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Neuro-correlates of Word Processing among Four-and-Five-Year-Old Children from Homes Varying in Socio-Economic Status

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Neuro-correlates of Word Processing among Four-and-Five-Year-Old Children from Homes Varying in Socio-Economic Status

by

Wendy Olsen

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctorate of Philosophy
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ABSTRACT

A large body of research relates families’ socioeconomic status (SES) to child language development (Hoff & Tian, 2005). Results from these studies indicate preschoolers from low SES backgrounds may have underdeveloped linguistic foundations required for future academic success (Sirin, 2005; Lacouri & Tissington, 2011). These differences have been said to create a 30 million word-gap between the language experiences of low and middle to high SES children by the age of 3 years. Thus, children who come from lower SES backgrounds often lack the vocabulary knowledge used in school and in textbooks (Hart & Risley, 1995). One index of SES is parental level of education, specifically maternal education (Hoff & Tien, 2005). The current study compared the language processes related to word knowledge of 17 preschoolers who live in lower maternal education attainment (LEA) homes and 17 preschoolers who live in higher maternal education attainment (HEA) homes. An event related potential (ERP) thought to index semantic congruity and comprehension monitoring, the N400, was used. Preschoolers listened to nouns and verbs presented aurally that matched or mismatched with pictures to understand how preschoolers from varying SES backgrounds process linguistic stimuli. Additionally, participants completed an Auditory Oddball Paradigm, or tone judgment task, to evaluate how preschoolers categorized and judged non-linguistic stimuli (e.g., standard and target pure tones). Tone judgment results revealed a Group x region midline interaction, indicating that the groups may recruit different neural resources to judge tones. The noun picture task results indicated that the HEA group processed familiar object labels more robustly and quicker than the LEA group. N400 results did not differ for the verb picture task. These results may indicate that both groups
require more neural resources to process action labels and that perhaps verbs represent a higher level of linguistic complexity for young children. These results provide preliminary evidence of neural linguistic processing differences between preschoolers from varying socioeconomic backgrounds. Because of the lack of minimal differences on associated behavioral measures of language, one may speculate that ERP underpinnings as exemplified in the current study may hold promise for identifying subtle underlying differences in the processing of language among preschoolers.
CHAPTER ONE: INTRODUCTION

Background

Over the last 30 years, there have been significant changes to the work force in low-wealth communities in the United States (Lichter & Jensen, 2002). More than 45 million people (14.5%) live below poverty levels in the United States (United States Census Bureau, 2017). Approximately 22% of this number are US citizens under the age of 18. A recent United Children’s Fund report indicated that the United States had the second highest childhood poverty rate in developed nations (UNICEF, 2013). More than 16.7 million children are living in unstable food secure households (Walker, 2013). Recent government programs have initiated coordinated attempts to address the rising tide of US citizens living in poverty, specifically families with small children (Pathways Out of Poverty, 2010). Arguably, one of the most important and promising means of combating the ill effects of poverty are programs to boost childhood development and especially teaching skills that are related to later academic achievement.

Poverty has been positively linked to household disorganization, which has been strongly linked to children’s academic success (Garrett-Peters, Mokrova, Vernon-Feagans, Willoughby, Pan, & The Family Life Project Key Investigators, 2016). Low income has been powerfully associated to family instability (e.g., single parenthood, parental incarceration, etc.) and level of familial education (Iceland, 2013). Furthermore, poverty can directly affect a student due to the limited availability of resources within the home (e.g., food, time, education, etc.) and school
setting (Lacouri & Tissington, 2011), indicating that poverty has the potential to negatively affect future generations of students and their academic achievement. Children from low SES backgrounds may experience a host of risk factors that have deleterious effects on social, language, cognitive, as well as neural development (Mezzacappa, 2004). Specifically, children from low SES backgrounds may exhibit differences when attending to and processing non-linguistic information (Giuliano, Karns, Roos, Bell, Petersen, Skowron, ... & Pakulak, 2018; Merz, Wiltshire, & Noble, 2018) and processing nouns and verbs (Haebig, Leonard, Ulser, Deevy, & Weber, 2018; Maguire, Schneider, Middleton, Ralph, Lopez, Ackerman, & Abel, 2018) when compared to children from medium to high SES backgrounds.

