

DEVELOPMENT OF LANGUAGE PROCESSING IN PRESCHOOLERS FROM LOWER  
SOCIOECONOMIC STATUS BACKGROUNDS: AN EVENT-RELATED POTENTIALS  
STUDY

By

Claire Ann Meconi

A THESIS

Submitted to  
Michigan State University  
in partial fulfillment of the requirements  
for the degree of

Communicative Sciences and Disorders – Master of Arts

2016

## ABSTRACT

### DEVELOPMENT OF LANGUAGE PROCESSING IN PRESCHOOLERS FROM LOWER SOCIOECONOMIC STATUS BACKGROUNDS: AN EVENT-RELATED POTENTIALS STUDY

By

Claire Ann Meconi

A rich body of literature has documented reduced language abilities in children from lower socioeconomic status (SES) environments compared to their higher SES peers. The current study evaluates the development of neural processes underlying language in children from lower SES backgrounds. Twenty-five preschoolers from lower SES backgrounds participated in this study. Behavioral performance and event-related potentials (ERPs) were used to evaluate changes in language skills and neural processes for language over a one year time period, from age four to age five. The children watched a claymation cartoon of Pingu the penguin. The cartoons contained semantic and syntactic canonical and violation sentences. For semantic conditions, results revealed a significant increase in N400 mean amplitudes from age four to five. These findings suggest that neural processes for semantic violations are still developing in young children from lower SES backgrounds. For standard English and Jabberwocky conditions, syntactic violations elicited N400 responses at age four with a trend toward smaller N400 amplitudes and a shift toward a positive response at age five. These results suggest that the children are not yet engaging typical neural systems for syntax even by age five. Comparison with previous findings suggest that these neural patterns in young children from lower SES households are delayed compared to peers from higher SES households. Together, the findings have implications for the importance of early education in supporting language development in young children from lower SES backgrounds.

Copyright by  
CLAIRE ANN MECONI  
2016

This master's thesis is dedicated to my family, including my mother and father, Julian, and my wonderful boyfriend Michael Clark.

## ACKNOWLEDGEMENTS

I would like to express my deepest appreciation to the many people who have provided support and encouragement throughout this process. This project would not have been possible without them. It is with immense gratitude that I acknowledge my supervisor, Dr. Amanda Hampton Wray, who provided endless support and expert guidance. She has taught me so much about this complex topic, dedicated so much of her time to reading my numerous revisions, and helped make sense of the confusion. Without her incredible patience and timely wisdom and counsel, this research would have been a frustrating and overwhelming pursuit. Additionally, thank you to my committee members, Dr. Eric Hunter and Dr. Fan Cao, who offered guidance and were more than generous with their expertise and precious time. Their excitement and willingness to provide feedback made the completion of this research an enjoyable experience.

Thank you to the Department of Communicative Sciences and Disorders at Michigan State University for awarding me a Thesis Completion Scholarship, and providing me with the financial means to complete this project. My appreciation also extends to the wonderful faculty in the Department, including Dr. Katie Strong and Mrs. Kristin Hicks, for their continuing advice and encouragement. And finally, thank you to my amazing boyfriend, parents, members of the Brain Systems for Language Lab, and numerous friends who have endured this long process with me, always offering support and love.

## TABLE OF CONTENTS

|                                                                                                    |     |
|----------------------------------------------------------------------------------------------------|-----|
| LIST OF FIGURES .....                                                                              | vii |
| CHAPTER 1: INTRODUCTION.....                                                                       | 1   |
| 1.1 Theories of Language Development .....                                                         | 1   |
| 1.2 The Development of Language .....                                                              | 5   |
| 1.3 The Effects of Environment on Language Development .....                                       | 9   |
| 1.4 The Neurobiology of Language Development .....                                                 | 13  |
| 1.5 The Current Study .....                                                                        | 16  |
| CHAPTER 2: METHOD.....                                                                             | 19  |
| 2.1 Participants .....                                                                             | 19  |
| 2.2 Behavioral Testing.....                                                                        | 20  |
| 2.3 ERP Language Stimuli .....                                                                     | 20  |
| 2.4 Procedure .....                                                                                | 22  |
| 2.5 Data Acquisition .....                                                                         | 22  |
| 2.6 EEG/ERP Data Analysis .....                                                                    | 23  |
| CHAPTER 3: RESULTS .....                                                                           | 25  |
| 3.1 Behavioral Data .....                                                                          | 25  |
| 3.1.1 Nonverbal IQ .....                                                                           | 25  |
| 3.1.2 Receptive Language Skills .....                                                              | 27  |
| 3.2 Semantics.....                                                                                 | 29  |
| 3.2.1 N400 .....                                                                                   | 29  |
| 3.2.2 P600 .....                                                                                   | 32  |
| 3.3 Syntax .....                                                                                   | 33  |
| 3.3.1 N400 .....                                                                                   | 33  |
| 3.3.2 P600 .....                                                                                   | 36  |
| 3.4 Jabberwocky .....                                                                              | 37  |
| 3.4.1 N400 .....                                                                                   | 37  |
| 3.4.2 P600 .....                                                                                   | 40  |
| CHAPTER 4: DISCUSSION .....                                                                        | 41  |
| 4.1 Changes in Behavior Over Time .....                                                            | 41  |
| 4.1.1 Nonverbal IQ .....                                                                           | 41  |
| 4.1.2 Receptive Language Skills .....                                                              | 45  |
| 4.2 Semantic Processing.....                                                                       | 47  |
| 4.3 Syntactic Processing.....                                                                      | 50  |
| 4.4 Jabberwocky Condition .....                                                                    | 52  |
| 4.5 Comparison Between Neural Responses in Children from Higher and Lower SES<br>Backgrounds ..... | 54  |
| CHAPTER 5: LIMITATIONS AND FUTURE DIRECTIONS .....                                                 | 56  |

|                             |    |
|-----------------------------|----|
| CHAPTER 6: CONCLUSION ..... | 58 |
| REFERENCES .....            | 59 |

## LIST OF FIGURES

|                                                                                                                                                                                                                                                     |    |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Figure 3.1.1: Scaled standard scores on the SB-5 Fluid Reasoning subtest revealed no significant difference between Year 1 and Year 2 .....                                                                                                         | 26 |
| Figure 3.1.2: Scaled standard scores on the SB-5 Quantitative Reasoning subtest revealed a significant difference between Year 1 and Year 2 .....                                                                                                   | 26 |
| Figure 3.1.3: Scaled standard scores on the SB-5 Working Memory subtest revealed no significant difference between Year 1 and Year 2 .....                                                                                                          | 26 |
| Figure 3.1.4: Scaled standard scores for Composite Nonverbal IQ revealed no significant difference between Year 1 and Year 2 .....                                                                                                                  | 26 |
| Figure 3.1.5: Scaled standard scores on the CELF-P2/4 Concepts and Following Directions subtest revealed a significant difference between Year 1 and Year 2 .....                                                                                   | 28 |
| Figure 3.1.6: Scaled standard scores on the CELF-P2/4 Sentence Structure subtest revealed no significant difference between Year 1 and Year 2 .....                                                                                                 | 28 |
| Figure 3.1.7: Scaled standard scores for Composite Receptive Language scores revealed a significant difference between Year 1 and Year 2 .....                                                                                                      | 28 |
| Figure 3.2.1: The ERP data for semantic canonical and violation sentences in Year 1; $n = 25$ . A small N400 response to semantic violations was visualized at central electrodes .....                                                             | 30 |
| Figure 3.2.2: The ERP data for semantic canonical and violation sentences in Year 2; $n = 25$ . Here, a change in neural response to semantic violations at central electrodes was visualized, illustrated by a larger N400 compared to Year 1..... | 31 |
| Figure 3.2.3: Interactions between semantic canonical and violation conditions across time demonstrated a trend toward significance, as illustrated here. $p = 0.099$ .....                                                                         | 32 |
| Figure 3.3.1: The ERP data for syntactic canonical and violation sentences in Year 1; $n = 25$ . Here, evidence of an N400 negativity to syntactic violations at central electrodes was visualized .....                                            | 34 |
| Figure 3.3.2: The ERP data for syntactic canonical and violation sentences in Year 2; $n = 25$ . Here, no evidence of a negativity to syntactic violations was visualized. A shift to less negative amplitudes is observed .....                    | 35 |
| Figure 3.3.3: Interactions between syntactic canonical and violation conditions demonstrated a trend toward significance across time, as illustrated here. $p = 0.082$ .....                                                                        | 36 |

|                                                                                                                                                                                                                                    |    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Figure 3.4.1: The ERP data for Jabberwocky canonical and violation sentences in Year 1; $n = 22$ . Here, evidence of an N400 negativity to Jabberwocky violations at central electrodes was visualized .....                       | 38 |
| Figure 3.4.2: The ERP data for Jabberwocky canonical and violation sentences in Year 2; $n = 22$ . Here, no evidence of a negativity to syntactic violations was visualized. A shift to less negative amplitudes is observed ..... | 39 |
| Figure 3.4.3: Interactions between Jabberwocky canonical and violation conditions laterally across time demonstrated a trend toward significance, as illustrated here. $p = 0.082$ .....                                           | 40 |

## **CHAPTER 1: INTRODUCTION**

### **1.1 Theories of Language Development**

Throughout history, the domains of both cognitive neuroscience and developmental psychology have investigated language development. The complicated interaction between the brain and the environment on the emergence of language has perplexed researchers in their attempt to understand how we acquire, process, and produce language. The capacity in which we learn and integrate language is based on the interplay between biology and the environment (Lennenberg, 1967). In the study of language development, it is known that most children master the basic structures of language by the age of four (Bates, Thal, Finlay, & Clancy, 2002). This complex cognitive accomplishment has been studied through observations of child language use across many decades. Despite the variance between children in their attainment of language, there is a natural developmental timetable for acquiring the skills of language. The study of the acquisition of language has been largely empirically based, thus resulting in the emergence of theories that attempt to quantify this phenomenon. Of the many philosophies that exist, derived from behavioral observations of language development, two main theories represent opposing ideologies about the nature of the mind. Jean Piaget (1896-1980) has been credited with laying the foundation for the constructivist theory, which emphasizes the role of the environment in language learning. The comprehensive works of Piagetian theory highlight the basic principles of constructivism. Piaget believed that learning was an active, ongoing, and constructive process; a child would learn by creating his or her own subjective representation of objective concepts in reaction to new experiences. Learners would internalize new information by linking new experiences to prior knowledge via association (Wadsworth, 1996). In addition, new information

is incorporated into the learners existing framework, resulting in changes in his or her schema as necessary (Wadsworth, 1996). In recent decades, constructivism has had a major impact on education and has emerged in the development of pedagogies. The theory and practice of education is largely impacted by Piagetian theory and has focused on manipulating the surroundings (i.e. basic curriculum, visual supports, tests, etc.) in order to facilitate knowledge growth. The primary message of constructivism is that active learning enables learners to build their own knowledge and make meaning of their environment.

Piaget was not alone in his ideologies. Many philosophers emphasized the environment in the analysis of human behavior. B. F. Skinner (born March 20, 1904) shared the idea that the environment played a key role in the learning process in his theory of behaviorism. Skinner believed that human behavior could be influenced by reactions to surrounding stimuli. Fundamental principles of the behaviorist approach include imitation and operant conditioning, in which behavioral responses to actions (reinforcement and punishment) promote or extinguish the antecedent behavior (Skinner, 1953). Behaviorism was founded on the idea that behavior change occurred when humans reacted to “operations” from his or her environment (Skinner, 1953). In Skinner’s theory, an environmental stimulus had the effect of increasing or decreasing the frequency of a specific behavior.

Although Piagetian theory of constructivism and the behaviorist views of B. F. Skinner are primarily used to rationalize global learning, their ideologies can be extended to language learning in children. Most constructivists study the relationships between language development and other concurrently developing cognitive and social skills (Clark, 2003). Piaget theorized the nature and importance of cognitive development on language acquisition (Wadsworth, 1996; Carruthers, 2002). He recognized that the learning of language was contingent upon the

development of cognition. A hallmark of Piaget's theory of cognitive development is the idea that our cognition is significant and powerful enough to encompass all mental abilities, even language abilities. Some researchers proposed that children build linguistic representations based on their early conceptual organization of cognitive development (Clark, 2004; Carruthers, 2002). However, it currently remains unclear as to whether or not cognition functions are a prerequisite to language, or whether they develop simultaneously.

A distinct and contrasting concept of human language development is the nativist theory, which places emphasis on our biological instinct to produce language. Whereas constructivists believe it is the learner who constructs knowledge on the basis of interaction with the environment, nativists believe the environment shapes our innate knowledge of language. Noam Chomsky (born December 7, 1928) was a strong advocate of the nativist perspective. He believed that greater attention should be given to children's innate ability to learn language. He also believed that the relative ease with which children learn the grammatical rules of language, despite limited teaching, could not be attributed to nurture alone. The primary focus of nativist theory is to assert that linguistic knowledge is inherent and modular, which accounts for children's language competence. Nativists, such as Chomsky, sought to understand why children could easily develop their native language but not others. He argued that language learning is a fundamental part of the human genome and exposure to a native language allows children to easily acquire that language (Clark & Lappin, 2010). This ideology was termed the "innateness hypothesis." Chomsky asserted in his theory that children have an inborn knowledge of the fundamental principles of grammar, making acquisition of their native language effortless despite the complexity of the process. To elaborate on and further develop his hypothesis, Chomsky introduced the concept of a Language Activation Device (LAD). The LAD was

described as an abstract part of the human brain that contains a Universal Grammar, which children use to acquire a native language (Clark & Lappin, 2010). The LAD was proposed in support of the idea that language has a set of explicit rules that could apply to any language and accounts for why explicit teaching is not necessary for a child to acquire a language.

There is evidence supporting a biological influence on language acquisition, specifically, the functional organization of the brain. Current technology has allowed researchers to identify specific areas of the brain that are involved in language production and comprehension (Lindenberg, Fangerau, & Seitz, 2007). Broca's area and Wernicke's area are distinct cortical regions known to be associated with main language functions, including syntax and semantics (Binder et al., 1997). Broca's area is anatomically located in the left hemisphere inferior frontal gyrus and is functionally related to speech production (Lindenberg et al., 2007). Etard and colleagues (2000) have discovered functional brain activation in Wernicke's area, which is located at the junction of the left temporal and parietal lobes, was involved in object naming and verb generating tasks. However, numerous studies of functional organization of the brain reveal that neither Broca's area nor Wernicke's area are strictly isolated to language function. Etard et al. (2000) also demonstrated that visual processing centers in the brain work in conjunction with Wernicke's area for certain tasks. Other researchers have identified that these areas are also engaged in additional cognitive functions, such as working memory (Grodzinski & Santi, 2008). Nativist theory argues that this is evidence that specific brain regions are inherently programmed for the processing of language, such as Broca's and Wernicke's area, which supports the innateness hypothesis proposed by Chomsky (Chomsky, 2000). In contrast, constructivists argue that brain regions are not genetically preprogrammed for a specific function, but instead, that experiences shape these brain regions to specialize in language.

Despite the many ideas about the nature of language development, to date, theorists have used scientific data to draw conclusions in their favor. It is often believed that no single theory of language development is correct, but truth exists in each theory and the combination of the interaction between all theories accounts for the learning of language (Bates, Dale, & Thal, 1995). We can acknowledge that neither theory stating only the environment or only biology justifies language learning, and instead acknowledge that language development likely encompasses an intricate amalgamation of both. The majority of researchers acknowledge that both environmental and biological influences play a role in language acquisition, and even linguistic theorists with opposite views about the ways in which language is acquired have recognized the importance and impact of the environment on language development.

