a delayed P600 while listening to the syntactically correct sentences (Figure 9). This finding is congruent with Hahne et al. (2004) who found that 7-year-old children presented with a positive going waveform during both syntactically correct and incorrect sentences. They hypothesized that this waveform may indicate difficulty with syntactic processing, even with syntactically correct sentences at this young age. Likewise, in the present study, the presence of the P600 indicates that CP-2 demonstrated syntactic processing difficulties, even on the correct sentences. During the syntactically incorrect sentences, CP-2 again presented with a P600 (Figure 10). This is congruent with the findings of Hahne et al. that a positivity was seen in syntactically correct and incorrect sentences. Also a reversal of polarities is seen across the two conditions. During the syntactically correct sentences, there is a negativity between 587 and 671 ms; whereas during the syntactically incorrect sentences a positivity is seen during this same time. Between 839 and 1007 ms a positivity is seen during the syntactically correct sentences whereas in the incorrect sentences a negativity is seen. This reversal of polarities cannot be accounted for and may be due to the language structural difficulties encountered in this age group. Further research needs to be conducted in order to determine the source of the polarity reversal.

During the syntactically correct sentences, SLI-2 presented with both an N400 and P600 (Figure 12). The N400 indicates that SLI-2 required additional cognitive processing in order to understand the semantic meaning of the sentence stimuli (Atchley et al., 2006; Freiderici & Hahne, 2001; Holcomb, Coffey, & Neville, 1992). The presence of the P600 is again congruent with the findings of Hahne et al. (2004) that young children present with a positive going waveform during syntactically correct sentences due to the complexity of the syntactic structure of the sentences.

During the syntactically incorrect sentences, SLI-2 presented with an N400 and P600 (Figure 13) that are both of similar latency, amplitude, and location of the N400 and P600 seen during the syntactically correct sentences for this participant. Again, this is similar to the observation by Sabisch et al. (2006) that the participants with SLI had an increased N400 during both the semantically correct and incorrect sentences. The finding that SLI-2 presents with a similar N400 across both conditions indicates that both the correct and incorrect stimuli place high semantic processing demands on SLI-2, whereas CP-2 did not present with an N400 which indicates that the stimuli did not influence CP-2's semantic processing. Also, the similarity in the P600 across conditions indicates that both the syntactically correct and syntactically incorrect sentences create high neuronal processing demands in SLI-2. However, considering a P600 was also seen in both conditions in CP-2, this indicates that the P600 is a reflection of the language structural difficulties and developmental differences due to age versus the language impairment of SLI-2 (Hahne et al., 2004).

Comparison between SLI-1 and SLI-2

Both SLI-1 and SLI-2 presented with an N400 during the syntactically correct and incorrect sentences. These findings are unexpected in that the N400 is typically seen with semantic errors and is not associated with syntactic errors (Atchley et al., 2006; Freiderici & Hahne, 2001; Holcomb, Coffey, & Neville, 1992). The presence of the N400 may reflect the increased lexical processing that occurs in children with SLI. Although SLI-1 did not present with a P600, SLI-2 demonstrated a P600 in both the syntactically correct and incorrect conditions. However, this processing may not be a result of the SLI but a result of the younger age of SLI-2. CP-2 also presented with a P600 in both conditions and previous studies have demonstrated that 7-year-old children have an increased positivity while listening to both syntactically correct and incorrect sentences (Hahne et al., 2004).

Conclusions

The results of this study indicate that children with SLI present with an N400 while listening to both syntactically correct and incorrect sentences. This suggests that these participants have greater lexical and semantic processing demands while listening to sentence stimuli. The finding that an N400 was present in both SLI participants across the two conditions reflects the high semantic processing demands placed on children with SLI. It may be that the semantic processing demands decreased the syntactic processing demands in the participants with SLI. The study also suggests that 7-year-olds have greater syntactic processing demands as seen by the presence of the P600 in both the correct and incorrect conditions in CP-2 and SLI-2. This was likely due to the complexity of the sentence stimuli which included irregular past tense and irregular plural forms. Also, the study demonstrates that the 9-year-old control participant presents with a P600 while listening to the syntactically incorrect sentences, which indicates that CP-1 was able to accurately detect the syntactic errors within the stimuli.