The Role of Poverty on Academic Success

Some research suggests that one successful avenue out of poverty is early childhood education and parental education (Walker, Wachs, Grantham-McGregor, Black, Nelson, Huffman, Baker-Henningham, Chang, Hamadani, Lozoff, & Gardner, 2011; Werner, 2004; Connell, 1994). One powerful aspect of familial SES is the level of parental education. Parent education and involvement has been positively correlated to academic success in children (Spera, 2005). Barnett (1998) reviewed 38 longitudinal studies examining early education and cognitive development in children living at or below poverty thresholds. Results indicated that public programs aimed at improving quality of education (i.e., Head Start, center-based enrichment, etc.) improved children’s academic achievement and success (e.g., high school graduation and lack of grade retention). However, some studies suggested that a prolonged and robust learning environment is necessary to make long-term academic gains. Burger (2010) investigated effects of early education programs on academic achievement and cognitive performance in children from disadvantaged families. It was posited that early educational opportunities and programs
offered to enhance academic and social skills in preschoolers from disadvantaged backgrounds would improve learning outcomes; results indicated that these programs enhanced social and academic skills. However, it was unclear how long these effects would last. These studies lead to the conclusion that there is an uneven academic and social start point between children who come from different socioeconomic backgrounds.

As more studies indicated that academic achievement differences existed between children from high/medium and low SES profiles, the idea of cultivating early intervention and educational programs to address these differences began to take root. Early investigations focused on language development and how early it began (Hoff & Tien, 2005; Hart & Risley, 1995; 2003). Early childhood is also a critical period for linguistic and cognitive development (Mezzacappa, 2004; Otero, 1997). These cognitive constructs are developed to aid children with future complex communication, such as speaking, reading, and writing (Zauche, Thul, Mahoney, & Stapel-Wax, 2016). Developing communication skills also enables children to advocate and participate in experiences necessary to navigate multifaceted academic situations. However, studies converged on a similar finding: those children from professional and working-class families had more robust and rich language environments than disadvantaged families (Hart & Risley, 1995; 2003; Zauche, Thul, Mahoney, & Stapel-Wax, 2016). Because children are not independent and must rely on others for survival, they enter or avoid poverty by the social, educational, and financial circumstances of their caregivers and/or families (Gunn & Duncan, 1997).

**Early Language Development**

In typically developing children, there are several theories that aim to explain how children develop the different properties associated with a robust language model. Most research
agrees that by age four, young children have acquired a well-developed, sophisticated language network (Bates, Thal, Finlay, & Clancy, 1992). Word comprehension, word production, word combinations, and grammatical development are evident by 48 months of age. However, what is most intriguing is that grammar used to express simple sentence meaning undergoes a complete reorganization between the ages of 4 and 6 years old in the typically developing child. And what is more intriguing is that vocabulary continuously undergoes development into late adulthood as the semantic mental lexicon expands (Bates, Thal, Finlay, & Clancy, 1992). These findings suggest that early language and vocabulary development are extremely critical in laying the foundational groundwork for sufficient language usage in a child’s early course of linguistic development. This begs the question of what factors can help enrich the linguistic development of preschoolers.

If a child’s language environment is not primed for robust and rich language acquisition, the effects can lead to an impoverished lexicon (Zauche, Thul, Mahoney, & Stapel-Wax, 2016). This process of language acquisition can best be explained by the usage-based theory (Tomasello, 2009). The usage-based theory asserts that individuals learn language through linguistic input and influences from how others use language. For a child to learn language, they must be surrounded by multiple contexts of language usage and be able to infer linguistic meaning (Tomasello, 2009). Children begin to create meaningful utterances at an early age (~18 months) to convey messages to communication partners. During the process of language acquisition, children will extract words from larger utterances, such as phrases or multiple sentences, and apply that information to their background knowledge. This process allows children to interact with their communication partners (e.g., caregivers or parents) (Tomasello,
2009; Zauche, Thul, Mahoney, & Stapel-Wax, 2016). It is essential to continue encouraging rich linguistic environments to cultivate advanced linguistic skills.