## **1.2 The Development of Language**

The majority of empirical literature on language development is limited to behavioral observations. These studies have revealed that receptive vocabulary begins to develop very early in life; within the first four to six months of age children begin to know the meaning of specific words (Miller, 1981). It is known that phonology first appears in the form of babbling between six and eight months of age, and meaningful speech emerges some time between ten and 12 months (Bates & Goodman, 1999). Children experience a period of rapid receptive and expressive vocabulary growth around 18 months (Paul & Norbury, 2012; Bates & Goodman, 1999) and by around two begin to put two words together, the early development of syntax (Paul & Norbury, 2012). Rapid syntactic development occurs over the next three to four years, with children having acquired the basic syntactic structures present in adult language by the age of six (Paul & Norbury, 2012). While children will continue to acquire more complex sentence

structures and vocabulary, the basic tenants of their language are in place relatively early in their life.

Language learning becomes increasingly complex as a child begins to integrate vocabulary and grammar. Expressive and receptive language is organized into lexical and syntactic elements. As children acquire language, concrete representations of objects are stored in a lexicon. The progression of language development allows the learner to apply a rule-based system of grammar to all linguistic forms. The relationship between lexical development and the emergence of grammar in typically developing children overlap as children progress through the early stages of language learning (Bates & Goodman, 1999). However, the extent of the interchange between lexical and grammatical development is not yet well understood. It has been proposed that an adequate lexical capacity is needed to build a grammatical system (Locke, 1997). Locke (1997) claimed that children first develop utterances prior to applying them to a grammar system; he believed that a causal relationship exists between the two elements of language. In contrast, Bates and Goodman (1999) argue that there is a constant and interdependent relationship between lexical and syntactic development and state that they do not disassociate from one another at any point in life. In order to objectively measure the age at which semantic and syntactic processing occurs, one can compare variables of mean length of utterance (MLU), age, and vocabulary size across children (Devescovi, Caselli, Marchione, Reilly, & Bates, 2005). Due to variance in the developmental trajectories of children, it is difficult to pinpoint the exact timeline of development.

An additional complex property of language is the development of prosody. Prosody is concerned with the suprasegmental qualities of speech including distinctions in rhythm, intonation, stress, and pitch. Although prosody is less able to be used convey meaning

independently, it often affects the semantic and syntactic messages of a speaker. Prosody commonly reflects the emotional state of the speaker and the ways in which a speaker conveys information regarding the structure and meaning of an utterance.

While children are rapidly developing these complex language skills, the physical structures of their brains are also rapidly changing. The brain has the remarkable ability to respond, adapt, and continually change, and these changes are thought to account for learning (Clancy & Finlay, 2001; Johnson & Newport, 1989). The process by which neural connections in the brain strengthen and dissolve is termed neuroplasticity. Neuroplasticity plays an essential role in language development. It is involved in promoting language acquisition through the brain's ability to modify its structure and function in response to linguistic experiences and changes in the environment (Narbona & Crespo-Eguilaz, 2012). Neural connections in the language centers of the brain have the ability to be modified as a result of continuous sensory input, learning, and feedback that children receive from their linguistic environment. Neuroplasticity supports language acquisition in that it strengthens important neural connections established during learning tasks in childhood, such as when children hear and/or receive feedback for use of acceptable grammatical and semantic language. Brain plasticity, particularly from birth to five years, facilitates language development and the rapid expansion of children's lexical and grammatical capacity (Narbona & Crespo-Eguilaz, 2012). Although neuroplasticity is most prominent in early childhood, it remains a fundamental and significant lifelong property in the brain. Johansson (2000) found that brain plasticity is even implicated in the rehabilitation of language skills resulting from various neurological ailments and impairments in adolescents and adults.

While there is a vast literature on language development, to date, little is known about the development of the neural mechanisms underlying language. There is evidence of the brain's plasticity and that the brain maintains the ability to learn new information throughout the lifespan. However, there is also evidence that suggests the brain reaches its peak plasticity for language in early childhood (Johnson & Newport, 1989). Newport (2011) supports the concept of a critical age window of opportunity for maximum language acquisition, also known as the critical period for language. This sensitive period is referred to as 'critical' because it is the optimal time for learning language, during which peak plasticity exists in language regions of the brain (Newport, 2011; Weber-Fox & Neville, 1996). After this critical time period, some language structures, such as phonology and grammar of language, become increasingly more difficult to learn; the plasticity of these neural processes gradually declines (Newport, 2011; Lenneberg, 1967). Typically, the brain remains relatively plastic beyond critical periods, which is why humans have the ability to learn new things across their lifespan. However, after the critical period, the plasticity of cortical regions underlying language-specific functions becomes reduced and learning is more effortful. Newport (2011) suggests the critical period for syntactic development is approximately five years, six months. In contrast, semantic development remains relatively plastic throughout an individual's life, which accounts for human's ability to learn new vocabulary with relative ease throughout life. This critical period for language learning and development provides a time period during which supports for the development of strong language skills are critical, including parental involvement, early education and preschool, or early intervention programs as needed.

### **1.3 The Effects of Environment on Language Development**

Many biological and environmental factors are thought to contribute to variations in the complex process of language development (Crimmins, Hayward, & Seeman, 2004; Hart & Risley, 1995). In the study of human behavior, numerous theories exist that attempt to explain the development of cognitive processes in children and how children acquire language. Among these theories, strong evidence exists supporting the importance of the environment in language acquisition in children (Hoff, 2003; Hoff, 2006; Shaffer, Wood, & Willoughby, 2002). As mentioned previously, theories that emphasize the learning perspective argue that children imitate what they see and hear in their environment, and that children learn from punishment and reinforcement (Shaffer et al., 2002). Skinner, a main proponent of this theoretical framework, argues that adults shape the speech of infants and children by reinforcing their vocal productions (Skinner, 1957, as cited by Shaffer et al., 2002). Other theorists (Piaget, 1952, as cited by Shaffer et al., 2002; Vygotsky, 1962, as cited by Shaffer et al., 2002) view the development of language as a complex interaction between the child and the environment, which is manipulated by both social and cognitive factors. Both Piaget and Vygotsky stated that children actively respond to their environment and develop concepts to help them understand their surroundings (Bidell, 1999; Glassman, 1994; Hoff, 2003; Lourenço, 2012). Despite differing theoretical positions, the study of language acquisition in children has been largely influenced by the relationships between environment and the developmental process.

Fundamental to the understanding of language development is the fact that significant variability exists in a child's environment, and that this variability influences the linguistic outcomes across individuals and across linguistic domains. Evidence suggests that social environments support language acquisition by providing an association between meaning and

linguistic content, presenting children with a language model and communicative opportunities to motivate the language acquisition process (Hoff, 2006). However, different environmental factors affect the rate of language acquisition to different degrees, which creates group and individual differences in the processes of language acquisition and use (Hoff, 2006). For example, two kinds of cultural variations in a child's language environment are well described in the literature. One is the degree to which a parent engages in prelinguistic communication with an infant (Choi, 2000). The exposure to linguistic stimuli will affect the linguistic outcome of the child. A second variation between cultures is observed specifically when comparing North American and Asian cultures in the degree to which parents focus on objects when talking to their children (Choi, 2000). For example, mothers from North American cultures tend to focus on concrete nouns when exposing their children to language, whereas mothers from Asian cultures are less object-oriented, and instead their speech contains proportionately more verbs (Choi, 2000). Other environmental factors, including parental education and quantity of book reading in the home, also influence language development, which help explain linguistic and academic variance between individuals.

One factor of particular interest to many researchers aiming to understanding variability in language development are the effects of socioeconomic status (SES), or the factors of the household in which a child grows up, on the development of language acquisition of children. SES is a complex proxy variable used to signify one's position in a social hierarchy, or stratification of social class (Hart & Risley, 1995). Although SES is most commonly measured using parental education, parental occupation, and income (Ensminger & Fothergill, 2003), other factors, including access to wanted resources, such as housing, food, clothing, safety, reading material, and parental interaction, are also often reflected by SES. Variances across households

as a function of SES have been found to contribute to differences in language outcomes, along with differences in a host of other cognitive, socioemotional, and health outcomes in children (Hart & Risley, 1995; Bates, Dale, & Thal, 1995; Hoff, 2003; Noble, Norman, & Farah, 2005; Payne, Whitehurst, & Angell, 1994). Although no single environmental mechanism exists to account for SES variability, a meta-analysis of human and animal models conducted by Hackman, Farah, and Meaney (2010) implicated cognitive stimulation in the home environment, parent-child interactions, and prenatal influences in the effects of SES on neural and linguistic development.

Although SES and language development are both multifaceted variables, a strong relationship is evident between SES and early language development (Hoff, 2003). Exposure to an early enriched environment is related to greater language abilities of children in the early years of life (Hart & Risley, 1995). Stronger early language skills are associated with better long-term outcomes, including academic success and job attainment (Barnett, 2008; Justice, Mashburn, Hamre & Pianta, 2008). Both Barnett (2008) and Justice and colleagues (2008) have provided evidence demonstrating that early education programs support early language development and have been found to produce positive long-term effects on children's learning and literacy skills. Clinical applications of their findings reveal the importance of an enriched early educational environment in supporting a child's optimal development.

It has been found that by the age of three years, children from lower SES households have been exposed to approximately 30 million fewer words than their higher SES peers (Hart & Risley, 1995), known as the 30 million word gap. Similarly, White, Graves, and Slater (1982) charted the growth of reading vocabulary of children in first- to fourth-grade from diverse elementary schools. Their results were derived from book reading, and revealed that first-grade

children from higher SES backgrounds know at least twice as many words as lower SES children from the same grade (Graves & Slater, 1987; White et al., 1990). They also found that, collectively, children from higher SES schools had larger reading vocabularies, decoded more words, and knew more word meanings than disadvantaged students (White et al., 1990). Although SES significantly affects vocabulary development, syntactic development is also affected. A child receiving input from a caregiver who uses few structurally complex sentences may be expected to construct sentences using simpler grammar than a child receiving input from a caregiver who uses more structurally complex language (Huttenlocher et al., 2010). These effects have been replicated in teacher-student relationships as well, indicating that environmental input, not genetics, play the key role in impacting syntactic use (Bates, Dale, & Thal, 1995).

Across many cultures, the amount of language exposure a child receives is related to the number of books to which he or she has access, and importantly, the number of books to which a child has access is closely linked to their level of academic success (Evans, Kelley, Sikora, & Treiman, 2010). Children from families with greater quantities of books in their homes, a factor that often varies as a function of SES (i.e., more books are typically available in higher SES households) are more likely to achieve higher levels of academic success and increased levels of educational attainment (Evans et al., 2010). On the other hand, negative academic outcomes have been linked to limited resources and limited access to books early in life (Battle, & Lewis, 2002).

Because language development is a highly intricate process, it is important to understand development across various domains of language in children from lower SES backgrounds. The current project aims to enhance our understanding of the impact of environment on the development of neural processes of language. Knowing the ways in which various aspects of

language change at which time points can inform the refinement and/or development of interventions targeting language outcomes in young children at risk for reduced language and academic outcomes.

#### **1.4 The Neurobiology of Language Development**

Although learning language is an outcome of specific exposure circumstances, biological factors exist that predispose infants and children to learn language (Musso et al., 2003; Gleitman, 1984, Lenneberg, 1967). To date, research has only begun to identify the biological factors that underlie language development and its neural processes. The evolution of the field of developmental cognitive neuroscience has contributed to our understanding of changes in specific language components at different time points across development. Current research has identified that children and adults process language using two distinct neural mechanisms, a processing system for semantic stimuli and a separate processing system for syntactic stimuli. One technique that has allowed for investigations of early language development in the brain is event-related brain potentials (ERPs). ERPs are a noninvasive measure of populations of neurons firing in synchrony time-locked to a specific stimulus. ERPs provide exquisite temporal resolution and can be acquired without an overt response, making them ideal for use with young children. Since the pioneering work of Kutas and Hillyard (1980), the measurements of neural activity using ERPs have helped researchers uncover the detection and processing of different modules of language, even in young children, evidenced by different patterns of electrical responses in the brain (e.g., Mills et al., 2004; Silva-Pereyra, Rivera-Gaxiola, & Kuhl, 2005).

Specific ERP components distinguish different types of language processing. Researchers have documented differential neurophysiological responses to violations of semantic and

syntactic structures, which indicate different neural processes engaged in processing each type of linguistic constraint. Two distinct characteristics are elicited by violations of semantics and syntax. Kutas and Hillyard (1980, 1984) discovered that when sentences contained semantically inappropriate features, a negative ERP component peaking around 400 ms after the presentation of the stimuli, known as an N400, was observed. In contrast, they found that deviations from normal sentence structure elicited a slow positive component peaking approximately 600 ms after the onset of the stimuli, the P600 (Kutas & Hillyard, 1980, 1984; Osterhout, & Holcomb, 1992).

Previous studies have revealed that the N400 component is an index of semantic processing, posited to reflect ease of semantic access and/or integration (Friederici, 1997; Kutas & Hillyard, 1984; Keifer et al., 1998; Silva Pereyra et al., 2005). Two studies of the development of the N400 from childhood to adulthood revealed a decrease in both amplitude and latency of the N400 with increasing age (Hahne, Eckstein, & Friederici, 2004; Holcomb, Coffey, & Neville, 1992). A study of school-age children revealed smaller N400 amplitudes in children with better language abilities (Hampton Wray & Weber-Fox, 2013). These findings were interpreted as reduced reliance on the context of the sentence to integrate anomalous words with age and/or increased language proficiency. However, to date, investigations of neural processes in preschool-age children have been limited.

A later positive ERP component, the P600, is typically elicited by syntactic violations. The P600 is thought to index repair or reprocessing of a sentence following a syntactic violation (Hahne et al., 2004; Friederici, 2011; Friederici, Pfeifer, & Hahne, 1993), or violation of a rule-based expectancy (Schmidt-Kassow & Kotz, 2009). The P600 has been found to increase in amplitude and decrease in latency with development (Hahne et al., 2004) and with increased

language skills (Hampton Wray & Weber-Fox, 2013). These findings suggest more neural resources dedicated to the repair and/or reanalysis of a sentence following a syntactic violation. The ability to use ERPs to evaluate different aspects of language processing allows us to gain insights into the developmental trajectory of language processing in young children from lower SES backgrounds.

A recent preliminary study of the developmental trajectory of neural processes underlying language in higher SES preschool-age children revealed similar patterns to previous studies of changes with age and language proficiency (Hampton Wray, 2015). For semantic violations, higher SES children revealed a decrease in N400 mean amplitudes and the emergence of the late positive component (LPC), which reflects reprocessing of the violation (Van Petten & Luka, 2012), from age four to age five. A similar pattern was observed for syntactic processing. From age four to age five, the amplitude of the broad negativity, similar to the N400, decreased and the P600 emerged. These findings indicate a significant transition toward more mature neural processes underlying semantics and syntax from age four to five in children from higher SES households. A similar pattern as observed in the syntactic condition was also observed for Jabberwocky stimuli, which is a condition with standard English grammar (e.g., articles, prepositions, and conjunctions) but reduced semantic context, in which nouns, adjectives, and verbs have been replaced with nonsense words (Carroll, 1883). For the Jabberwocky condition, a late positivity emerged between the ages of four and five years in children from higher SES households. This preliminary study indicates significant transitions toward adult-like patterns for neural processes underlying both semantic and syntactic processing in preschool-age children from higher SES backgrounds (Hampton Wray, 2015).

## **1.5 The Current Study**

One way to better understand the neurobiological processes of language development in young children from lower SES households is to evaluate changes over time in the neural processes underlying language. The current project aims to extend to our knowledge about neural processes underlying language development by measuring semantic (meaning) and syntactic (grammar) processing in preschool-age children from lower SES backgrounds, an understudied population. To date, research on the development of neural processes underlying language in young children and in children from lower SES backgrounds has been limited. Specifically, we aim to identify the patterns of change in neural indices of semantic and syntactic processing in lower SES preschoolers.

The current study used an ecologically valid auditory language paradigm, which allowed us to acquire ERPs elicited by correct and anomalous sentences containing semantic and syntactic violations from young children growing up in lower SES households. Children also completed a battery of behavioral tasks, including nonverbal IQ and receptive language tasks. Behavioral and ERP data were acquired when the children were age four years and again one year later, at age five years. The changes in ERP components elicited by these sentences over the one-year period reflect development in neural processes underlying the semantic, and syntactic processing.