Directions for Future Research

The findings of this present study indicate a need for future research in order to better understand the role of the P600 and N400 in children with SLI. The results of the study indicate that children with SLI present with an N400 while listening to both syntactically correct and incorrect sentences. In SLI-1 an N400 was seen across both conditions; whereas in SLI-2 both an N400 and a P600 were seen across both conditions. It is difficult to determine whether the presence of the P600 across both conditions in SLI-2 was a reflection of the participant's language impairment or due to age. Further research with older SLI participants needs to be conducted in order to determine the semantic and syntactic cognitive processing of children with SLI while listening to syntactically correct and incorrect sentences.

Also, further research needs to be conducted regarding the cognitive development of syntactic structures within certain age groups. A list of progressively more complex grammatical structures could be compiled and presented to children of certain ages to see when the cognitive processing for certain syntactic structures fully matures. It would be especially interesting to study if children of younger ages present with a P600 while listening to both syntactically correct and incorrect stimuli as seen in this study and the study performed by Hahne et al. (2004) only if the syntactic structure is complex or also during age-appropriate syntactic structures. It may be that younger children present with a positivity even with early developing syntactic structures or that they only present with a positivity during later developing syntactic structures. This type of study would help researchers to better understand the cognitive development of syntactic structures.

Much can be learned regarding the language processing of typically developing children and children with SLI through the use of long latency ERPs. Electrophysiological measures make it possible to study the neurophysiological activity that occurs during language development and in children with SLI. This will provide useful information to help researchers better understand the neurological basis for language impairments, which will help researchers and clinicians to develop more appropriate therapy tools for children with language impairments.

References

Atchley, R. A., Rice, M. L., Betz, S. K., Kwasnyu, K. M., Sereno, J. A., & Jongman, A. (2006). A comparison of semantic and syntactic event related potentials generated by children and adults. *Brain and Language, 99,* 236–246.

Attias, J., & Pratt, H. (1992). Auditory event related potentials during lexical categorization in the oddball paradigm. *Brain and Language, 43,* 230–239.

Bentin, S., Kutas, M., & Hillyard, S. A. (1993). Electrophysiological evidence for task effects on semantic priming in auditory word processing. *Psychophysiology, 30,* 161–169.

Besson, M., & Faita, F. (1995). An event-related potential (ERP) study of musical expectancy: Comparison of musicians with nonmusicians. *Journal of Experimental Psychology: Human Perception and Performance*, *21,* 1278–1296.

Besson, M., Faita, F., Czternasty, C., & Kutas, M. (1997). What's in a pause: Event-related potential analysis of temporal disruptions in written and spoken sentences. *Biological Psychology, 46,* 3–23.

Besson, M., Faita, F., & Requin, J. (1994). Brain waves associated with musical incongruities differ for musicians and non-musicians. *Neuroscience Letters, 168,* 101–105.

Bishop, D. V. M., & McArthur, G. M. (2005). Individual differences in auditory processing in specific language impairment: A follow-up study using event-related potentials and behavioural thresholds. *Cortex*, *41*, 327–341.

Canseco-Gonzalez, E. (2000). Using the recording of event-related brain potentials in the study of sentence processing. In Y. Grodzinsky, L. P. Shapiro, & D. Swinney

(Eds.), *Foundations of neuropsychology: A series of textbooks, monographs, and treatises* (pp. 229–266). San Diego: Academic Press.

Coulson, S., King, J. W., & Kutas, M. (1998). Expect the unexpected: Event-related brain response to morphosyntactic violations. *Language and Cognitive Processes, 13,* 21–58.

Featherston, S., Gross, M., Münte, T., & Clahsen, H. (2000). Brain potentials in the processing of complex sentences: An ERP study of control and raising constructions. *Journal of Psycholinguistic Research*, *29*, 141–154.

Friederici, A. D. (1995). The time course of syntactic activation during language processing: A model based on neuropsychological and neurophysiological data. *Brain and Language*, *50*, 259–281.

Friederici, A. D. (1997). Neurophysiological aspects of language processing. *Clinical Neuroscience, 4,* 64–72.