Most studies identify the preschool years as the pivotal time early language skills required for academic success are cultivated. Early language skills such as alphabet knowledge, phonemic awareness, and semantic knowledge have been positively correlated to future reading and writing skills (Storch & Whitehurst, 2002). These skills have been powerfully linked to academic success which can lead to an enriched quality of life (Whitehurst & Lonigan, 1998; Albert & Keith, 1997; Loschert, 2016). Longitudinal studies determined that early difficulties with oral language skills strongly predict future reading difficulties (Hoff & Tian, 2005; Snow, Burns, & Griffin, 2005; Parish-Morris, Mahajan, Hirsh-Pasek, Golinkoff, & Collins, 2013). Children who are not reading proficiently by third grade are more likely to drop out of high school and encounter significant challenges in society (Annie E. Casey Foundation, 2017). Because of these findings, preschool language and literacy research has been deemed a priority by the US Department of Education (Jacobson, Olsen, Rice, Sweetland, & Ralph, 2001). This study aims to investigate some of these concerns.

**The Role of SES in Language Development**

Hoff (2006) describes several social contexts that help support language and vocabulary development in young children. Ultimately, all human environments help support language development. Not only must children receive linguistic input, as previously reviewed, they must also have opportunities to draw attention to speech, sound segmentation, and have opportunities to make sound-mapping meanings. In the Western culture, this is typically done through maternal engagement.
As previously mentioned, one nuance of SES is familial education. More specifically, a mother’s level of education is strongly correlated to her child’s early use of nouns and verbs (Hoff, 2013). Mothers with greater levels of education (i.e. bachelor’s degree, Master’s, etc.) have been shown to be more responsive to their children during language learning opportunities when compared to mothers with lower levels of education (i.e., Vocational training, associate degree, Some college, etc.) (Vernon-Feagans, Garrett-Peters, Willoughby, Mills-Koonce, & The Family Life Project Key Investigators, 2012; Hoff, 2009). More specifically, the way a mother talks to her child during joint-attention, early word learning, and language learning opportunities is influenced by the level of education she attains. Mothers with lower education attainment (LEA) tend to demonstrate linguistic characteristics that present limited opportunities for language expansion, smaller vocabularies, and tend to talk less overall when compared to mothers with higher education attainment (HEA) (Hoff & Tian, 2005).

In a recent study Fernald, Marchman, and Weisleder (2012) examined how 48 young children from various SES backgrounds processed vocabulary and language behaviorally. Results suggested that 18-month old infants from higher SES backgrounds processed linguistic stimuli more quickly than 18-month old infants from lower SES backgrounds. Children were followed for another 6 months and at 24 months this vocabulary and language gap persisted between groups. Researchers attributed this gap to environmental factors to help explain these differences.

A recent review conducted by Zauche, Thul, Mahoney, and Stapel-Wax (2016) investigated the influence of language nutrition in young children from various socioeconomic backgrounds. Language nutrition is a term used to describe the quality and quantity of language interactions within a child’s language environment. Researchers observed vocabulary differences
between families from high-middle and low SES backgrounds. Children from high-middle SES backgrounds had larger vocabularies than children from low SES backgrounds. Comparatively, researchers speculate that variability in language nutrition is a possible contributing factor for these differences. A convergence of evidence suggests that offering more opportunities for joint-attention interactions, lexical diversity, linguistic productivity, and an increase in gestures during speech can help improve a child’s overall language nutrition.

Altogether there is significant evidence that indicates there are several contributing factors to a child’s long-term academic success, and researchers have yet to identify one causal factor for academic poor academic achievement. There are several studies that have identified poverty as a high-risk factor associated with children’s academic achievement and maladaptive development (Lacour & Tissington, 2011; Hair, Hanson, Wolfe, & Pollak, 2015; Williams, Bryan, & Morrison, 2017; Sattler & Gershoff, 2019). It is equally important to recognize that children from low SES backgrounds are not destined for poor academic achievement. There are several studies that reported children from low SES backgrounds have achieved academic success and experienced successful professional careers (Sattler & Gershoff, 2019; Dudek, Reddy, & Lekwa, 2018). These findings highlight the significance of determining if any differences exist between children from different SES backgrounds vocabulary and language skills in the early school age years.