In behavior, we predicted that the children's standard scores would remain stable over time. With increasing age, children must perform at a higher level to achieve the same standard score. Thus, achieving a stable standard score across a one-year time period will indicate that the children's performance on measures of language and nonverbal IQ improved in accordance with expectations for their age.

The current study also evaluated neural processes underlying semantics and syntax. Our ERP predictions for both semantic and syntactic processing were based on previous findings in older children (Hahne et al., 2004; Holcomb et al., 1992) and preliminary data from children growing up in higher SES households (Hampton Wray, 2015). For semantic processing we hypothesized that the neural indices of semantics would be robust early in development, by age four, indicating intact semantic processing at age four. We also predicted that the N400 would remain stable or possibly decrease in amplitude from age four to five. Preschool-age children from higher SES backgrounds exhibit a reduced N400 amplitude as well as the development of a late positive component (LPC) between ages four and five. We do not anticipate that the lower SES children will exhibit as robust maturation of semantic processing as the higher SES children. Instead, the hypothesized change in the lower SES children would suggest stable semantic processing (stable N400 mean amplitudes) or increased ease of lexical access and/or integration in older children (decreased N400 mean amplitudes), a more mature response at age five than age four, but still less mature than their higher SES peers.

For syntactic processing, we predicted a different developmental pattern. We hypothesized that syntactic processing would change significantly across the one-year time. At age four, we did not anticipate significant differences between condition, with an emerging positivity at age five, revealed by a small P600 amplitude. This pattern would indicate evidence of syntactic processing that is moving toward the expected adult-like patterns. This increase in P600 amplitude would reflect increased neural resources engaged in repair and/or reanalysis of syntactic information. We predict that syntactic processing in lower SES children lags behind that of their higher SES peers, who exhibit a small P600 at age four and a robust P600 at age

five. Thus, children from lower SES background will exhibit less mature syntactic processing than their higher SES peers.

Similarly, based on the existing literature on syntactic processing in older children (Hahne et al., 2004), we expected that anomalies in syntactically appropriate sentences with significantly reduced semantic context, the Jabberwocky condition, would elicit neural responses comparable to those of the correct English syntactic condition. At age four, both the canonical and violation conditions will elicit similar ERP patterns. However, at age five, violations in grammatical structure for sentences with reduced semantic context (Jabberwocky conditions) will elicit a small P600, of the emergence of P600 mean amplitudes, suggesting developing neural resources for repair or reprocessing violations of rule-based expectancy (Schmidt-Kassow & Kotz, 2009) and a more adult-like response pattern from age four to age five.

The current study will contribute to gaps in our knowledge regarding the developmental trajectory of neural indices for language in children, and specifically in children from lower SES backgrounds. Findings from the current study will aim to characterize the neural patterns of language development in this understudied population and will directly inform future research programs designed to characterize language development across broader populations, and potentially identify targets for language interventions in children with lower language skills.

## CHAPTER 2: METHOD

### 2.1 Participants

Twenty-five children, eleven males and fourteen females, participated in the current study. These children were selected from a larger group of children participating in a longitudinal project evaluating the efficacy of an intervention program targeting Head Start preschoolers and their families, living at or below the poverty line. The children in the current project were all part of the control group, participating in Head Start as usual; none of the children in this project have participated in the intervention program. Data acquisition occurred at the University of Oregon, and all analyzed were performed in collaboration with researchers at the University of Oregon.

All children included in this project had data points in Year 1 (age four; mean (*SE*) age 4.42 (*0.084*)) and one year later in Year 2 (age five; mean (*SE*) age 5.64 (*0.09*)). All participants were right handed, monolingual speakers of English, with no history of neurological impairments and normal or corrected-to-normal vision, per parent report. All children passed a hearing screening at 20 dB at 1000, 2000, and 4000 Hz in both ears at both time points. Prior to participation, all children verbally assented and parents or caregivers signed consent forms for participation in the project, which was approved by the Institutional Review Board at the University of Oregon.

SES was determined using the Hollingshead Index (Hollingshead, 1975). Components of the Hollingshead index include a rating scale to quantify the highest level of education achieved by the child's mother and father. The scale ranged from 1, less than seventh grade education, to 7, indicating completion of a graduate degree. Additionally, parental occupation is ranked based

on the social status of each parents' current job, ranging from 0-9. A weighted formula provides an overall household SES value, ranging from 8-66. The SES of the children remained consistent over time (mean (*SE*) SES was 30.38 (2.50) in Year 1, 31.60 (2.90) in Year 2;  $F(1, 20) = 0.232$ ,  $p = 0.64$ ,  $n_p^2 = 0.011$ ).

## **2.2 Behavioral Testing**

At both time point one and time point two, children participated in two laboratory sessions, a behavioral testing session and an ERP session. The behavioral session involved a battery of tests, which included: nonverbal IQ, evaluated by the Fluid Reasoning, Quantitative Reasoning, and Working Memory subtests of the Stanford-Binet Intelligence Scales Fifth Edition (SB-5; Roid, 2003); receptive language skills, evaluated by the Concepts and Following Directions and Sentence Structure subtests of the Clinical Evaluation of Language Fundamentals – Preschool-2 (CELF-P2; Wiig, Secord, & Semel, 2004) or 4 (CELF-4; Semel, Wiig, & Secord, 2003), depending on age at time of testing; as well as additional measures of working memory and pre-literacy skills, which are not the focus of the current project. Behavioral testing was completed in one testing session lasting approximately two to three hours, with breaks as needed. If necessary, the child returned to the laboratory for a second day to complete the behavioral tasks.

## **2.3 ERP Language Stimuli**

ERP data acquisition involved the use of a novel, ecologically valid paradigm that paired auditory sentences with a visual cartoon of Pingu, a claymation penguin, and his friends. The Pingu cartoons depicted the activities and adventures of Pingu, his family, and friends and was

produced without verbal narration. Copyright permission was obtained to overlay verbal stimuli over the cartoon for research purposes. The videos created an engaging paradigm, allowing for high quality EEG data acquisition from young children.

Auditory sentences were created using vocabulary highly familiar to young children, with all target words included on the MacArthur Communicative Development Inventory (CDI; Fenson et al., 2007). Sentences were designed to accompany the visual cartoons. There were five linguistic conditions included in the paradigm: 1) Semantic Condition (“The kids are in their *beds* under the blankets.”/ “The kids are in their *eyes* under the blankets.”); 2) Phrase-Structure Condition (“Pingu chases the penguins around *his* house.”/ “Pingu chases the penguins around that *his* house.”); 3) Regular Verb-Agreement Condition (“Pingu *waits* to see if they stop.”/ “Pingu *wait* to see if they stop.”); 4) Irregular Verb-Agreement Condition (“Daddy is waking up.”/ “Daddy *are* waking up.”); and 5) Jabberwocky Condition (“Shoard he basbi with *his* doak.”/ “Shoard he basbi with that *his* doak.”). All words were counterbalanced, such that a word that served as a violation in one condition served as a control in a separate condition. Ten separate video/audio stories were created. Each story had two versions, A and B. Sentences that were correct in version A served as a violation in version B, and vice versa. This resulted in twenty different Pingu stories children could potentially watch. Each story consisted of approximately 100 sentences, with 10 trials of each condition (e.g., 10 canonical and 10 violation sentences for the semantic condition) in each video. Each year, a participant watched five of the Pingu stories, which consisted of approximately 500 total sentences, and 50 sentences per control and 50 per violation condition. The subsequent year, children viewed five different Pingu stories. Story versions were counterbalanced across participants and across years.

## **2.4 Procedure**

Each year at time point one and time point two, the children completed two days of laboratory experiments. On their first visit to the lab, children and families became acquainted with the laboratory set-up and research assistance. Due to the young age of the participants, familiarizing them to the testing environment facilitated better data quality and reduced detrimental behaviors. Once the child was comfortable in the research environment and all assent and consent forms were signed, children completed the battery of behavioral testing. The second session involved the acquisition of ERP data. Again, after the child became comfortable with the ERP acquisition room, researchers placed the electrode cap on the child's head. The child and a researcher then sat in a sound-attenuating booth to watch the Pingu videos. Images were presented on a computer screen, and auditory stimuli were presented between 70-72 dB HL from a speaker at the midline. Children viewed the five Pingu stories in year one, and viewed five different Pingu stories in year two.

## **2.5 Data Acquisition**

Continuous electrical brain activity, electroencephalographic (EEG) data, was acquired using an elastic cap embedded with 32 Ag/Ag-Cl electrodes arranged according to the International 10-20 system (Biosemi, Amsterdam, Netherlands). Electrode locations included in the analysis were as follows: Frontal: F7/8, F3/4; Fronto-temporal: FT7/8, FC5/6; Central: T7/8, C5/6; Centro-parietal: CP5/6, C3/4; Parietal: P7/8, P3/4; and Occipital: PO3/4, O1/2. Additional electrodes were placed over the left and right mastoids. Ocular movement and artifact was recorded from electrodes placed over the left and right outer canthi (HEOG), and the right

inferior orbital ridge (VE). Data was recorded unfiltered at 512 Hz relative to a Common Mode Sense (CMS) electrode.

## **2.6 EEG/ERP Data Analysis**

Offline, data was down-sampled to 256 Hz and re-referenced to the average of the left and right mastoids and filtered from 0.1 to 40 Hz. Artifact was removed from the data using independent component analysis by identifying ICA components containing eye artifact using EEGLAB (Delorme & Makeig, 2004). An additional step of manual artifact rejection was performed to ensure all eye and other artifact was removed from the data using EEGLAB (Delorme & Makeig, 2004) and ERPLAB (Lopez-Calderon & Luck, 2014). EEG data was epoched between -1000 prior to and 2000 ms after to the onset of each target word. Trials were then averaged across like stimuli for each condition separately for each time point using and ERPLAB (Lopez-Calderon & Luck, 2014). The mean (*SD*) number of trials accepted (out of 46-48) for each condition were as follows: Year 1 – Semantic: Canonical 24 (7.29), Violation 24 (7.34); Syntax: Canonical 23 (7.68), Violation 23 (6.50); Jabberwocky: Canonical 19 (6.56), Violation 21 (6.82). Year 2 – Semantic: Canonical 24 (8.06), Violation 24 (8.58); Syntax: Canonical 23 (8.30), Violation 23 (7.30); Jabberwocky: Canonical 21 (6.96), Violation 22 (7.08).

Based on previous findings in preschool-age children from higher SES backgrounds, the current data analyses focused on three conditions, semantic, syntactic, and jabberwocky. Mean amplitudes of the ERP components, the N400 and P600, elicited by semantic, syntactic, and jabberwocky canonical and violation target words were measured for each participant at each time point. Temporal windows for measurement were determined based on visual inspection of the current data and the existing ERP literature in young children (Hahne, Eckstein, & Friederici,

2004; Hampton Wray, 2015; Weber-Fox & Neville, 1996). The time windows in which mean amplitudes were measured were: the N400 between 400 and 700 ms, and the P600 between 750 and 1250 ms. Mean amplitudes were measured as the mean area under the curve within the specified time window and were determined using ERPLAB (Lopez-Calderon & Luck, 2014; Luck, 2005).

To evaluate change over time in behavioral performance, one-way ANOVAs were used with a within-subject factor of time (Year 1, Year 2). ERP data analyses involved omnibus repeated-measures ANOVAs with within-subject factors of time (year one, year two), condition (canonical/violation), hemisphere (left/right), anterior-posterior (frontal, fronto-central, central, centro-parietal, parietal, occipital), and laterality (lateral/medial). Separate ANOVAs were conducted for each component (N400, P600) elicited by the semantic, syntactic, and jabberwocky conditions. Significance values were set at  $p < 0.05$ . Trends in data from  $p < 0.10$  were also reported. Interactions in the omnibus analyses were further explored using step-down ANOVAs, combining across non-significant factors. For all repeated measures with greater than one degree of freedom in the denominator, Huynh-Feldt adjusted  $p$ -values were reported. Effects sizes, indexed by partial-eta squared ( $\eta_p^2$ ), were reported for all significant effects.

## CHAPTER 3: RESULTS

### **3.1 Behavioral Data**

#### ***3.1.1 Nonverbal IQ***

Nonverbal IQ was measured using the Stanford-Binet Fifth Edition (SB-5; Roid, 2003). Average Composite IQ scores (CIQ) were derived from scaled standard scores from the subtests of Fluid Reasoning, Quantitative Reasoning, and Working Memory of the SB-5. Data from the Fluid Reasoning subtest of the SB-5 revealed a mean (*SE*) scaled standard score of 12.80 (0.59) in Year 1, and 12.40 (0.58) in Year 2. No significant change was observed over time, illustrated in Figure 3.1.1 ( $F(1, 24) = 0.417, p = 0.524, n_p^2 = 0.017$ ). Data from the Quantitative Reasoning subtest of the SB-5 revealed a mean (*SE*) scaled standard score of 13.04 (0.54) in Year 1, and 11.80 (0.35) in Year 2 (Figure 3.1.2). A significant decline in performance was observed in Quantitative Reasoning from Year 1 to Year 2, illustrated in Figure 3.1.2 ( $F(1, 24) = 5.893, p = 0.023, n_p^2 = 0.197$ ). The Working Memory subtest of the SB-5 yielded a mean (*SE*) scaled standard score of 12.56 (0.51) in Year 1, and 12.72 (0.47) in Year 2. Analysis across time revealed no significant change from Year 1 to Year 2, illustrated in Figure 3.1.3 ( $F(1, 24) = 0.119, p = 0.733, n_p^2 = 0.005$ ). Overall performance in nonverbal IQ was based on averaged CIQ scores, which yielded a mean (*SE*) scaled standard score of 12.79 (0.45) in Year 1 and 12.31 (0.37) in Year 2. Statistical analysis for CIQ scores across time did not reveal significant change over time, illustrated in Figure 3.1.4 ( $F(1, 24) = 1.905, p = 0.180, n_p^2 = 0.074$ ).

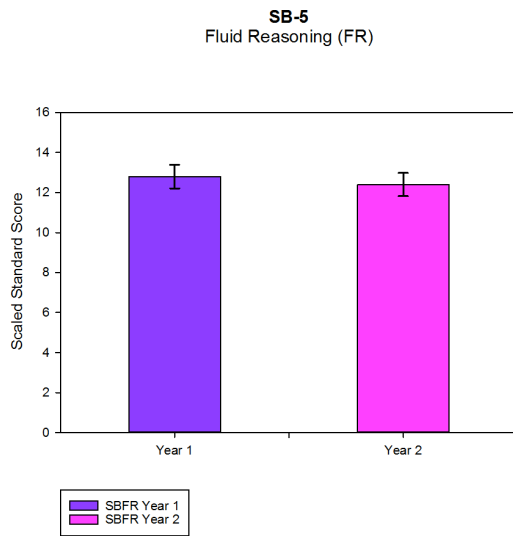


Figure 3.1.1: Scaled standard scores on the SB-5 Fluid Reasoning subtest revealed no significant difference between Year 1 and Year 2.

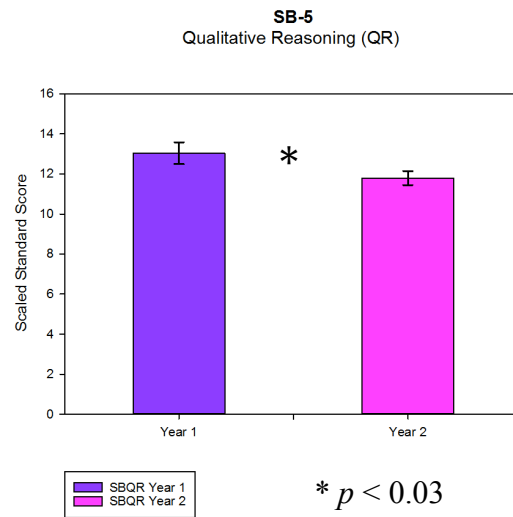


Figure 3.1.2: Scaled standard scores on the SB-5 Quantitative Reasoning subtest revealed a significant difference between Year 1 and Year 2.