Friederici, A. D., & Hahne, A. (2001). Development patterns of brain activity reflecting semantic and syntactic processes. In J. Weissenborn & B. Houle (Eds.), *Approaches to bootstrapping: Phonological, lexical, syntactic, and neurophysiological aspects of early language acquisition* (2nd ed.; pp. 231–246). Philadelphia: John Benjamins Publishing Company.

Frisch, S., Kotz, S. A., von Cramon, D. Y, & Friederici, A. D. (2003). Why the P600 is not just a P300: The role of the basal ganglia. *Clinical Neurophysiology*, *114*, 336–340.

Fujihara, N., Nageishi, Y., Koyama, S., & Nakajima, Y. (1998). Electrophysiological evidence for the typicality effect of human cognitive categorization. *International Journal of Psychophysiology*, *29*, 65–75.

Gunter, T. C., Stowe, L. A., & Mulder, G. (1997). When syntax meets semantics. *Psychophysiology, 34,* 660–676.

Hagoort, P., & Brown, C. (2000). ERP effects of listening to speech compared to reading: The P600/SPS to syntactic violations in spoken sentences and rapid serial visual presentation. *Neuropsychologia*, *30*, 1531–1549.

Hahne, A., Eckstein, K., & Friederici, A. D. (2004). Brain signatures of syntactic and semantic processes during children's language development. *Journal of Cognitive Neuroscience*, *16*, 1302–1318.

Hahne, A., & Friederici, A. D. (1999). Rule-application during language comprehension in the adult and the child. In A. D. Friederici & R. Menzel (Eds.), *Learning: Rule extraction and representation* (pp. 71–88). Berlin: Walter de Gruyter.

Hanks, W. D., & Rose, K. J. (1993). Middle ear resonance and acoustic immittance measures in children. *Journal of Speech and Hearing Research*, *36*, 218–222.

Hillyard, S. A., & Kutas, M. (1983). Electrophysiology of cognitive processing. *Annual Review of Psychology, 34,* 33–61.

Holcomb, P. J., Coffey, S. A., & Neville, H. J. (1992). Visual and auditory sentence processing: A developmental analysis using event-related brain potentials. *Developmental Neuropsychology, 8,* 203–241.

Jasper, H. H. (1958). The 10-20 electrode system of the International Federation. *Electroencephalography and Clinical Neurophysiology, 10,* 371–375.

Johnson, Jr., R. (1989). Auditory and visual P300s in temporal lobectomy patients: Evidence for modality dependent generators. *Psychophysiology, 26,* 651–667.

Kolk, H. H. J., Chwilla, D. J., van Herten, M., & Oor, P. J. W. (2003). Structure and limited capacity in verbal working memory: A study with event-related potentials. *Brain and Language, 85,* 1–36.

Kutas, M., & Hillyard, S. A. (1980a). Event-related brain potentials to semantically inappropriate and surprisingly large words. *Biological Psychology, 11,* 99–116.

Kutas, M., & Hillyard, S. A. (1980b). Reading between the lines: Event-related brain potentials during natural sentence processing. *Brain and Language, 11,* 354–373.

Kutas, M., & Hillyard, S. A. (1980c). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science, 207,* 203–205.

Kutas, M., & Hillyard, S. A. (1983). Event-related brain potentials to grammatical errors and semantic anomalies. *Memory and Cognition, 11,* 539–550.

McArthur, G. M., & Bishop, D. V. M. (2004). Which people with specific language impairment have auditory processing deficits? *Cognitive Neuropsychology, 21,* 79–94.

McArthur, G. M., & Bishop, D. V. M. (2005). Speech and non-speech processing in people with specific language impairment: A behavioural and electropysiological study. *Brain and Language, 94,* 260–273.

McPherson, D. L., & Ballachanda, B. (2000). Middle and long latency auditory evoked potentials. In R. Roeser, M. Valente, & H. Hosford-Dunn (Eds.), *Audiology: Diagnosis* (pp. 471–501). New York: Thieme Medical Publishers.

Mitchell, P. F., Andrews, S., & Ward, P. B. (1993). An event-related potential study of semantic congruity and repetition in a sentence-reading task: Effects of context change. *Psychophysiology, 30,* 496–509.

Münte, T. F., Heinze, H. J., Matzke, M., Wieringa, B. M., & Johannes, S. (1998). Brain potentials and syntactic violations revisted: No evidence for specificity of the syntactic positive shift. *Neuropsychologia, 36,* 217–226.