**Limitations and Extensions of Language Production in Preschoolers**

It is important to understand that vocabulary knowledge supports oral language skills, and oral language skills build the foundation for future reading skills (Borovsky, Kutas, & Elman, 2010; Hart & Risley, 1995; 2003; Torgesen, 2002). Studies examining the nature of word learning, such as Hart and Risley (2003), indicated that by age 3 children who come from a high
SES background have heard 30 million more words than children living in poverty. This is referred to as the 30-million-word gap. Research suggests that children who live in poverty on average have half the vocabulary size than children who have professional parents. Furthermore, vocabulary measures used at age 3 accurately predict results of reading comprehension and other academic measures when children are 9-10 years-old (Walker, Greenwood, Hart, & Carta, 1994; Dickenson & Porche, 2011). This achievement gap tends to widen as children progress through their school-age years; perhaps due to the advanced academic language in textbooks. Behavioral evidence suggests that differences in language and other cognitive constructs exist among SES backgrounds (Noble, McCandliss, & Farah, 2007; Noble, Houston, Kan, & Sowell, 2012; Weldon, 2014). Maguire and colleagues (2018) investigated the relationship between SES and predictive word learning in the later school years and what mediates the relationship. Interestingly, results indicated that vocabulary knowledge mediated the relationship between SES and word learning in grade school. Furthermore, researchers suggested that future word learning is dependent on children’s ability to accurately use known words in multiple contexts. Beck and colleagues (2013) suggest that there are different levels of word mastery. Specifically, a child may demonstrate shallow mastery of a word when they cannot define the word but detect when the word has been used incorrectly. This phenomenon can be observed when children are being assessed behaviorally using standardized tests.

Although standardized tests and behavioral performance reflect an overt response to language assessment, they fail to illuminate the processing involved “behind the curtain,” or more specifically, at a neural level. Do behavioral measures account for the majority of observed vocabulary knowledge and mental lexicon development in preschoolers? If so, what differences exist at a neural level among children from different SES backgrounds that may explain
differences in their vocabulary knowledge or semantic lexicons? What other ways are available to noninvasively measure covert responses to vocabulary knowledge between HEA and LEA preschoolers?

**Neuro-Imaging Studies of Real-Time Language Production in Preschoolers**

Mezzacappa (2004) hypothesizes that cognitive-linguistic differences observed in low SES children may be due to the underdevelopment of the neurological underpinnings responsible for language acquisition and cognition. Two fMRI studies conducted reported SES differences in the function of the left fusiform (Noble, Wolmetz, Ochs, Farah, & McCandliss, 2006; Noble, Farah, & McCandliss, 2006; Stevens, Lauinger, & Neville, 2009) and the left inferior gyrus (Raizada, et al., 2008). Romeo, Leonard, Robinson, West, Mackey, Rowe, and Gabrieli (2018) conducted an fMRI study that demonstrated that the quality of children’s home language environments are strongly associated with neural language processing. A follow-up fMRI study by Romeo and colleagues (2018) showed that greater child-adult turn taking in conversations is strongly associated with more white matter connectivity in the left arcuate and superior longitudinal fasciculi near their anterior termination at Broca’s area in the left frontal cortex, the area of the brain strongly associated with language processing and production. Structural neuroimaging has reported smaller hippocampal, left inferior gyrus, and amygdala regions in children who come from lower SES backgrounds (Coch, Sanders, Neville, 2005; Hanson, et al., 2011; Noble, et al., 2012). Other studies have found that children from lower SES backgrounds have significantly less cortical gray matter or thinner cortex than children from high SES backgrounds (Jordonog, Altarelli, Monzalvo, Fluss, Dubois, Billard, Dehaene-Lambertz, & Ramus, 2012).
Although structural differences have been observed between children from low and high SES backgrounds, it is important to note that structural differences do not necessarily equate to functional differences. To better understand cognitive-linguistic functioning in children from varying SES backgrounds, other methods that have been used such as continuous electroencephalogram (EEG) and event related potentials (ERPs). Data from these methods revealed that children from lower SES backgrounds have lower frontal gamma waves and prefrontal activation when compared to children from higher SES backgrounds (Tomalski, Moore, Ribeiro, Axelsson, Murphy, Karmiloff-Smith, Johnson, & Kushnerenko, 2013; Kishiyama, Boyce, Jimenez, Perry, & Knight, 2009). These results indicated that children from lower SES backgrounds were not as neural-conscious as children from a high SES background. Another study examined electroencephalogram (EEG) function among Mexican preschoolers from different SES backgrounds (Otero, 1997). Results indicated that there were significant differences in alpha and beta waves between children from low and high SES. Alpha waves are thought to measure a relaxing state, while beta waves are thought to measure an alert state (Muthukumaraswamy, 2019). A follow-up study by Otero and colleagues (2003) indicated that the preschoolers from low SES backgrounds did not demonstrate similar EEG waves as the preschoolers from the high SES group, 5 years later. Children from low SES had significantly attenuated alpha and beta amplitudes when compared to children from high SES backgrounds. Additionally, researchers have found that children from low SES backgrounds pay more attention to irrelevant information or stimuli compared to children from high SES backgrounds (Stevens, Lauinger, & Neville, 2009; Skoe, Krizman, & Cross, 2013; Neville, Stevens, Pakulak, Bell, Fanning, Klein, & Isbell, 2013). Although these studies help enhance our knowledge about neural differences in preschool children from varied SES backgrounds, there is a substantial gap
in understanding how preschool children process oral language skills and vocabulary at a neural level (Mills, Coffey-Corina, & Neville, 1994; Pavlakis, Noble, Pavlakis, Ali, & Frank, 2015).