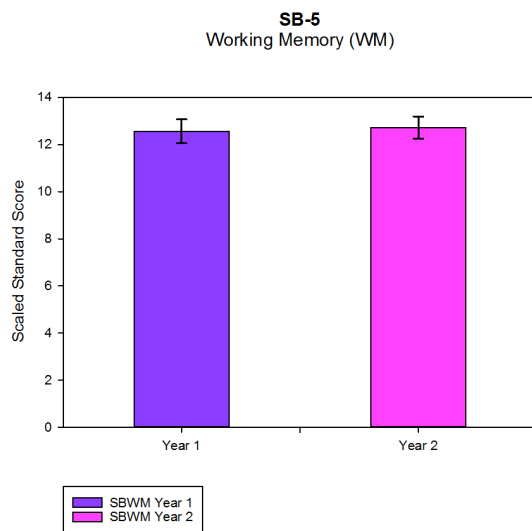


Figure 3.1.3: Scaled standard scores on the SB-5 Working Memory subtest revealed no significant difference between Year 1 and Year 2.

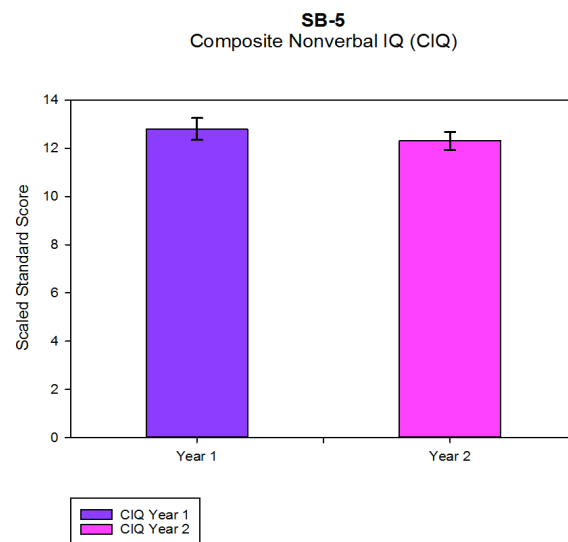


Figure 3.1.4: Scaled standard scores for Composite Nonverbal IQ revealed no significant difference between Year 1 and Year 2.

### ***3.1.2 Receptive Language Skills***

Behavioral assessments for receptive language skills involved portions of the Clinical Evaluation of Language Fundamentals-Preschool-2 (CELF-P2; Wiig, Secord, & Semel, 2004) or –Fourth Edition (CELF-4; Semel, Wiig, & Secord, 2003), depending on age of the participant at time of testing. The CELF-P2 was administered to all children in Year 1 and children aged 4 years and under in Year 2. The CELF-4 was administered only in Year 2 to children aged 5 years and older. Performance on the CELF-P2/-4 subtests of Concepts and Following Directions and Sentence Structure was used to obtain an average Composite Receptive Language score (CLA).

Performance on the Concepts and Following Directions subtest revealed a mean (*SE*) standard score of 10.00 (0.62) in Year 1, and 11.857 (0.94) in Year 2. Statistical analyses exhibited a significant increase in performance over time for this subtest, illustrated in Figure 3.1.5 ( $F(1, 6) = 8.593, p = 0.026, n_p^2 = 0.589$ ; Figure 3.1.5). For the Sentence Structure subtest, data revealed a mean (*SE*) standard score of 12.72 (0.46) in Year 1, and 13.48 (0.40) in Year 2. Data analyses revealed no significant change over time ( $F(1, 24) = 1.694, p = 0.205, n_p^2 = 0.066$ ), as illustrated in Figure 3.1.6. However, the average CLA, revealed significant improvement over the one-year course of this study in receptive language skills, exemplified in Figure 3.1.7 ( $F(1, 24) = 10.281, p = 0.004, n_p^2 = 0.300$ ). Mean (*SE*) standard scores for the CLA in Year 1 were 11.26 (0.40) and were 12.81(0.40) in Year 2.

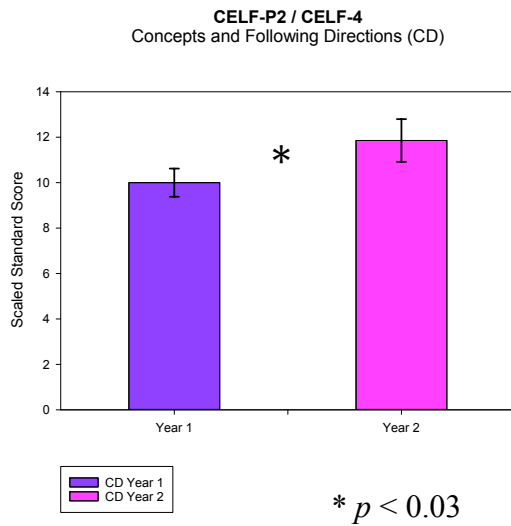


Figure 3.1.5: Scaled standard scores on the CELF-P2/4 Concepts and Following Directions subtest revealed a significant difference between Year 1 and Year 2.

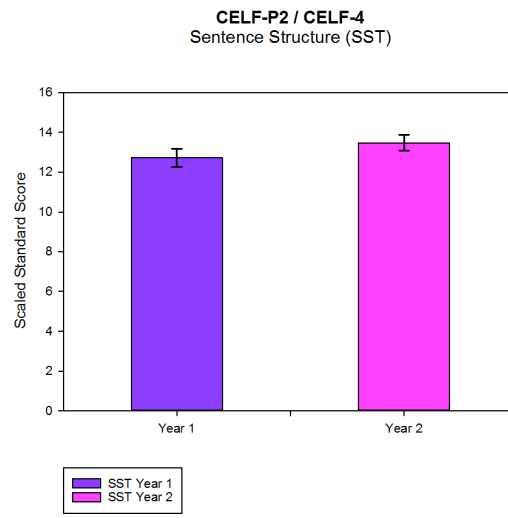


Figure 3.1.6: Scaled standard scores on the CELF-P2/4 Sentence Structure subtest revealed no significant difference between Year 1 and Year 2.

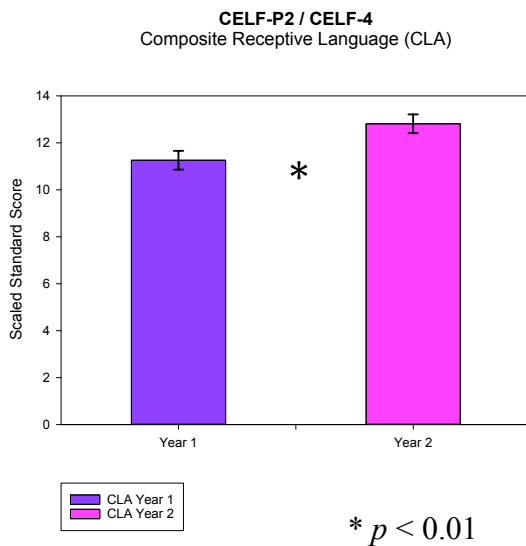


Figure 3.1.7: Scaled standard scores for Composite Receptive Language scores revealed a significant difference between Year 1 and Year 2.

## **3.2 Semantics**

### ***3.2.1 N400***

In Year 1, there was a trend for an N400 effect (Year 1 Condition:  $F(1, 24) = 3.294, p = 0.082, n_p^2 = 0.116$ ), illustrated in Figure 3.2.1, with an N400 mean (*SE*) amplitude of  $-0.132 \mu V (0.63)$  for the canonical condition and a mean (*SE*) amplitude of  $-1.580 \mu V (0.58)$  for the violation. In Year 2, a significant N400 effect was revealed for the semantic condition (Year 2 Condition:  $F(1, 24) = 18.921, p < 0.001, n_p^2 = 0.431$ ), with an N400 mean (*SE*) amplitude of  $-0.502 \mu V (0.54)$  for the canonical condition and a mean (*SE*) amplitude of  $-3.569 \mu V (0.59)$  for the violation condition, illustrated in Figure 3.2.2. Over time, a trend toward a significant interaction of time and condition was observed ( $F(1, 24) = 2.940, p = 0.099, n_p^2 = 0.105$ ), with a larger N400 elicited by the semantic violation in Year 2 than in Year 1 (Figure 3.2.3). A step-down ANOVA revealed the significant N400 amplitude difference was driven by change over time in the amplitude of the N400 elicited by the semantic violation, with larger N400 amplitudes in Year 2 than in Year 1 (Violation – Time:  $F(1, 24) = 9.892, p = 0.004, n_p^2 = 0.283$ ). N400 amplitudes elicited by the canonical conditions were similar in Year 1 and Year 2 (Canonical – Time:  $F(1, 24) = 0.277, p = 0.603, n_p^2 = 0.011$ ).

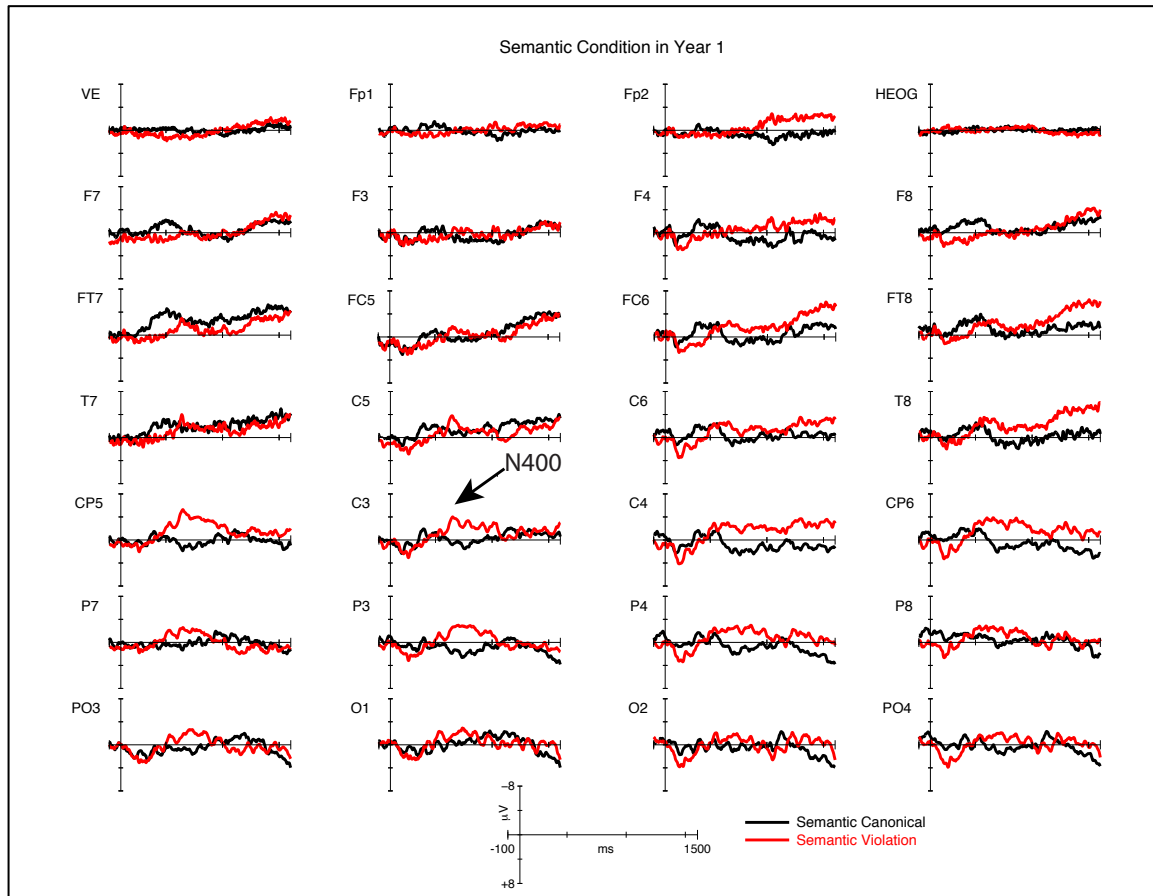


Figure 3.2.1: The ERP data for semantic canonical and violation sentences in Year 1;  $n = 25$ . A small N400 response to semantic violations was visualized at central electrodes.

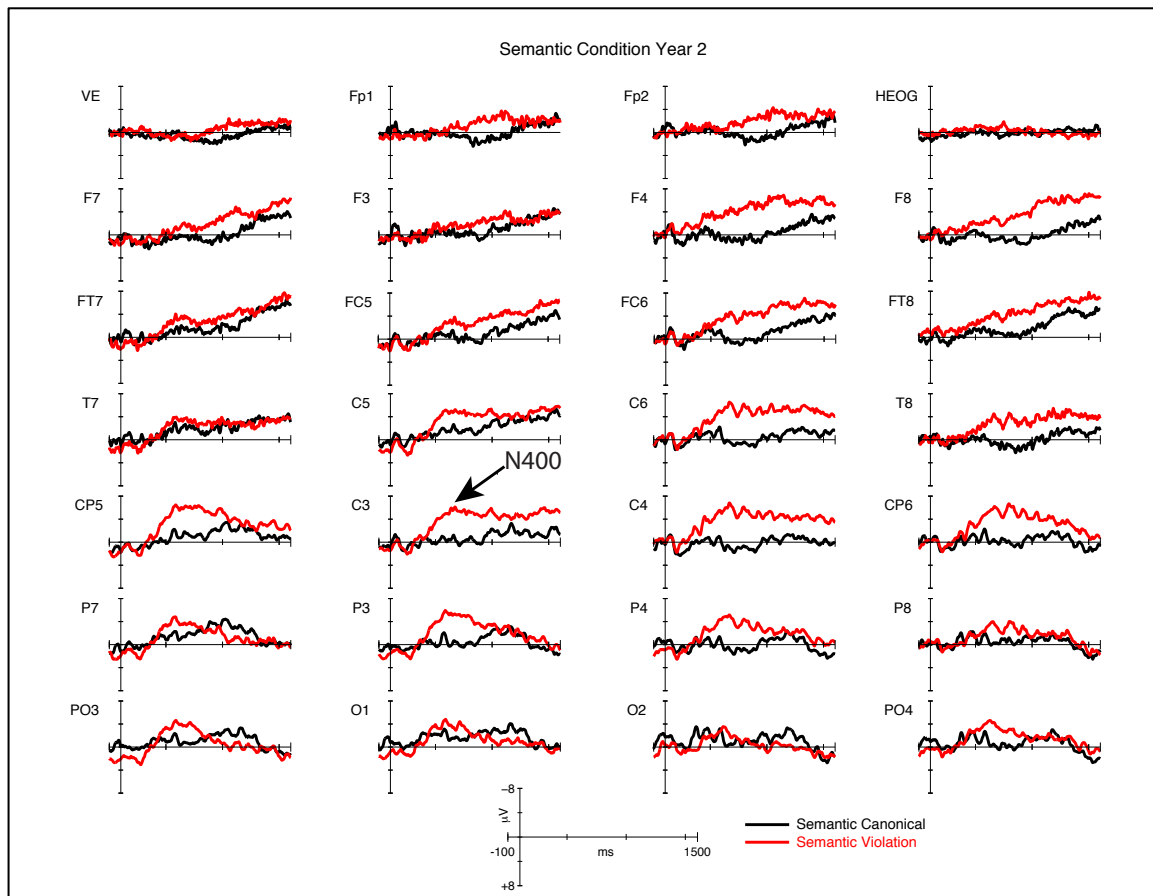


Figure 3.2.2: The ERP data for semantic canonical and violation sentences in Year 2;  $n = 25$ . Here, a change in neural response to semantic violations at central electrodes was visualized, illustrated by a larger N400 compared to Year 1.