Neville, H. J., Coffey, S. A., Holcomb, P. J., & Tallal, P. (1993). The neurobiology of sensory and language processing in language-impaired children. *Journal of Cognitive Neuroscience, 5,* 235–253.

Northern, J. L., & Downs, M. P. (1991). *Hearing in Children* (4th ed.). Baltimore: Williams & Wilkins.

O'Donnnell, B. F., Shenton M. E., McCarley, R. W., Faux, S. F., Smith, R. S., Salisbury, D. F., et al. (1993). The auditory N2 component in schizophrenia: Relationship to MRI temporal lobe gray matter and to other ERP abnormalities. *Biological Psychiatry, 34,* 26–40.

Ors, M., Lindgren, M., Blennow, G., Nettelbladt, U., Sahlen, B., & Rosen, I. (2002). Auditory event-related brain potentials in children with specific language impairmen. *European Journal of Paediatric Neurology, 6,* 47–62.

Osterhout, L., & Holcomb, P. J. (1992). Event-related brain potentials elicited by syntactic anomaly. *Journal of Memory and Language, 31,* 785–806.

Osterhout, L., & Holcomb, P. J. (1993). Event-related potentials and syntactic anomaly: Evidence of anomaly detection during the perception of continuous speech. *Language and Cognitive Processes, 8,* 413–437.

Osterhout, L., & Mobley, L. A. (1995). Event-related brain potentials elicited by failure to agree. *Journal of Memory and Language, 34*, 739–773.

Pang, E. W., & Taylor, M. J. (2000). Tracking the development of the N1 from age 3 to adulthood: An examination of speech and non-speech stimuli. *Clinical Neurophysiology, 111,* 388–397.

Picton, T. W., & Stuss, D. T. (1984). Event-related potentials in the study of speech and language: A critical review. In D. Caplan, A. R. Lecours, & A. Smith (Eds.), *Biological perspectives on language* (pp. 303–360). Cambridge, MA: MIT Press.

Polich, J. (1985). Semantic categorization and event-related potentials. *Brain and Language, 26,* 304–321.

Ponton, C. W., Eggermont, J. J., Kwong, B., & Don, M. (2000). Maturation of human central auditory system activity: Evidence from multi-channel evoked potentials. *Clinical Neurophysiology, 111*, 220–236.

Radeau, M., Besson, M., Fonteneau, E., & Castro, S. L. (1998). Semantic, repetition and rime priming between spoken words: Behavioral and electrophysiological evidence. *Biological Psychology, 48*, 183–204.

Riter, W., Simson, R., & Vaughn, H. G. (1983). Event-related potential correlates of two stages of information processing in physical and semantic discrimination tasks. *Psychophysiology, 20,* 943–961.

Ruchkin, D. S., Johnson, Jr., R., Canoune, H. L., Ritter, W., & Hammer, M. (1990). Multiple sources of P3b associated with different types of information. *Psychophysiology, 27,* 157–176.

Sabisch, B., Hahne, A., Glass, E., von Suchodoletz, W., & Friederici, A. D. (2006). Lexical-semantic processes in children with specific language impairment. *Developmental Neuroscience, 17,* 1511–1514.

Stevens, C., Sanders, L., & Neville, H. (2006). Neurophysiological evidence for selective auditory attention deficits in children with specific language impairment. *Brain Research, 1111,* 143–152.

Stuss, D. T., Picton, T. W., & Cerri, A. M. (1988). Electrophysiological manifestations of typicality judgment. *Brain and Language, 33,* 260–272**.**

Thompson, N. C., Cranford, J. L., & Hoyer, E. (1999). Brief-tone discrimination by children. *Journal of Speech, Language, and Hearing Research, 42,* 1061–1068.

van Herten, M., Kolk, H. H., & Chwilla, D. J. (2005). An ERP study of P600 effects elicited by semantic anomalies. *Cognitive Brain Research, 22,* 241–255.

Appendix A

Parental Informed Consent for Child to Act as a Human Research Subject

David L. McPherson, Ph.D.
Department of Audiology and Speech Language Pathology
Brigham Young University
(801) 422-6458

Name of Participant:____________________________ Date of Birth:__________________

Purpose of Study

This research is designed to examine the processing of language by the brain in children with specific language impairment using electrophysiological measures known as event-related potentials. Participation in this study will help teachers and scientists better understand the brain's ability to process language and will be useful to professionals who are responsible for diagnosing and treating language disorders.