Although behavioral methods are commonly used to assess language and word knowledge in preschoolers, these measures provide limited information on how children may differ in their real-time processing of language and word knowledge. For example, vocabulary learning may differ among LEA and HEA preschoolers in intervention research, but the underlying reasons are left to speculation (Kelley & Goldstein, 2014). Meyer et al. (1988) argue that behavioral data describe the final output of cognitive and language processing but does “not offer an especially close look at underlying component processes” (p. 41). More sensitive information about differences in vocabulary knowledge and language processing may be garnered utilizing neurological processing measures.

One advancement has been to use brain event-related potentials (ERPs) to investigate real-time language processing with increasing precision. Scalp-recorded ERPs reflect at least some of the electrophysiological activity generated by the brain as people process stimuli, make decisions, and regulate behavior. More specifically, ERPs are the consistent pattern of electrophysiological responses elicited by specific stimuli during continuous EEG recordings. As described in Hagoort and Kutas (1995) behavioral data are the final result of stimulus processing and, ERPs can detect the online effects of linguistic stimulation. Thus, ERPs may make it possible to monitor the immediate consequences of an experimental manipulation (e.g., the semantic violation that occurs when an unexpected word is encountered with a stimulus item or the brain’s response to different auditory pure tones).

Since the late 1990s, ERPs have been used to investigate hypotheses about mechanisms of language in typically developing children. Averaged ERP activity can be decomposed into
several different components, many of which reliably index specific language or cognitive processes (Otten & Rugg, 2005; Luck, 2014). The ERP of interest for the current study is the N400. The N400 occurs approximately 400 ms following the presentation of a stimulus item and is negative in its polarity, relative to a 100 ms baseline. It is associated with visual and auditory word and sentence comprehension (Kutas & Hillyard, 1980). The N400 has been shown to index the magnitude to which words positioned at the end of a sentence agree with the sentence’s preceding context.

The N400 effect is elicited by a cross-conditional comparison (Kutas & Federmeier, 2011), meaning participants are presented with a congruent and incongruent condition. In the congruent condition, participants are presented with a stimulus item that semantically agrees with the preceding context or primer. In the incongruent condition, the participants are presented with a stimulus item that does not semantically agree with the preceding context. The amount of attention required to elicit the N400 is still uncertain (Osterhout & Holcomb, 1995). However, the N400 can be elicited passively, meaning no manual response from participants is required, by presenting linguistic incongruity (Conolly & Phillips, 1994; Key, Dove, & MacGuire, 2005). The N400 is typically displayed as difference wave (subtracting a congruent ERP condition from an incongruent ERP condition) (Kutas & Federmeier, 2011). Suspected neural generators of the N400 include several cortical areas, but has been primarily studied in adults. Halgren and colleagues (2002) describe an activation pattern for the N400 that begins primarily at Wernicke’s area, travels to anterior temporal sites, to Broca’s area, to dorsolateral prefrontal cortices, and then to anterior orbital and frontopolar cortices within ~120 ms. Lau, Phillips and Poeppel (2008) generally support activation near the posterior middle temporal cortex for the N400 effect. This phenomenon has been elicited in populations across the lifespan using different methods.
examining semantic incongruity. For the purposes of this study we reviewed the methods eliciting the N400 in young children using word stimuli to inform our use of a similar paradigm.