### Semantic (400-700): Time X Condition

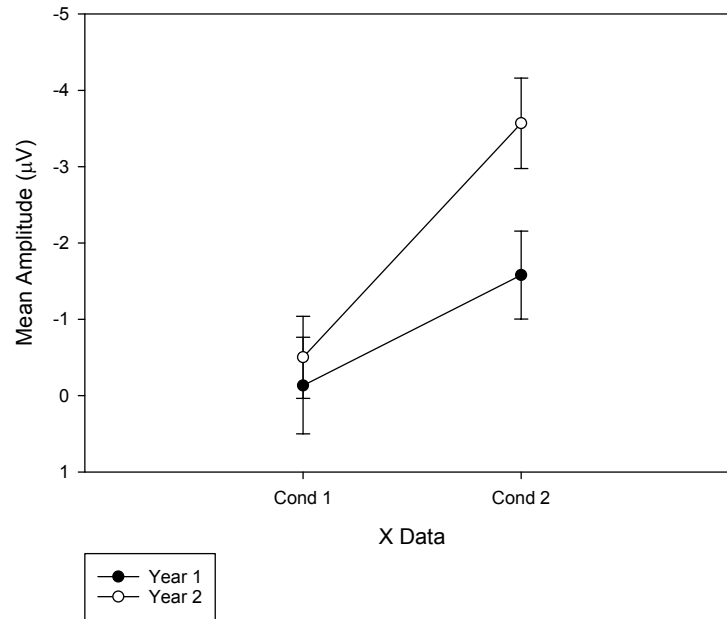


Figure 3.2.3: Interactions between semantic canonical and violation conditions across time demonstrated a trend toward significance, as illustrated here.  $p = 0.099$

### 3.2.2 P600

There were no effects of time or condition, or interactions of time and condition, for the later P600 time window for the semantic condition (all  $F(1, 24) < 1$ ), also known as the late positive component (LPC).

### **3.3 Syntax**

#### ***3.3.1 N400***

In Year 1, the four-year-old children demonstrated a significant distinction between the syntactic canonical and violation conditions (Year 1 Condition:  $F(1, 24) = 13.034, p = 0.001, n_p^2 = 0.343$ ), illustrated in Figure 3.3.1, with an N400 mean (*SE*) amplitude of  $0.139 \mu V (0.42)$  for the canonical condition, and  $-1.964 \mu V (0.53)$  for the violation condition. No significant condition effect was revealed in Year 2 (Year 2 Condition:  $F(1, 24) = 0.688, p = 0.415, n_p^2 = 0.027$ ), illustrated in Figure 3.3.2, with an N400 mean (*SE*) amplitude of  $-1.094 \mu V (0.43)$  for the canonical condition, and  $-1.635 \mu V (0.45)$  for the violation condition. A trend towards significance was observed for the interaction between time and condition ( $F(1, 24) = 3.294, p = 0.082, n_p^2 = 0.116$ ), illustrated in Figure 3.3.3. Step-down ANOVAs revealed a trend towards significance between canonical conditions from Year 1 to Year 2 (Canonical – Time:  $F(1, 24) = 3.717, p = 0.065, n_p^2 = 0.129$ ). No significant differences were revealed for the violation condition across time (Violation – Time:  $F(1, 24) = 0.273, p = 0.606, n_p^2 = 0.011$ ).

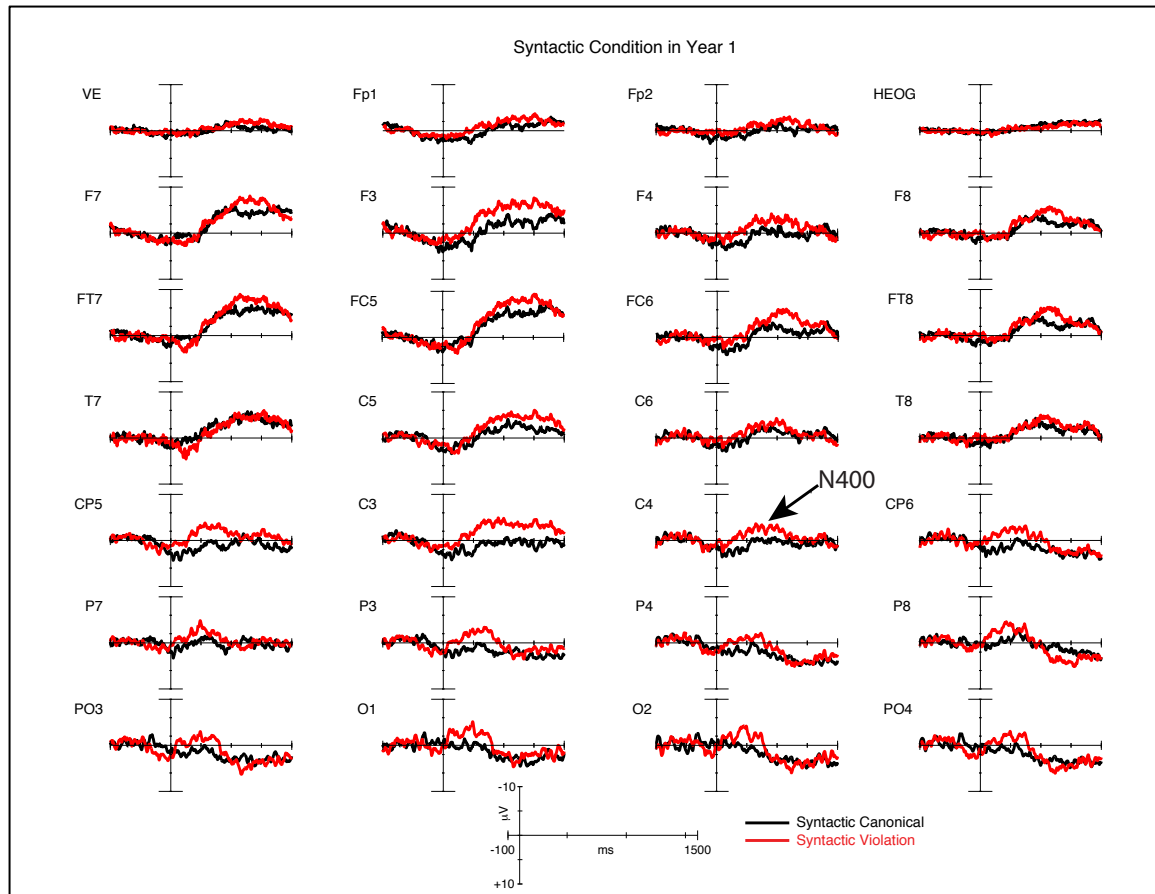


Figure 3.3.1: The ERP data for syntactic canonical and violation sentences in Year 1;  $n = 25$ . Here, evidence of an N400 negativity to syntactic violations at central electrodes was visualized.

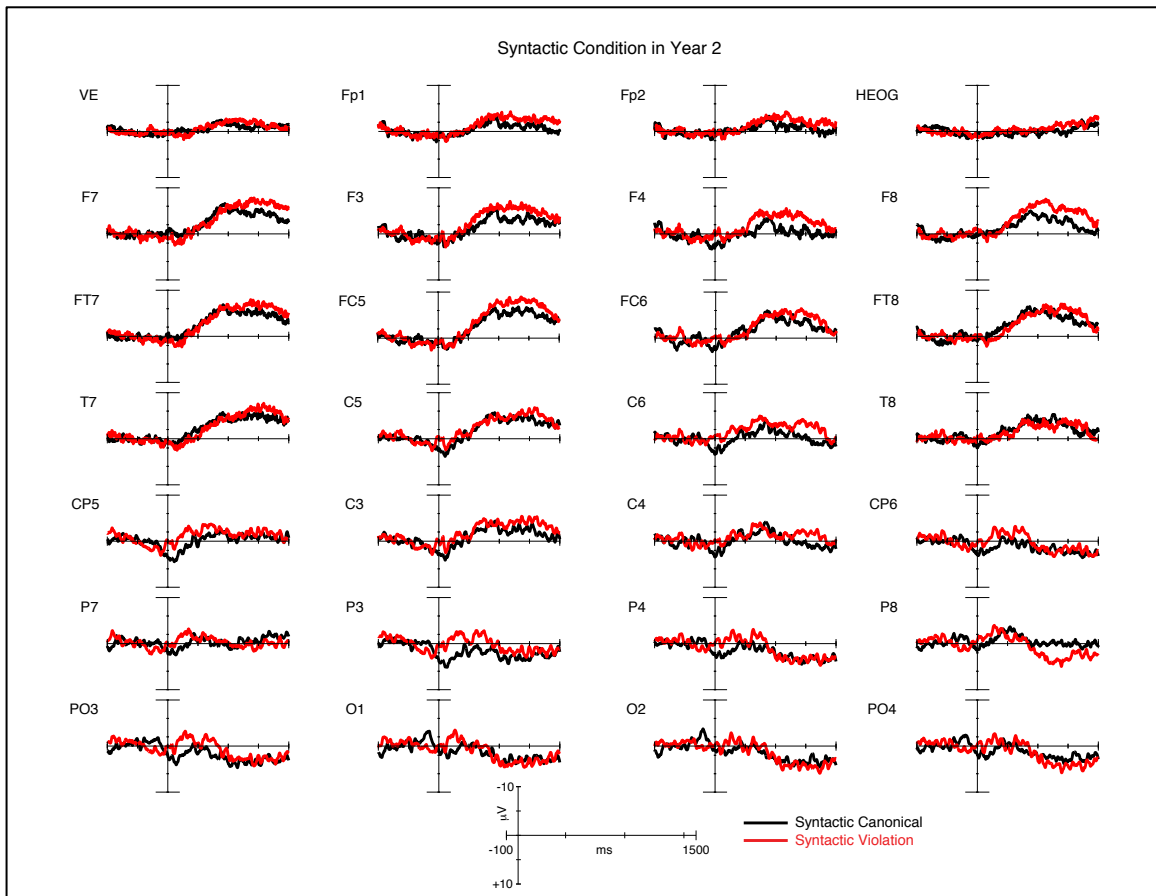


Figure 3.3.2: The ERP data for syntactic canonical and violation sentences in Year 2;  $n = 25$ . Here, no evidence of a negativity to syntactic violations was visualized. A shift to less negative amplitudes is observed.

### Syntax (400-700): Time X Condition

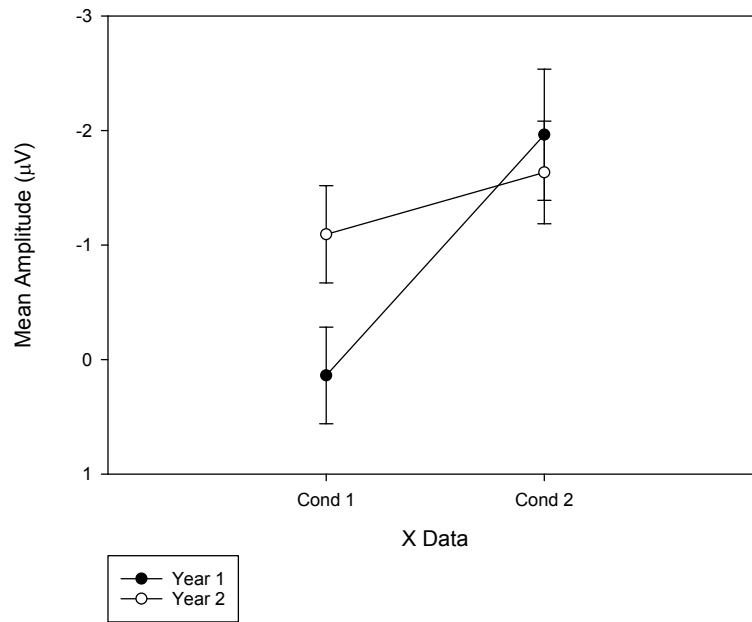


Figure 3.3.3: Interactions between syntactic canonical and violation conditions demonstrated a trend toward significance across time, as illustrated here.  $p = 0.082$ .

### 3.3.2 P600

There were no effects of time or condition, or interactions of time and condition, for the later P600 time window for the syntactic condition (all  $F(1, 24) < 1$ ).

### **3.4 Jabberwocky**

#### ***3.4.1 N400***

Three participants included in the study had data containing excessive artifact in either Year 1 or Year 2 that was not usable for the jabberwocky condition only. Thus, only 22 children were included in the analyses for the jabberwocky condition. In the current study, no differences were identified between conditions in Year 1 (Year 1 Condition:  $F(1, 21) = 2.899, p = 0.103, n_p^2 = 0.121$ ), illustrated in Figure 3.4.1, with an N400 mean (*SE*) amplitude of  $-0.816 \mu V (0.51)$  for the canonical condition, and  $-2.148 \mu V (0.48)$  for jabberwocky violations. No differences between conditions were observed in Year 2 either (Year 2 Condition:  $F(1, 21) = 0.951, p = 0.340, n_p^2 = 0.043$ ). Year 2 (Figure 3.4.2) yielded an N400 mean (*SE*) amplitude of  $-1.894 \mu V (0.46)$  for canonical condition and an N400 mean (*SE*) amplitude of  $-1.321 \mu V (0.48)$  for the violation condition. Over time, a trend toward significance emerged in the interaction of time, condition, and laterality ( $F(1, 21) = 3.332, p = 0.082, n_p^2 = 0.137$ ), illustrated in Figure 3.4.3. In Year 1, the Jabberwocky violation condition elicited more negative N400 mean amplitudes than the canonical condition. However, in Year 2, N400 mean amplitudes were comparable between the canonical and violation conditions, with the violation eliciting slightly more positive mean amplitudes. These effects were more pronounced over medial compared to lateral electrode locations.

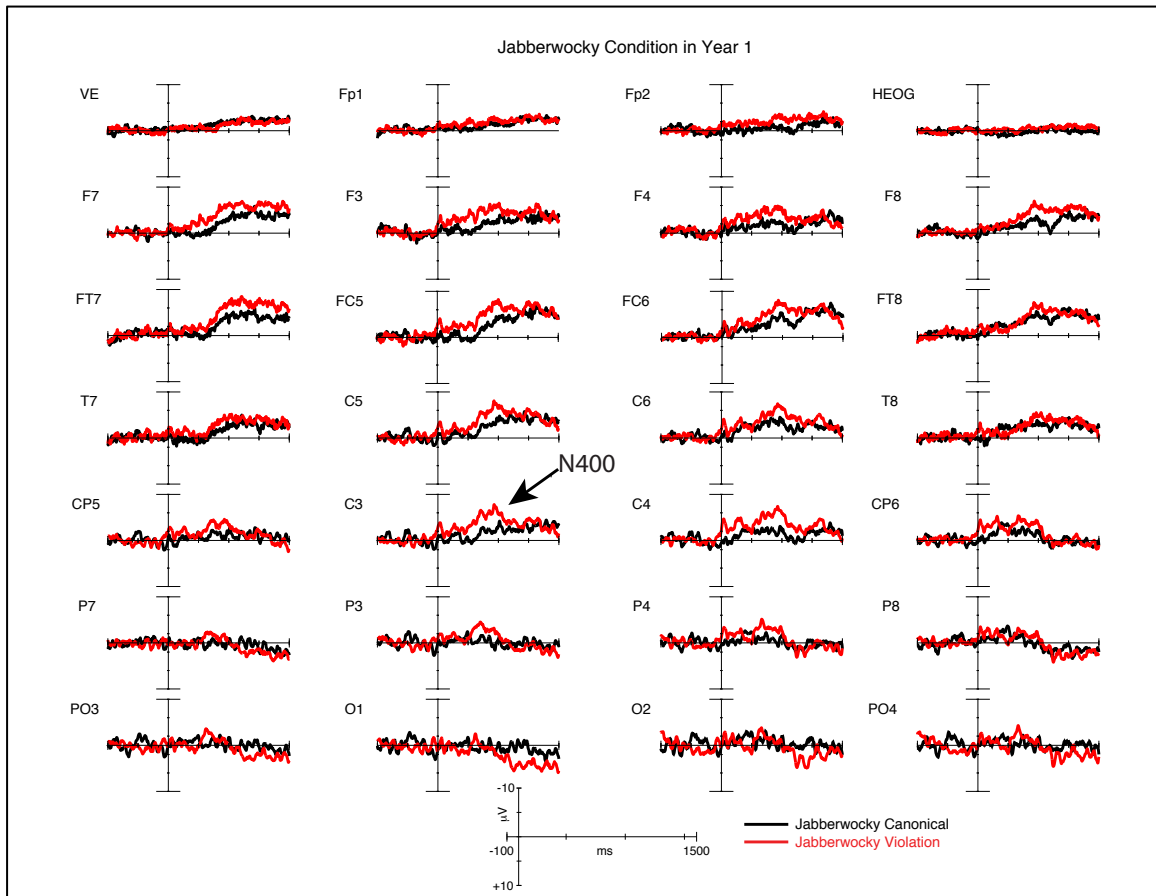


Figure 3.4.1: The ERP data for Jabberwocky canonical and violation sentences in Year 1;  $n = 22$ . Here, evidence of an N400 negativity to Jabberwocky violations at central electrodes was visualized.