Procedures

Your child has been asked to participate in a research study conducted by Dr. David L. McPherson and / or such assistants as may be selected by him.

The study will be conducted at your child's school and in room 111 of the John Taylor Building on the campus of Brigham Young University. The testing at the school will consist of two sessions. One session will test your child's IQ and the second session will test your child's language. Each session at the school will take approximately 1 hour. Testing at Brigham Young University, including orientation and testing, requires one 2-3 hour session. Your child may ask for a break at any time during testing. Basic hearing tests will be administered during the first half-hour of the session.

Surface electrodes (metal discs about the size of a dime) will be used to record electrical activity of your child's brain. These discs will be applied to the surface of the skin with a cream or gel and are easily removed with water. Blunt needles will be used as a part of this study to help apply the electrode gel. They will *never* be used to puncture the skin. Your child may feel uncomfortable using the cap and having gel on his or her face and head. If your child is uncomfortable, he or she will be assured that they will only have the electrodes on for a short period of time. If your child has a negative reaction to the electrodes, the electrodes and gel will be removed. The gel is easily removed with warm, but not hot water. Discomfort from the electrode cap immediately dissipates upon removal of the cap. This is similar to a "sports cap" that adds slight pressure to the scalp.

Language processing will be measured using an electrode cap, which simply measures the electrical activity of my child's brain and *does not* emit electricity, and no electrical impulses will be applied to the brain. These measurements of the electrical activity are similar to what is known as an "EEG" or brain wave test. These measurements are of normal, continuous electrical activity in the brain.

Your child will wear the electrode cap while he/she listens to 240 sentences, during which time the electrical activity of his/her brain will be recorded on a computer. Your child will be asked to give responses during the hearing test, standardized language test, and the electrophysiological recording.

The procedures used to record the electrophysiological responses of the brain are standardized and have been used without incident in many previous investigations. The combination of sentences presented is experimental, but the recording procedure is not.

Risks

There are very few potential risks from this procedure, and these risks are minimal. The risks of this study include possible allergic reactions to the conductive gel or to the skin prepping gel. Allergic reactions to the gel are extremely rare. There is also a possibility for an allergic reaction to the electrodes. If any of these reactions occur, a rash would appear. Treatment would include removing the electrodes and gel and exposing the site to air, resulting in alleviation of the irritation. If there is an allergic reaction, testing procedures would be discontinued. Another unlikely risk is a small abrasion on the scalp when the blunt needle is used to place electrode gel. Treatment would also include removing the electrode and gel, exposing the site to air and testing procedures would be discontinued.

There are no other known risks with this procedure. It is understood that participation in this study is voluntary and the participant may withdraw during any part of the testing without any negative consequences now or in the future.

Benefits

Benefits from participating in this study include an assessment of hearing, language and IQ. I will be notified if any clinical deficits are found in these areas. I also understand that there may be no direct benefit to me or my child. However, the information obtained will help to further the understanding of language processing, which will be beneficial to professionals involved in treating speech and hearing disorders.

Confidentiality

Participation in this study is voluntary and your child has the right to refuse to participate or withdraw at any time. All information obtained from testing is strictly confidential and is protected under the laws governing privacy. No information specifically pertaining to your child, other than reporting of test results without identifying information may be released without your signature. All identifying references will be removed and replaced by control numbers which will identify any disclosed or published data. Data collected in this study will be stored in a secured area accessible only to personnel associated with the study.

Other Considerations

There are no charges incurred by you or your child for participation in this study. There is no treatment or intervention involved in this study.

The procedures listed above have been explained to me and my child by: ____________________ in a satisfactory manner and any questions relating to such risks have been answered. If there are any further questions or concerns regarding this study, I may ask any of the investigators or contact David McPherson, Ph.D., Audiology and Speech-Language Pathology, 129 Taylor Building, Provo, Utah 84602; phone (801) 422-6458; email: david_mcpherson@byu.edu.