Early nouns and verb acquisition are crucial for future vocabulary and oral language development. Nouns are a word class that allow individuals to label and reference objects within their environment and share meaningful experiences with communication partners. Mastering the acquisition of this word class allows communicators to discuss and explain objects that are not within their immediate environment and can lead to the development of compensatory strategies to acquire novel vocabulary. Verbs, or action words, are meant to provide word labels for a sequence of events and have been referenced as the gateway to grammar. Action words are an important word class, or type of vocabulary, necessary to describe how a noun acts upon another object, place or thing. Without verbs or nouns, communicators could not describe how the world around them functions or operates. So how do humans acquire and integrate this knowledge into their mental lexicon? Perhaps it is based on the frequency of how often the noun and verb is used within their native language and home environment. Some ERP studies have attempted to capture information regarding this phenomenon in young children.

Friedrich and Friederici (2004) investigated the N400 in 17-19 months old using a picture matching paradigm. On each trial children saw a picture that depicted a high frequency and high agreement noun. Essentially, this means that the object depicted in the picture would be very recognizable and would have a very familiar word label (e.g., ball, dog, cat, etc.). An adult speaker named the picture correctly or incorrectly. Results indicated that the children elicited an N400 effect to pictures that were named incongruently. These results indicate that children can detect semantic incongruity as early as 17 months old. A similar study was conducted with monolingual French children 18-24 months old (Rama, Sirri, & Serres, 2013). Researchers used
pictures depicting nouns to elicit the N400. Results indicated that children with high vocabulary demonstrated enhanced N400s compared to those children with lower vocabulary scores.

Pace, Carver, & Friend (2013) examined how 24-month-olds and adults processed action events using the N400. Each participant, child and adult, were exposed to an intact and interrupted action sequence. Results indicated that the adult ERPs reflected a simultaneous multi-level processing sequence. The children’s ERP results reflected a prolonged duration of the interruption-effect. Researchers suggested this may be due to a spread-activation process for the action retrieval in the mental lexicon.

Tan and Molfese (2009) used ERPs to determine if preschoolers could determine the difference between nouns and verbs. Target words were animated videos that utilized a match-mismatch paradigm. Researchers presented 8 stimuli items with congruent and incongruent labels to 22 preschoolers. Results indicated that preschoolers differentiated between nouns and verbs and that using an auditory-visual match-mismatch paradigm can be a powerful tool in assessing noun and verb knowledge in preschoolers.

Haebig, Leonard, Usler, Deevy and Weber (2018) sought to elicit the N400 in typically developing preschoolers and preschoolers with specific language impairment (SLI) by presenting pictures of objects with a match-mismatch label (e.g., dog – dog vs. dog – pen). Results indicated that typically developing children and SLI children elicited similar N400 profiles of common objects. However, the typically developing group better demonstrated a late positive component, a P600, which was interpreted to be indicative of a more developed lexicon than their SLI counterparts. Abel and colleagues (2018) examined word learning processes in grade school children, 11-14 years old, by utilizing the N400. Each participant completed a word learning task in which researchers presented target words with sentences that had embedded meanings.
Results indicated that when children were able to decipher word meaning from sentences, they demonstrated a larger N400 amplitude when compared to words they did not know. Unknown words elicited an “incongruent” effect. Overall, the N400 has contributed insight into how young children process linguistic stimuli. However, there is a gap in the literature about how preschoolers from varying socioeconomic backgrounds process nouns and verbs.

**Current Study**

Although there is some information regarding real time noun and verb label processing in young children attending grade school (Duta & Plunkett, 2012; Friedrich & Friederici 2004, 2008; Gliga, Volien, & Csibra, 2010; Abel et al., 2018), there is little known about how preschoolers from varying socioeconomic backgrounds process linguistic stimuli, specifically nouns and verbs, using ERPs. This study used event-related potentials (ERPs) to measure the brain’s response to stimulus items, specifically black line drawings of high agreement and high frequency nouns and verbs. Previous research used pictures to elicit the N400 reliably and found that it was semantically analogous to words (Nigam, Hoffman, & Simons, 1992). We utilized a modified version of Haebig and colleagues (2018) method to examine preschoolers’ language processing of nouns and verbs using black line pictures. The ERP component of interest was the N400. The N400 has demonstrated sensitivity to semantic agreement and comprehension monitoring (Kutas & Hillyard, 1980; 1983; Kutas, et al., 1987), and has been used previously with toddlers and preschoolers (Friedrich & Friederici, 2004, 2008; Rama, Sirri, & Serres, 2013; Friend & Pace, 2011; Haebig et al., 2018)
Summary and Research Questions