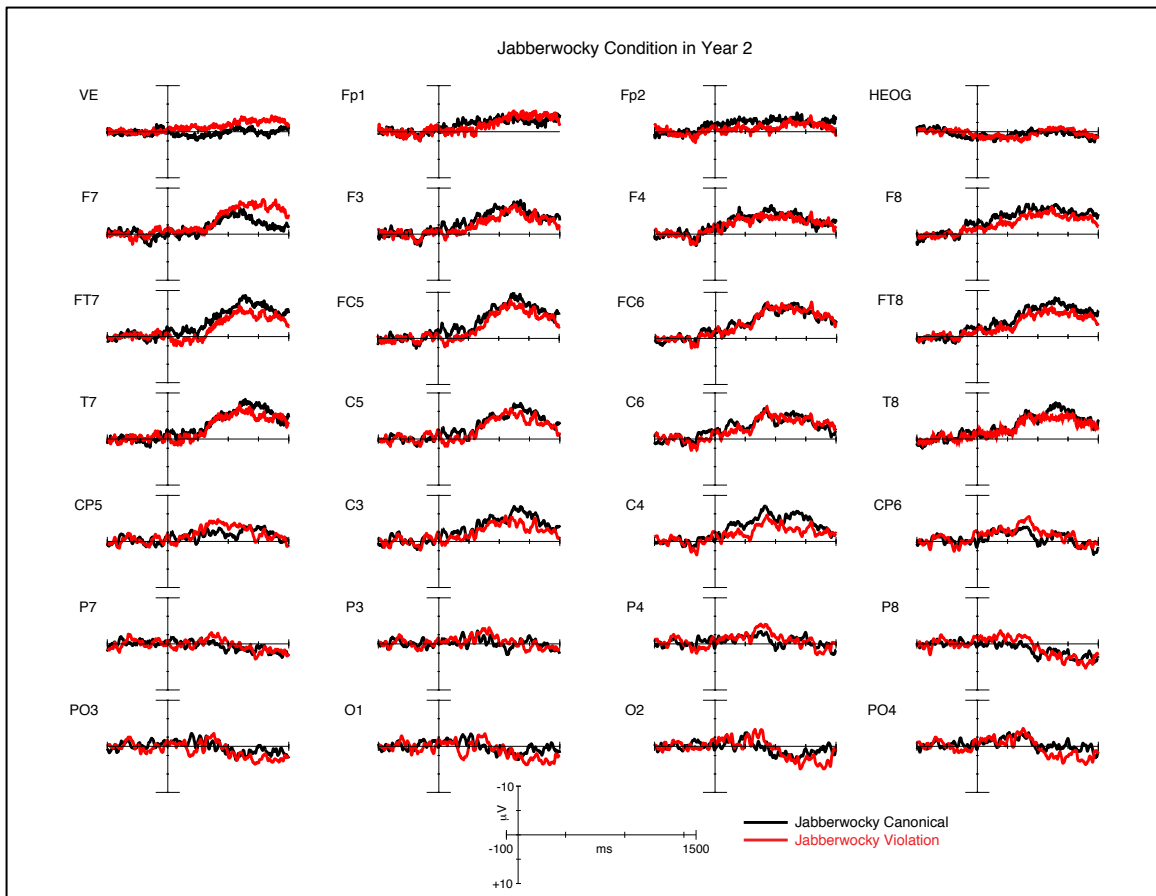


Figure 3.4.2: The ERP data for Jabberwocky canonical and violation sentences in Year 2;  $n = 22$ . Here, no evidence of a negativity to syntactic violations was visualized. A shift to less negative amplitudes is observed.

### Jabberwocky (400-700): Time X Condition X Lat

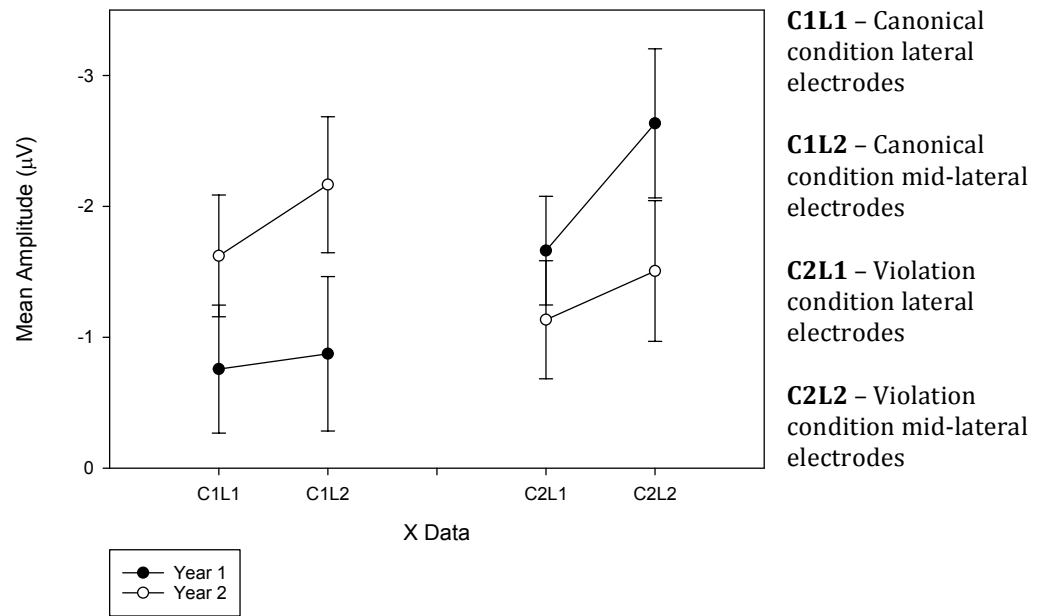


Figure 3.4.3: Interactions between Jabberwocky canonical and violation conditions laterally across time demonstrated a trend toward significance, as illustrated here.  $p = 0.082$ .

### 3.4.2 P600

There were no effects of time or condition, or interactions of time and condition, for the later P600 time window for the Jabberwocky condition (all  $F(1, 21) < 1$ ).

## **CHAPTER 4: DISCUSSION**

The current project evaluated changes in behavior and neural processes underlying language in preschool-age children from lower SES background across a one year time period. Specifically, semantic and syntactic processes during auditory sentence comprehension were investigated. Results indicated that, from age four to age five years, children from lower SES households exhibited increased N400 mean amplitudes. This result may reflect increased reliance on the context of the sentence for processing semantic violations at age five. Additionally, for both English and Jabberwocky sentences, children exhibited reduced negativity in N400-like responses elicited by syntactic violations. These findings potentially reflect an early transition toward a more adult-like positive response to syntactic violations, a P600. Together, these results indicate significant changes in neural patterns for language processing in children from lower SES backgrounds from age four to five. Furthermore, compared to existing data, the current findings suggest that preschool-age children from lower SES households exhibit delayed neural processes for language compared to preschool-age children from higher SES backgrounds.

### **4.1 Changes in Behavior over Time**

#### ***4.1.1 Nonverbal IQ***

It is important to understand changes in behavior over time as well as changes in neural processes in evaluating the development of language processing in preschool-age children. The behavioral data obtained in this study provided empirical data that can be compared to existing literature as well as to the ERPs acquired over time.

We did not predict that typically developing children would demonstrate changes in scaled standard scores over time, as scaled scores require increased performance with age to achieve the same score. As expected, we did not see change over time in nonverbal IQ scores (Figure 3.1.4). In fact, the data revealed a trend toward a decline in quantitative reasoning skills from Year 1 to Year 2 (Figure 3.1.2). Because this study investigated the nonverbal IQ performance in children from lower SES backgrounds, their trajectory of learning may deviate from that of their average or higher SES peers. In order to attempt to explicate the trend found in the data, it is important to first evaluate the converging evidence on the environmental and neurological variability of children from low SES backgrounds.

The null change in participant performance of nonverbal IQ from Year 1 to Year 2 may be largely contributed to environmental variances in SES mediated by differences in health, cognitive stimulation, and parental styles (i.e., Guo & Harris, 2000). A large body of evidence suggests that the combination of these factors is detrimental to a child's intellectual development, which is likely reflected in the results of this study.

It is possible that similar or poorer performance across time on behavioral test measures from lower SES children is mediated by poor health and/or chronic stress. Adler and colleagues (1994) examined health reports from individuals from varying degrees of SES and found that lower SES is linked to physical and mental illness in children and adults. Their findings can be applied to children in a school environment due to the fact that a child's illness may interfere with their test-taking ability. If the child is not feeling well during testing, they are more vulnerable to performing in ways that do not reflect their true skill. Additionally, children may perform poorly due to poor nutrition affecting their test taking ability. Meta-analysis from Rampersaud and colleagues (2005) revealed that proper nutrition might improve cognitive

function related to memory, test grades, and school attendance. Children from lower SES backgrounds have less access to nutrient-dense foods and are more likely to eat low-cost processed food, such that an inverse relationship develops between poverty and obesity (BMI) (Rampersaud, et al., 2005). Additionally, Adler and colleagues (1994) also found disparities between SES and psychological health, including chronic stress. Lower SES is associated with higher levels of stress (Adler, et al., 1994; Evans, 2004). SES-related stress has been found to impact both cognitive and behavioral outcomes by changing neural mechanisms, such as the stress response, in the brain. The stress response alters cognitive processes that may impede a child's ability to perform well on a test despite being knowledgeable of the content (Evans, 2004). One study found notably higher salivary cortisol levels in 6- to 10-year-old children from lower SES versus higher SES backgrounds (Lupein, King, Meaney, and McEwan, 2001), suggesting that the stressful environments of lower SES children have resulted in long-term changes to physiological function. The SES effect on mental health may have negatively affected the children in this study, reflected in their reduced performance across time.

Abundant research has also suggested that SES variance influences attention skills in children. Young children are often difficult to assess accurately due to their high level of activity, typically shorter attention spans, and inconsistent performance in unfamiliar environments. Further, children from lower SES households have been found to have reduced attention skills compared to their higher SES peers (Stevens, Lauinger, & Neville, 2008). D'Anguilli, Herdman, Stapells, and Hertzman (2008) have found similar SES-related differences in attention. Specifically, they found that lower SES children demonstrated reduced ERP evidence of selective attention despite performing similar to higher SES peers in accuracy and reaction time. Differences in attention may correlate to a lack of, or reduced, performance on nonverbal IQ

tasks (Mezzacappa, 2004). Particularly, quantitative reasoning involves the processes of numerical reasoning, problem solving, concentration, and knowledge and application of numerical concepts (Semel, Wiig, & Secord, 2003; Wiig, Secord, & Semel, 2004). If the child is having difficulty with the concentration component during testing, performance may not reflect a child's true nonverbal IQ skills.

Confounding this matter, demographic variables, such as SES, are thought to contribute to increases in diagnoses of Attention-Deficit/ Hyperactivity Disorder (ADHD) in children. Pineda and colleagues (1999) found that when looking at a random sample of 540 children with varying ages (from four to 17 years old), SES (low, middle, high), and gender, ADHD was most prevalent in male preschoolers from lower SES backgrounds. Although the testing environment from Year 1 to Year 2 did not change, the participants may have become more distracted by their environment, thus decreasing the already compromised attention spans of the participants. The current results may suggest that children performed the same or worse in Year 2 as in Year 1 due to long-term deficits associated with reduced attention skills.

Several studies have also reported that deficits in specific cognitive functions associated with lower SES may be a factor. For example, Farah and colleagues (2006) revealed that significant disparities in spatial cognition and cognitive control exist between lower SES and middle SES children due to differences in neurological functioning of the left perisylvian/language and medial temporal/memory systems. The children in the current study may have had a similar functional cognitive delay due to environmental factors, which could contribute to declines observed for quantitative reasoning scores across time. We would predict that in several years, the children's nonverbal IQ scores would increase in raw score, but standard scores would continue to lag behind age expectations and their higher SES peers.

However, in order to reach a conclusive judgment about this trend in nonverbal IQ performance, we must also weigh the degree to which limitations exist in the acquisition of data. We must consider the possibility that extraneous variables could also potentially influence the participants' behavior in this area. One of the most significant factors to consider is the amount of variability involved in children, particularly from lower SES backgrounds. Although this study matched participants on many factors, unknown factors beyond control of the researchers in this study may have indirectly influence results.

#### ***4.1.2 Receptive Language Skills***

Performance on receptive language tasks revealed a significant improvement in performance in this area over time (Figure 3.1.6). The young children in this study improved their ability to comprehend spoken language, recall, and act upon spoken direction. More specifically, a significant improvement was observed on the Concepts and Following Directions subtest of the CELF-P2/4 (Figure 3.1.5). These findings were unexpected, as a significant improvement in scaled standard score in Year 2 requires children to perform beyond the level of age expectations they demonstrated in Year 1. The young children in the current study exhibited stronger skills in processing and interpreting verbal directions of increasing complexity, remembering the names, characteristics, and order of objects, as well as identifying among several choices of a sequence of mentioned objects (Semel, Wiig, & Secord, 2003; Wiig, Secord, & Semel, 2004). These high-level skills are building blocks necessary for relevant classroom behavior. Proficiency in this area facilitates following classroom and teacher directions, participation in games, and locating objects and items in the environment. This skill is crucial for class work, pre-literacy activities, and the understanding of stories. Given the age of the

participants and the outcomes in this study, a transition toward school readiness is observed over time.

Significant improvement in a child's receptive language skills, illustrated by this study, may be at least partially attributed to participation in the Head Start Program. Part of the entrance criteria for this study required the participants to have been enrolled in a Head Start program, which is a program that aims to improve the learning skills, the social skills, and health status of impoverished children (Head Start Act, 2007). The Head Start program is part of a comprehensive effort to combat poverty in America and it is designed to promote equal education for disadvantaged preschoolers so that they are able to begin schooling at the same educational level at their more advantaged peers (Head Start Act, 2007). Head Start has also been found have long-lasting impacts on children, including reduced grade repetition, teenage pregnancy, and high school dropout rates (Currie & Thomas, 1993). Although there is overwhelming support for this program, many of its goals are broad and have little evidence in support of these vast and numerous conclusions. The current study provides evidence supporting participation in Head Start, and similar early childhood education programs, and the important improvements that can be observed in language skills over a relatively short time period.

Children who are born into lower SES families are less likely to engage in experiences that help to nurture and develop language. This includes story telling, reading, and opportunities for learning at home. Hoff-Ginsberg (1991) found that low-income mothers spend less time in mutual play with their children and talk less to their children than middle SES mothers. Hoff-Ginsberg (1991) also reported that low-income mothers talk differently to their children compared to higher SES mothers. Lower SES mothers use speech that is more aimed at directing a child's behavior than for the purpose of engaging in meaningful conversation.