If there are any questions regarding my rights as a participant in this research project, we may contact Renea Beckstrand, PhD, Chair of Institutional Review Board, 422 SWKT, Brigham Young University, Provo, Utah 84602; phone (801) 422-3873; email: renea_beckstrand@byu.edu.

I give permission for my child to participate in the study explained above.

______________________________ ______________

Signature of Parent/Guardian Date

______________________________ ______________

Signature of Witness Date

Appendix B

Child Informed Consent to Act as a Human Research Subject

David L. McPherson, Ph.D.
Department of Audiology and Speech Language Pathology
Brigham Young University
(801) 422-6458

This study is to look at how the brain processes words that we hear. Being part of this study will help teachers and scientists better understand how the brain reacts to speech. What we learn will be useful to people who help children with speech problems. My parents have agreed that I can help with this research.

I will be pulled out of class twice for testing. During this time, if I get tired I can ask for a break from testing. I will visit BYU one time. During my visit, my hearing will be checked. Also, I will wear a silly hat that has connections attached to the computer. The hat looks like a shower cap with holes. In the holes, the clinician will put some sticky, clear gel. When the gel is put on my head, it may tickle for a moment. It may also feel gooey. If I don't like the feel of the gel and cap, I can ask the clinician to take it off at any time. I will hear some sentences through the ear probes. I will press a button to tell the researcher if the sentence I heard was "good" or "bad." If I get tired, I can ask for a rest.

I understand that I do not have to do any part of this study. If I change my mind, I can quit the study at any time.

I would like to be part of this study.

______________________________ _______________

Signature of Participant Date

______________________________ _______________

Signature of Witness Date

Appendix C

Stimulus Sentences

A. Third Person Forms

Houghton Mifflin English: Teacher's Edition, *Level 2.* (1995). Boston. Houghton Mifflin Company. (p. 95–187)

Correct	*Incorrect*
1. The mother smiles.	1. The mother smile.
2. A boy looks.	2. A boy look.
3. A baby laughs.	3. A baby laugh.
4. The wind blows.	4. The wind blow.
5. The boats sail.	5. The boats sails.
6. The dog digs.	6. The dog dig.
7. The whale swims.	7. The whale swim.
8. Two children run.	8. Two children runs.
9. One girl swings.	9. One girl swing.
10. They run.	10. They runs.
11. The kite flies.	11. The kite fly.
12. The ballerina dances.	12. The ballerina dance.
13. They sing.	13. They sings.
14. The teacher reads.	14. The teacher read.
15. The girls cheer.	15. The girls cheers.
16. The rollercoaster shakes.	16. The rollercoaster shake.
17. The class sits.	17. The class sit.
18. The bus driver waits.	18. The bus driver wait.
19. My sister plays.	19. My sister play.
20. The nurse helps.	20. The nurse help.
21. The author writes.	21. The author write.
22. I wonder what he thinks.	22. I wonder what he think.
23. Trees and flowers grow.	23. Trees and flowers grows.
24. The truck driver waves.	24. The truck driver wave.
25. The people leave.	25. The people leaves.
26. The bread bakes.	26. The bread bake.
27. The duck quacks.	27. The duck quack.
28. The washing machine washes.	28. The washing machine wash.
29. Sally likes to walk.	29. Sally like to walk.
30. The figure skater ice skates.	30. The figure skater ice skate.
31. The lion escapes.	31. The lion escape.
32. The ranger hikes.	32. The ranger hike.
33. The athlete drinks.	33. The athlete drink.
34. Charlie paints.	34. Charlie paint.
35. Sally cries.	35. Sally cry.

B. Past Tense Verb Forms: *-ed* and irregular

Houghton Mifflin English: Teacher's Edition, Level 2. (1995). Boston. Houghton Mifflin Company. (p. 95–187)

Correct

1. The girl laughed.
2. The train moved.
3. My friend smiled.
4. The balloon popped.
5. The horse kicked.
6. The plane flew.
7. The doorbell rang.
8. Uncle Ed ran.
9. Santa Claus came.
10. The guests left.
11. The librarian whispered.
12. We started.
13. The runner rested.
14. The patient coughed.
15. The little boy fell.
16. The mailman drove.
17. Andy threw.
18. Jeff swung.
19. The tiger slept.
20. We watched.
21. The star twinkled.
22. The worm crawled.
23. The ball bounced.
24. The student learned.
25. The carousel tuned.
26. The hippo splashed.
27. The horn honked.
28. The kitten meowed.
29. The water boiled.
30. The woman sang.
31. The artist drew.
32. The dolphin swam.
33. The ship sunk.
34. The cowboy rode.
35. The team lost.
36. The contestant won.
37. The family ate.
38. The strangers met.
39. The puppy grew.