The purpose of this study is to answer specific questions regarding preschoolers’ language processing at a neural level when listening to familiar nouns and verbs being labeled. Our first set of research questions reflected ERP responses under control conditions. First, do HEA and LEA preschoolers demonstrate similar performance on a tone judgment task, as reflected by the P3b, using a pure tone auditory oddball paradigm? We predicted similar wave patterns, amplitudes and latencies in each group, which would indicate that, in the absence of linguistic stimuli, both groups categorize auditory stimuli similarly. Second, do HEA and LEA preschoolers demonstrate similar semantic incongruity effects, as reflected by the N400, using a modified picture-noun task from Friedrich and Friederici (2004)? Our hypothesis was that both groups of preschoolers will demonstrate differences in N400 amplitude and latency. That is, HEA preschoolers may process noun stimuli more quickly and robustly than the LEA preschoolers. This hypothesized result would demonstrate that HEA and LEA preschoolers identify and process congruent and incongruent familiar nouns differently. Behavioral measures will help lend evidence to clarify the neural observations.

Secondly, we are interested in how the brain responds to familiar linguistic stimuli. Specifically, we are interested in how the brain responds to noun-label and verb-action associations. There is a fundamental gap in the literature that examines how preschoolers develop noun-label and verb-action associations within their mental lexicons and if differences exist between preschoolers who come from varied SES backgrounds. The N400 offers the opportunity for online language processing and passive comprehension monitoring in this population. This is especially ideal for those children who may lack the oral language skills to offer overt responses. Our hypothesis is that LEA preschoolers will exhibit smaller N400
amplitudes and longer latencies than HEA preschoolers, which may be indicative of smaller semantic lexicons. Differences may be accentuated for verbs, as it may be more difficult to process actions.

Third, the current study will examine whether HEA and LEA preschoolers respond similarly on behavioral tasks, when asked to press a button in response to the incongruent word labels. Our hypothesis is that HEA preschoolers will produce quicker and more accurate button responses than LEA preschoolers.

Fourth, we will examine the relationship between the N400 measures and the behavioral measures (i.e., language scores). We expect that variables will share significant associations. More specifically, we hypothesize that the N400 amplitude will be most strongly correlated to language scores. We expect to see these associations based on previously reported behavioral and EEG results in older children (Maguire, Abel, Schneider, Fitzhugh, McCord, & Jeekumakumar, 2015; Abel, Schneider, & Maguire, 2017). Additionally, we asked parents to complete a survey of how often their child uses the stimuli words utilized in the study, at home. We then measured how these reports correlated to the N400 amplitude and latency values. We expected to see these relationships to be present and stronger in the HEA group when compared to the LEA group. Findings from the current study will help inform the scientific gap regarding preschoolers’ and young children’s online linguistic processing of picture-word stimuli in a match-mismatch paradigm aimed to elicit the N400.
CHAPTER 2: METHOD

Participants

Forty-one participants were screened for inclusion in the current study. Participants were recruited from the local Tampa Bay area. Inclusion criteria were based on a wide range of typical linguistic, social, cognitive, neurological, and biological development. Participants were required to complete screening measures before EEG recording took place.