Not only are the environments of children in lower SES households disadvantageous to their language development, socioeconomic diversity impacts the access to high-quality early education. Cascio and Schanzenback (2013) illustrated the correlations seen between preschool enrollment of children from higher SES backgrounds and later superior academic achievement over lower SES peers who did not attend preschool. Due to the financial difficulty of low-income families, often times preschool programs are not available for the lower SES children, thus result in long-term academic disadvantages. Our findings demonstrating that children participating in the government-funded preschool Head Start program exhibit significant language development, beyond-age expected growth. This provides further support for programs providing free or affordable early childhood education opportunities to children growing up in lower SES households. The current results support Head Start as a strong program helping to provide positive outcomes for school readiness.

Despite the numerous disadvantages to cognitive and linguistic development of young children from low SES households, the data revealed an improvement in scaled standard scores for the participant's overall receptive language skills over time. Inclusion in a Head Start program and other factors may have contributed to this trend in the data. The analysis of this study's behavioral results provided insight on the longitudinal evidence necessary to help strengthen the correlations between SES variations and cognitive-linguistic development in children.

## **4.2 Semantic Processing**

Consistent with a large body of research (e.g., Hahne, Eckstein, & Friederici, 2004; Holcomb, Coffey, & Neville, 1992; Holcomb & Neville, 1990; Kutas & Hillyard, 1980), the

children in this study demonstrated significantly larger N400 mean amplitudes elicited by semantic violations compared to canonical conditions (Figure 3.2.1 and Figure 3.2.2). These findings suggested that children as young as age four years were able to detect semantic violations and require more effort to integrate the violation into the sentence context than was required by canonical sentences. Though later and larger in amplitude, the N400 effect in the four-year-olds in the current study was consistent with the N400 effect observed in older children (Canseco-Gonzalez, 2000; Hahne, Eckstein, & Friederici, 2004; Hampton Wray & Weber-Fox, 2013) and adults (Holcomb, 1993; Kutas & Hillyard, 1980; 1984). The children were differentiating between the two conditions, as expected.

When evaluating change in the N400 effect over time, no differences in neural responses elicited by semantic canonical sentences were observed between Year 1 and Year 2. Since the canonical sentences embody the typical features of language and do not contain violations of meaning or anticipated meaning, we would anticipate a small N400 response, even in young children (Friederici, 1997; Kutas & Hillyard, 1984; Keifer et al., 1998; Silva Pereyra et al., 2005).

In contrast, semantic violations elicited relatively small N400 mean amplitudes in Year 1 (Figure 3.2.1), while in Year 2, N400 mean amplitudes elicited by the violation were significantly larger, as illustrated in Figures 3.2.2. This direction of change over time was unexpected. We hypothesized that by the age of four years, semantic processing would be robust and would not change significantly from age four to age five. Instead, the children from lower SES backgrounds in the current study were demonstrating an increase in N400 mean amplitudes from age four to five. This indicates that the children are relying on the meaning of the sentence

to understand a violation more at age five than age four. This change suggests that semantic processing is not yet robust at age four and is continuing to develop into age five.

One possible reason for the increase in negativity in response to semantic violations may correspond to the participants' increased vocabulary knowledge from Year 1 to Year 2. By Year 2, the children may be better able to predict which word(s) will come next in the sentences. Then, when the now-stronger expectation is violated, we observe a larger N400 amplitude in response to the violation. In other words, lower SES children at age five may have better understanding of sentence-level meaning, thus larger responses when attempting to integrate words that violate the meaning into the sentence. In a study of toddlers aged fourteen to 20 months, Mills and colleagues (2004) found that inexperienced word learners (at fourteen month olds) do not phonetically discriminate words and thus produce the same neural response when they heard a familiar word (i.e., "bear") and a phonetically similar nonsense word (i.e., "gare"). On the other hand, experienced word learners (at 20 months old) elicited different ERP patterns than when they processed a phonetically similar nonsense word and a phonetically different nonsense word (i.e., "kobe"). Both the fourteen month olds and the 20 month olds produced a larger amplitude negative response to familiar versus unfamiliar words (Mills et al., 2004).

Studies of higher SES and older children have reported smaller N400 amplitudes with increased age and language abilities. This is generally thought to reflect greater ease when integrating an unexpected word into a sentence. The current study may be capturing a pivotal period in semantic development of young children from lower SES backgrounds. These children may still be in the process of vocabulary building, similar to children in the study by Mills and colleagues (2004). Instead of exhibiting the expected more efficient neural pattern of smaller N400 amplitudes elicited by unexpected semantic stimuli, we are observing a pattern more

consistent with younger children who are still in a period of rapid vocabulary growth. We might predict that at age six or seven, we would begin to see the reduction in N400 mean amplitudes observed in higher SES and older children. These findings emphasize the importance of vocabulary skills in the development of semantic processing.

Neural patterns in the N400 amplitude may also reflect changes in general cognitive development of the children from age four to age five rather than driven solely by changes in language skills. Rapid development of cognition occurs early in life and may be intricately related to language acquisition (Fischer, 1980). Cognitive development in childhood is thought to be a progressive system by which children constantly reorganize their mental processes resulting in maturation and experience building. Children continually expand their ability to conceptualize their environment and build upon previous knowledge. It could be speculated that the increase in negativity resulting from semantic violations from Year 1 to Year 2, may indicate increases in general cognitive skills secondary to overall growth and structural changes that occur during this time period of development.

The pattern of delayed neural maturation compared to other reports of higher SES children in the same age range (Hampton Wray, 2015) is consistent with behavioral reports of delayed vocabulary and semantic learning in children from lower SES backgrounds (Hoff, 2003). The current findings extend previous behavioral work by demonstrating a delayed maturation not only of behavior, but also of neurophysiological function.

### **4.3 Syntactic Processing**

Negativities elicited by violations of syntax, consistent with N400 response timing and scalp distribution, revealed the early stages of transition from a negative to a positive ERP

response. Neural responses elicited by syntactic violations in Year 1 were characterized by a robust N400 (Figure 3.3.1). A decrease in negativity was observed in Year 2 (Figure 3.3.2). We might hypothesize that the pattern of a decreased N400 response elicited by violations after one year may continue, with the emergences of a positive, P600 response in two-to-four years.

Research from Neville, Mills, and Lawson (1992) has differentiated syntactic and semantic functions to be distinct sub-processes of the language domain. Particularly, the P600 component is typically associated with syntactic deviations, as seen with older children (Friederici, 2011; Friederici, Pfeifer, & Hahne, 1993; Hahne, Eckstein, & Friederici, 2004; Neville, Nicol, Barss, Forster, & Garrett, 1991; Silva-Pereyra et al., 2005). There has been some disagreement in the literature of which specific syntactic components are processed with the presence of a latent positive wave. Some speculate violations in morpho-syntactic structure (Müntz & Heinze, 1994). However, the P600 is generally elicited from several anomalies, including phrase-structure violations and verb agreement violations (Hagoort, Brown, & Groothusen, 1993).

Consistent with our hypothesis, the children underwent a change in their neural responses to syntactic violations across time. However, the nature of the change was partially unanticipated. In the current study, ERPs elicited by violations in phrase-structure revealed an N400 effect in Year 1 and a more positive-going wave in Year 2. Studies of older children have demonstrated robust P600 responses to syntactic violations (Silva-Pereyra et al., 2005). The N400 response to the syntactic violation observed in this study may be an early, immature response to the adult-like ERPs elicited by syntactic violations, the P600.

The children in this study may be continuing to rely on semantic knowledge to process syntactic violations. It is known that children first acquire a lexical capacity before relationships

between words are recognized (e.g., Silva-Pereyra et al., 2005). Knowledge of grammatical structures begins once a basic mastery of semantic knowledge is developed. Thus, before a strong rule-based knowledge of grammar exists, language processing relies mostly on comprehension of word meaning rather than grammatical structures. Children rely largely on semantic processing for about the first three years of language development (Silva-Pereyra et al., 2005). It is possible that the children in this study are continuing to exhibit this N400-like neural processing pattern for syntax because their syntactic knowledge is not fully developed.

Once the children begin to understand and apply grammatical rules, we would expect a transition from a reliance on semantic processing to the later positive P600 component observed in higher SES and older children; a neural differentiation between semantic and syntactic processing. Perhaps the N400 response observed in Year 1 indicates the ongoing reliance on semantic processing for understanding language, while in Year 2, a transition toward more reliance on syntactic processing streams for syntactic violations is beginning to emerge. If this hypothesis is true, we would predict that in one to two years, we would see the expected P600 component elicited by syntactic violations, as is observed in higher SES peers and older children.

#### **4.4 Jabberwocky Condition**

Violations in the Jabberwocky condition elicited similar ERP responses as the violations in syntactic structure. Canonical Jabberwocky sentences contained syntactically appropriate structure with significantly reduced semantic context, while Jabberwocky violations contained an insertion phrase-structure violation with significantly reduced semantic context. The Jabberwocky condition allowed us to examine neurological responses involved in syntactic processing with minimal semantic context. We hypothesized that children would elicit ERP

responses similar to those elicited by the insertion phrase-structure violations as a result of the similarity in sentence structure. The current findings are both consistent with and different from our predictions. We predicted that children would exhibit a large positivity, P600, by age five, which is not observed in the current data (Figure 3.4.2). However, we also predicted that neural responses to both the English and Jabberwocky sentences would be similar, which was observed in the current data. Both English and Jabberwocky phrase-structure violations elicited large amplitude negativities, similar to the N400, at age four, with decreased negativity at age five. These findings may suggest that children from lower SES backgrounds are beginning to engage syntactic processing resources to process syntactic violations, specifically phrase-structure violations by age five year. However, these emerging syntactic processing patterns are still immature compared to their higher SES peers.

Hahne and Jescheniak (2001) found that participants who were presented with blocks of Jabberwocky sentences and blocks of regular sentences at least one week apart demonstrated an early left anterior negativity (N150) elicited by phrase structure violations in both types of sentence. The N150 was followed by a P600, indicating an attempt to repair or reprocess the sentence. Another study by Silva-Pereyra, Conboy, Klarman, and Kuhl (2007) demonstrated that preschoolers at the age of thirty-six months exhibited similar neural processing patterns as adults when processing normal English sentences with phrase structure violations. The children exhibited ERP patterns analogous to the N150 and P600 in adults, but shifted later in time. In contrast, when the children were presented with Jabberwocky phrase-structure violations, preschoolers demonstrated activity similar to an N400, typically associated with semantic processing in adults, along with a diminished P600. The children in the current study do not yet exhibit robust P600 effects. One likely explanation is that the children from lower SES

households do not yet have the grammatical knowledge and/or skills to generate the P600 in response to violations of grammar. As responses to Jabberwocky violations were similar to the neural patterns elicited by English syntactic violations, we can hypothesize that in one to two years, the children will elicit a clear P600 response when their grammatical knowledge becomes more mature.

#### **4.5 Comparison Between Neural Responses in Children from Higher and Lower SES**

##### **Backgrounds**

To date, investigation of the neural processes underlying language in young children has been limited. Even fewer studies have examined SES-related differences in neural processes of language in children. Preliminary research by Hampton Wray (2015) has identified patterns of language development in young higher SES children from age four to age five. In this longitudinal study of children from higher SES backgrounds using ERPs, marked differences in neural responses were observed across time for both semantic and syntactic conditions. Semantic violations elicited smaller N400 mean amplitudes from age four to age five. In contrast, English phrase-structure violations transitioned from almost no response at age four to a robust P600 response at age five. Neural patterns for Jabberwocky violations were consistent with those for English syntactic violations. These preliminary results suggest that neural processes for language in children from higher SES households are undergoing rapid changes from age four to age five, revealing more adult-like patterns of maturation across this one-year time (e.g., Hahne et al., 2004; Hampton Wray, 2015; Silva Pereyra et al., 2005).

Comparisons of results from Hampton Wray (2015) to the results in the current study yielded marked discrepancies in language development as measured by ERPs. Children of the

same age from lower SES backgrounds revealed less mature processes underlying semantics and syntax over one year. At age five, children from lower SES backgrounds were only just beginning to initiate evidence of positive ERP components in response to syntactic violations, whereas children from higher SES backgrounds exhibited robust P600 responses to the same stimuli. Together, these results indicate that children from lower SES backgrounds are exhibiting neural processes underlying language that are delayed compared to their higher SES peers at age four, and are thus delayed at age five. With only two time points for each group, it is currently unclear whether the rate of maturation between higher and lower SES children is similar or different. However, at ages four and five, neural processes for language in children from lower SES households lag behind those of children from higher SES households.

## **CHAPTER 5: LIMITATIONS AND FUTURE DIRECTIONS**

Although much research has focused on investigations of the disparities in behavior and language development as a function of SES, investigations into the neural mechanisms underlying language development have just begun. One limitation of this study involves the behavioral tests chosen. Interpretations of the findings might provide clearer relationships between behavioral performance and neural processes underlying language if tests of more specific language skills, such as vocabulary knowledge and/or semantic integration, or tests that specifically measure different aspects of syntax, such as verb agreements, grammar, and morphology, were included. Future studies would benefit from administration of more specific behavioral measures, as these might help us draw more specific conclusions regarding the relationship between behavioral performance and neural evidence.

Another limitation of the current study is the relatively small number of participants with highly controlled variables. For example, all children were right-handed monolingual speakers of English, with no history of neurological or language impairments. The majority of participants were also of Caucasian background, with limited cultural diversity. Hearing and vision acuity were within functional limits for all participants in the current study. All participants were also living at or below the poverty line in the state of Oregon. This homogenous sample size potentially limits the applicability or generalizability of results to other populations. While we believe that these results reveal important changes in language development over time in children from lower SES backgrounds, future studies can build upon the current project by including larger numbers of participants, more diverse participants, including cultural diversity and linguistic diversity, such as children who are bilingual, and following participants over

longer time periods. Including these additional participants in subsequent studies will enhance our understanding of the complex interactions of environmental and biological factors that affect language development in children. As income inequality continues to exist throughout the world, it is crucial to examine the neural mechanisms that mediate the effect of SES on language development across a broad range of children. The current study is a first step in this direction. However, future studies with more inclusionary factors, will be key to understand the effects of these factors on individual variability in language development and abilities.

## **CHAPTER 6: CONCLUSIONS**

This novel longitudinal study has provided an initial investigation into the influence of SES on neural processes underlying language and the development of these processes over time. The current findings provide initial evidence of maturation of neural indices of language in preschool-age children, from age four to age five, from lower SES backgrounds. Importantly, the maturational patterns appear to be delayed compared to their higher SES peers. These findings underscore the importance of early education for lower SES children to help bridge these differences in language skills as a function of SES and lay the foundation for future studies evaluating the development of neural processes underlying language in children.

## REFERENCES

## REFERENCES

- Adler, N. E., Boyce, T., Chesney, M. A., Cohen, S., Folkman, S., Kahn, R. L., & Syme, S. L. (1994). Socioeconomic status and health: the challenge of the gradient. *American psychologist*, 49(1), 15.
- Barnett, W. S. (2008). *Preschool education and its lasting effects: Research and policy implications*. Boulder and Tempe: Education and the Public Interest Center & Education Policy Research Unit. Retrieved May 2015 from <http://epicpolicy.org/publication/preschool-education/>
- Bates, E., Dale, P. S., & Thal, D. (1995). Individual differences and their implications for theories of language development. *The handbook of child language*, 96-151.
- Bates, E., Thal, D., Finlay, B., & Clancy, B. (1992). Early language development and its neural correlates. *Handbook of neuropsychology*, 7, 69-69.
- Battle, J., & Lewis, M. (2002). The increasing significance of class: The relative effects of race and socioeconomic status on academic achievement. *Journal of Poverty*, 6(2), 21-35.
- Bidell, T. (1999). Vygotsky, Piaget, and the Dialectic of Development. *Lev Vygotsky: Critical assessment*, 1, 262-81.
- Binder, J. R., Frost, J. A., Hammeke, T. A., Cox, R. W., Rao, S. M., & Prieto, T. (1997). Human brain language areas identified by functional magnetic resonance imaging. *The Journal of Neuroscience*, 17(1), 353-362.
- Canseco-Gonzalez, E. (2000). Using the recording of event-related brain potentials in the study of sentence processing. *Language and the brain: Representation and processing*, 229-66.
- Carroll, L. (1883). *Through the looking-glass*. Macmillan and Co; New York.
- Carruthers, P. (2002). The cognitive functions of language. *The Behavioral and Brain Sciences*, 25(6), 657-674.
- Carta, J., Greenwood, C., Walker, D., & Buzhardt, J. (2010). *Using IGDIs: Monitoring Progress and Improving Intervention for Infants and Young Children*. Brookes Publishing Company: Baltimore, MD.
- Choi, S. (2000). Caregiver input in English and Korean: Use of nouns and verbs in book-reading and toy-play contexts. *Journal of Child Language*, 27, 69-96.
- Chomsky, N. (2000). *New horizons in the study of language and mind*. Cambridge University Press.