Incorrect

1. The girl laugh.
2. The train move.
3. My friend smile.
4. The balloon pop.
5. The horse kick.
6. The plane flied.
7. The doorbell ringed.
8. Uncle Ed runned.
9. Santa Claus comed.
10. The guests leaved.
11. The librarian whisper.
12. We starts.
13. The runner rest.
14. The patient cough.
15. The little boy falled.
16. The mailman drived.
17. Andy throwed.
18. Jeff swinged.
19. The tiger sleeped.
20. We watches.
21. The star twinkle.
22. The word crawl.
23. The ball bounce.
24. The student learn.
25. The carousel turn.
26. The hippo splash.
27. The horn honk.
28. The kitten meow.
29. The water boil.
30. The woman singed.
31. The artist drawed.
32. The dolphin swimed.
33. The ship sinked.
34. The cowboy rided.
35. The team losed.
36. The contestant wined
37. The family eated.
38. The strangers meted.
39. The puppy growed.

C. Regular and Irregular Plural Nouns

Houghton Mifflin English: Teacher's Edition, Level 3. (1990). Boston. Houghton Mifflin Company. (pp. 26, 74–89)

Correct

1. The sleeves covered both hands.
2. The coat had two big pockets.
3. She found a key in one pocket.
4. The key will open many doors.
5. Dennis saw three blue belts.
6. Kerry wore a striped skirt.
7. Did you see this red shirt?
8. How did Donna look in those gloves?
9. One child hopped on both feet.
10. A cat chased three mice.
11. The bus passed some geese.
12. A baby was playing with a toy mouse.
13. Fe fell and hit his two front teeth.
14. Grandma picked corn.
15. My father drives a truck.
16. His truck has sixteen wheels.
17. Dad drives the truck to a dock.
18. The he drove to a store.
19. Uncle Henry is a cook.
20. He works at a school.
21. Mr. Lee ate three cups.
22. My cousins own a huge pool.
23. My sister is having a party.
24. Two boys are swimming in the water.
25. Many foods come from plants.
26. A king lived in a huge castle.
27. The queen showed the guests each room.
28. Food was served on long tables.
29. The children played in a box.
30. Some horses waited by a gate.
31. The tree had many branches.
32. Some people build houses.
33. Farmers grow fruit and vegetables.
34. Drivers take packages to cities.
35. Teachers show children how to read books.
36. Doctors and nurses help sick people.
37. Laura read some stories.
38. Some animals like to eat berries.
39. Baby dogs are called puppies.

Incorrect

1. The sleeves covered both hand.
2. The coat had two big pocket.
3. She found keys in one pockets.
4. The key will open many door.
5. Dennis say three blue belt.
6. Kerry wore a striped skirts.
7. Did you see this red shirts?
8. How did Donna look in those glove?
9. One child hopped on both feets.
10. A cat chased three mouses.
11. The bus passes some gooses.
12. A baby was playing with a toy mouses.
13. He fell and hit his two front tooths.
14. Grandma picked corns.
15. My father drives a trucks.
16. His truck has sixteen wheel.
17. Dad drives the truck to a docks.
18. Then he drove to a stores.
19. Uncle Henry is a cooks.
20. He works at a schools.
21. Mr. Lee ate three cup.
22. My cousins own a huge pools.
23. My sister is having a parties.
24. Two boys are swimming in the waters.
25. Many foods come from plant.
26. A king lived in a huge castles.
27. The king showed the guests each rooms.
28. Food was served on long table.
29. The children played in a boxes.
30. Some horses waited by a gates.
31. The tree had many branch.
32. Some people build house.
33. Farmers grow fruit and vegetable.
34. Drivers take packages to city.
35. Teachers show children how to read book.
36. Doctors and nurses help sick persons.
37. Laura read some story.
38. Some animals like to eat berry.
39. Baby dogs are called puppy.