- Clancy, B., & Finlay, B. (2001). Neural correlates of early language learning. *Language development: The essential readings*, 307-330.
- Clark, E. V. (2003). *First language acquisition*. Cambridge: Cambridge University Press.
- Clark, E. V. (2004). How language acquisition builds on cognitive development. *Trends in Cognitive Sciences*, 8(10), 472-478.
- Clark, A. S., & Lappin, S. (2010). *Linguistic nativism and the poverty of the stimulus*. Hoboken, NJ: John Wiley & Sons, Ltd.
- Crimmins, E. M., Hayward, M. D., & Seeman, T. E. (2004). Race/ethnicity, socioeconomic status, and health. *Critical perspectives on racial and ethnic differences in health in late life*, 310-352.
- Currie, J., & Thomas, D. (1993). *Does Head Start make a difference?* (No. w4406). National Bureau of Economic Research.
- D'Angiulli, A., Herdman, A., Stapells, D., & Hertzman, C. (2008). Children's event-related potentials of auditory selective attention vary with their socioeconomic status. *Neuropsychology*, 22(3), 293.
- Delorme, A., & Makeig, S. (2004). EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods*, 134(1), 9-21. doi: 10.1016/j.jneumeth.2003.10.009
- Devescovi, A., Caselli, M. C., Marchione, D., Pasqualetti, P., Reilly, J., & Bates, E. (2005). A crosslinguistic study of the relationship between grammar and lexical development. *Journal of Child Language*, 32(04), 759-786.
- Donchin, E., Ritter, W., & McCallum, W. C. (1978). Cognitive psychophysiology: The endogenous components of the ERP. *Event-related brain potentials in man*, 349-411.
- Ensminger, M. E., & Fothergill, K. E. (2003). A decade of measuring SES: What it tells us and where to go from here. *Socioeconomic status, parenting, and child development*, 13-27.
- Etard, O., Mellet, E., Papathanassiou, D., Benali, K., Houdé, O., Mazoyer, B., & Tzourio-Mazoyer, N. (2000). Picture naming without Broca's and Wernicke's area. *Neuroreport*, 11(3), 617-622.
- Evans, G. W. (2004). The environment of childhood poverty. *American psychologist*, 59(2), 77.
- Evans, M. D., Kelley, J., Sikora, J., & Treiman, D. J. (2010). Family scholarly culture and educational success: Books and schooling in 27 nations. *Research in Social Stratification and Mobility*, 28(2), 171-197.

- Farah, M. J., Shera, D. M., Savage, J. H., Betancourt, L., Giannetta, J. M., Brodsky, N. L., ... & Hurt, H. (2006). Childhood poverty: Specific associations with neurocognitive development. *Brain research*, 1110(1), 166-174.
- Fischer, K. W. (1980). A theory of cognitive development: The control and construction of hierarchies of skills. *Psychological review*, 87(6), 477.
- Fenson, L., Dale, P.S., Reznick, J.S., Thal, D., Bates, E., Hartung, J.P., Pethick, S., & Reilly, J.S. (1993). *The MacArthur Communicative Development Inventories: User's Guide and Technical Manual*. Baltimore, MD: Paul H. Brookes Publishing Co.
- Friederici, A. D. (2011). The brain basis of language processing: From structure to function. *Physiological Reviews*, 91, 1357-1392.
- Friederici, A. D. (1997). Neurophysiological aspects of language processing. *Clinical Neurosciences*, 4, 64-72.
- Friederici, A. D. (2006). The neural basis of language development and its impairment. *Neuron*, 52(6), 941-952.
- Friederici, A. D., Pfeifer, E., & Hahne, A. (1993). Event-related brain potentials during natural speech processing: Effects of semantic, morphological and syntactic violations. *Cognitive brain research*, 1(3), 183-192.
- Glassman, M. (1994). All things being equal: The two roads of Piaget and Vygotsky. *Developmental Review*, 14(2), 186-214.
- Gleitman, L. R. (1984). Biological predispositions to learn language. In *The biology of learning* (pp. 553-584). Springer: Berlin Heidelberg.
- Grodzinsky, Y., & Santi, A. (2008). The battle for Broca's region. *Trends in cognitive sciences*, 12(12), 474-480.
- Graves, M. F., & Slater, W. H. (1987). The development of reading vocabularies in rural disadvantaged students, inner-city disadvantaged students, and middle-class suburban students. In *annual meeting of the American Educational Research Association*, New York.
- Guo, G., & Harris, K. M. (2000). The mechanisms mediating the effects of poverty on children's intellectual development. *Demography*, 37(4), 431-447.
- Hackman, D. A., Farah, M. J., & Meaney, M. J. (2010). Socioeconomic status and the brain: mechanistic insights from human and animal research. *Nature Reviews Neuroscience*, 11(9), 651-659.

- Hagoort, P., Brown, C., & Groothusen, J. (1993). The syntactic positive shift (SPS) as an ERP measure of syntactic processing. *Language and cognitive processes*, 8(4), 439-483.
- 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(7), 1302-1318.
- Hahne, A., & Jescheniak, J. D. (2001). What's left if the Jabberwock gets the semantics? An ERP investigation into semantic and syntactic processes during auditory sentence comprehension. *Cognitive Brain Research*, 11(2), 199-212.
- Hampton Wray, A. (2015). *Development of neural processes for language in young children: A longitudinal event-related potential study*. Poster session presented at the Society for the Neurobiology of Language Annual Meeting, Chicago, IL.
- Hampton Wray, A., & Weber-Fox, C. (2013). Specific aspects of cognitive and language proficiency account for variability in neural indices of semantic and syntactic processing in children. *Developmental cognitive neuroscience*, 5, 149-171.
- Hart, B., & Risley, T. R. (1995). *Meaningful differences in the everyday experience of young american children*. Baltimore, MD: Paul H. Brookes Publishing Co.
- Head Start Act of 2007, 42 U.S.C. §§ 9801 *et. seq.* (2007).
- Hoff, E. (2006). How social contexts support and shape language development. *Developmental Review*, 26(1), 55-88.
- Hoff, E. (2003). The specificity of environmental influence: Socioeconomic status affects early vocabulary development via maternal speech. *Child Development*, 74(5), 1368-1378.
- Hoff-Ginsberg, E. (1991). Mother-child conversation in different social classes and communicative settings. *Child development*, 62(4), 782-796.
- Holcomb, P. J. (1993). Semantic priming and stimulus degradation: Implications for the role of the N400 in language processing. *Psychophysiology*, 30(1), 47-61.
- 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(2-3), 203-241.
- Holcomb, P. J., & Neville, H. J. (1990). Auditory and visual semantic priming in lexical decision: A comparison using event-related brain potentials. *Language and cognitive processes*, 5(4), 281-312.
- Hollingshead, A. B. (1975). Four factor index of social status.

- Huttenlocher, J. (1998). Language input and language growth. *Preventive Medicine*, 27(2), 195-199.
- Huttenlocher, J., Waterfall, H., Vasilyeva, M., Vevea, J., & Hedges, L. V. (2010). Sources of variability in children's language growth. *Cognitive psychology*, 61(4), 343-365.
- Johansson, B. B. (2000). Brain plasticity and stroke rehabilitation The Willis lecture. *Stroke*, 31(1), 223-230.
- Jonson, J., & Newport, E. (1989). Critical period effects in second language learning: The influence of maturational state on the acquisition of English as a second language. *Cognitive Psychology*, 21, 60-99.
- Justice, L. M., Mashburn, A. J., Hamre, B. K., & Pianta, R. C. (2008). Quality of language and literacy instruction in preschool classrooms serving at-risk pupils. *Early Childhood Research Quarterly*, 23(1), 51-68.
- Kiefer, M., Weisbrod, M., Kern, I., Maier, S., & Spitzer, M. (1998). Right hemisphere activation during indirect semantic priming: Evidence from event-related potentials. *Brain & Language*, 64, 377-408.
- Kuhl, P. & Rivera-Gaxiola, M. (2008). Neural substrates of language acquisition. *Annual Review of Neuroscience*, 31, 511-534.
- Kutas, M., & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature*, 307, 161-163.
- Kutas, M., & Hillyard, S. A. (1980). Event-related brain potentials to semantically inappropriate and surprisingly large words. *Biological psychology*, 11(2), 99-116.
- Lenneberg, E. H. (1967). *Biological Foundations of Language*. New York: Wiley.
- Lindenberg, R., Fangerau, H., & Seitz, R. J. (2007). "Broca's area" as a collective term? *Brain and Language*, 102(1), 22-29.
- Locke, J. L. (1997). A theory of neurolinguistic development. *Brain and Language*, 58(2), 265-326.
- Lopez-Calderon, J., & Luck, S. J. (2014). ERPLAB: An open-source toolbox for the analysis of event-related potentials. *Frontiers in Human Neuroscience*, 8:213. doi: 10.3389/fnhum.2014.00213
- Lourenço, O. (2012). Piaget and Vygotsky: Many resemblances, and a crucial difference. *New Ideas in Psychology*, 30(3), 281-295.

- Luck, S. J. (2005). Ten simple rules for designing ERP experiments. *Event-related potentials: A methods handbook*, 262083337.
- Lupien, S. J., King, S., Meaney, M. J., & McEwen, B. S. (2001). Can poverty get under your skin? Basal cortisol levels and cognitive function in children from low and high socioeconomic status. *Development and psychopathology*, 13(03), 653-676.
- Martin, N., & Brownell, R. (2005) *Test of auditory processing skills, third edition (TAPS-3)*. Novato, CA: Academic Therapy Publications.
- Mezzacappa, E. (2004). Alerting, orienting, and executive attention: Developmental properties and sociodemographic correlates in an epidemiological sample of young, urban children. *Child development*, 75(5), 1373-1386.
- Miller, J. (1981). *Assessing language production in children*. Boston, MA: Ally & Bacon.
- Mills, D. L., Prat, C., Zangl, R., Stager, C. L., Neville, H. J., & Werker, J. F. (2004). Language experience and the organization of brain activity to phonetically similar words: ERP evidence from 14-and 20-month-olds. *Journal of Cognitive Neuroscience*, 16(8), 1452-1464.
- Münte, T. F., & Heinze, H. J. (1994). ERP negativities during syntactic processing of written words. In *Cognitive electrophysiology* (pp. 211-238). Birkhäuser Boston.
- Musso, M., Moro, A., Glauche, V., Rijntjes, M., Reichenbach, J., Büchel, C., & Weiller, C. (2003). Broca's area and the language instinct. *Nature neuroscience*, 6(7), 774-781.
- Narbona, J., & Crespo-Eguilaz, N. (2012). Brain plasticity for language in children and adolescents. *Revista de neurologia*, 54, S127-30.
- Neville, H. J., Mills, D. L., & Lawson, D. S. (1992). Fractionating language: Different neural subsystems with different sensitive periods. *Cerebral Cortex*, 2(3), 244-258.
- Neville, H., Nicol, J. L., Barss, A., Forster, K. I., & Garrett, M. F. (1991). Syntactically based sentence processing classes: Evidence from event-related brain potentials. *Journal of cognitive Neuroscience*, 3(2), 151-165.
- Newport, L. D. (2011). The critical period for language acquisition. *Child Development*, 49(4), 1114-1128.
- Noble, K. G., Norman, M. F., & Farah, M. J. (2005). Neurocognitive correlates of socioeconomic status in kindergarten children. *Developmental Science*, 8(1), 74-87.
- Osterhout, L., & Holcomb, P. J. (1992). Event-related brain potentials elicited by syntactic anomaly. *Journal of Memory and Language*, 31(6), 785-806.

- Paul, R., & Norbury, C. (2012). *Language disorders from infancy through adolescence: Listening, speaking, reading, writing, and communicating*. Elsevier Health Sciences.
- Payne, A. C., Whitehurst, G. J., & Angell, A. L. (1994). The role of home literacy in the development of language ability in preschool children from low-income families. *Early Childhood Research Quarterly*, 9(3-4), 427-440.
- Pineda, D., Ardila, A., Rosselli, M., Arias, B. E., Henao, G. C., Gomez, L. F., ... & Miranda, M. L. (1999). Prevalence of attention-deficit/hyperactivity disorder symptoms in 4-to 17-year-old children in the general population. *Journal of abnormal child psychology*, 27(6), 455-462.
- Rampersaud, G. C., Pereira, M. A., Girard, B. L., Adams, J., & Metz, J. D. (2005). Breakfast habits, nutritional status, body weight, and academic performance in children and adolescents. *Journal of the American Dietetic Association*, 105(5), 743-760.
- Roid, G. H. (2003). *Stanford-binet intelligence scales, fifth edition*. Itasca, IL: Riverside Publishing.
- Schmidt-Kassow, M., Kotz, S.A. (2009). Event-related brain potentials suggest a late interaction of meter and syntax in the P600. *Journal of Cognitive Neuroscience* 21, 1693–1708.
- Semel, E., Wiig, E. H., & Secord, W. A. (2003). *Clinical evaluation of language fundamentals, fourth edition (CELF-4)*. San Antonio, TX: The Psychological Corporation, Harcourt Assessment, Inc.
- Shaffer, D. R., Wood, E., & Willoughby T. (2005). *Developmental Psychology: Childhood and adolescence*. Nashville, TN: Thomas Nelson.
- Silva-Pereyra, J., Conboy, B. T., Klarman, L., & Kuhl, P. K. (2007). Grammatical processing without semantics? An event-related brain potential study of preschoolers using jabberwocky sentences. *Journal of cognitive neuroscience*, 19(6), 1050-1065.
- Silva-Pereyra, J., Rivera-Gaxiola, M., & Kuhl, P. K. (2005). An event-related brain potential study of sentence comprehension in preschoolers: Semantic and morphosyntactic processing. *Cognitive Brain Research*, 23, 247-258.
- Skinner, B. F. (1953). *Science and human behavior*. New York, NY: Simon and Schuster.
- Stevens, C., Lauinger, B., & Neville, H. (2009). Differences in the neural mechanisms of selective attention in children from different socioeconomic backgrounds: an event-related brain potential study. *Developmental science*, 12(4), 634-646.
- Van Petten, C., & Luka, B. J. (2012). Prediction during language comprehension: Benefits, costs, and ERP components. *International Journal of Psychophysiology*, 83(2), 176-190.

- Wadsworth, B. J. (1996). Piaget's theory of cognitive and affective development: Foundations of constructivism (5<sup>th</sup> ed.). White Plains, NY: Longman Publishing.
- Weber-Fox, C. M., & Neville, H. J. (1996). Maturational constraints on functional specializations for language processing: ERP and behavioral evidence in bilingual speakers. *Journal of Cognitive Neuroscience*, 8(3), 231-256.
- Wechsler, D. (2003). *Wechsler intelligence scale for children, fourth edition (WISC-IV)*. San Antonio, TX: The Psychological Corporation.
- White, T. G., Graves, M. F., & Slater, W. H. (1990). Growth of reading vocabulary in diverse elementary schools: Decoding and word meaning. *Journal of Educational Psychology*, 82(2), 281.
- Wiig, E. H., Secord, W. A., & Semel, E. (2004). *Clinical evaluation of language fundamentals - Preschool (CELF-P:2)* (Preschool 2nd edition ed.). San Antonio, TX: The Psychological Corporation: Harcourt Assessment, Inc.