Participants were excluded from the study if: 1) they have a formal diagnosis of a speech or language impairment, 2) were currently taking any medicines that could alter cognition (e.g., stimulants, some pain relievers, anti-depressants, sleep aids), 3) had experienced neurological trauma (e.g., concussion, hydrocephloplagia, cephaloplagia, epilepsy, traumatic brain injury, etc.), 4) enrolled in speech services, 5) bilingual, 6) received a standard score lower than 75 on the standardized language assessments administered, 7) were left handed, 8) were below 4;0 years of age or above 5;11 years of age, or 9) failed the hearing or vision screenings. Participants were included if: 1) they were 4;0 to 5;11 years of age, 2) monolingual English speakers, 3) received a standard score of 75 or higher on the standardized assessments administered, 4) right handed, 5) passed a bilateral hearing screening, and 6) passed a vision screener with normal or corrected to normal vision. It should be noted that some children included in the study were attending kindergarten. However, they were evenly distributed between groups: 3 in the LEA group and 3 in the HEA group.
Before arriving, 41 families were interviewed about their home language environments to ensure participants were monolingual English speakers, were not hearing impaired, and were right handed. Upon arrival, 37 families were given an informed consent document. Participants were 17 HEA and 17 LEA, 4 to 5 years old, children recruited locally. The mean age was $M = 59.8$ months for the HEA group ($SD = 8.63$) and $M = 60.94$ months for the LEA group ($SD = 5.47$). Age was not statistically significant, $t(1, 27.08) = 1.99$, $p = 0.64$, between groups. Each participant’s legal guardian provided written informed consent prior to the study. Children provided verbal assent. During the informed consent process, parents and/or legal guardians were informed that if their child were to complete the study they would receive a $25$ WalMart gift card for their participation. However, if their child began the study and withdrew at any time they would receive a $12.50$ WalMart gift card as compensation for their travel. Children provided verbal assent. Despite parental consent, 3 children from an LEA background withdrew due to lack of assent prior to beginning the study and 4 (3 LEA, 1 HEA) withdrew after the study began. Demographic questionnaires were administered to determine handedness, income, level of education, of all adults, in the home, and other in-home factors. At time of testing, the 34 participants were reportedly in good health, had no history of neurological injury or disease, were not taking medications that could potentially alter cognitive function, and were monolingual native-English speakers. Participants were then screened for their vision, hearing, core language, and vocabulary scores. Each child had normal or corrected-to-normal vision, and had normal hearing following the administration of the screeners. The Peabody Picture Vocabulary Test, Fourth Edition, Form B (PPVT-4; Dunn & Dunn, 2007) was administered to assess receptive vocabulary knowledge. The Clinical Evaluation of Language Fundamentals
Preschool-Second Edition (CELF-P2; Wiig, Secord, & Semel, 2004) Core Language subtest was administered to garner information regarding the participants’ language abilities.

**Table 1.** Descriptive data for HEA and LEA preschoolers.

<table>
<thead>
<tr>
<th></th>
<th><strong>HEA</strong> (N=17)</th>
<th><strong>LEA</strong> (N=17)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (in months)</strong></td>
<td>59.76 (SD = 8.63)</td>
<td>60.94 (SD = 5.47)</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td>13 (Males: 4)</td>
<td>7 (Males: 10)</td>
</tr>
<tr>
<td><strong>CELF-P2 SS</strong></td>
<td>102.76 (SD = 9.00)</td>
<td>100.06 (SD = 11.15)</td>
</tr>
<tr>
<td><strong>PPVT-4 SS</strong></td>
<td>114.76 (SD = 13.15)</td>
<td>105.71 (SD = 13.41)</td>
</tr>
<tr>
<td><strong>Noun Parent Survey Scores</strong></td>
<td>329.00 (SD = 41.65)</td>
<td>329.12 (SD = 45.85)</td>
</tr>
<tr>
<td><strong>Verb Parent Survey Scores</strong></td>
<td>325.06 (SD = 39.89)</td>
<td>310.65 (SD = 49.78)</td>
</tr>
</tbody>
</table>

*Note* SS = Standard Score

The participants were then divided into two groups based on their mothers’ highest level of education attained. If the highest level of education attained was less than a college degree, then those participants were placed in the LEA group (e.g., high school diploma, vocational degree, some college but no degree was obtained). If the highest level of education attained was a college degree (e.g., associate degree, bachelors, etc.), then those participants were placed in the HEA group. To further assess factors that contribute to SES and academic achievement, an informal qualitative survey examining chaos factors associated with poverty was collected and used as descriptive information (see Schrier, Roy, Frimer, & Chen, 2014; Evans, Gunnella, Marcynyszyn, Gentile, & Salpekar, 2005; Johnson, Martin, Brooks-Gunn, & Petrill, 2008).

Noun and verb surveys were distributed to parents to gather information regarding how frequently their child produced stimulus words at home (see Appendix I). Parents were asked to rate each word on a 5-point Likert scale: 5 = A lot, 4 = Fairly Often, 3 = Sometimes, 2 = Almost Never, and 1 = Never. Each survey contained 80 words and the ratings for each word were
Thus, the best possible score was 400 and the worst possible score was 80 for each participant.

**Stimuli**

To elicit an N400, black line drawings were taken from the International Picture Naming Project (IPNP; Szekely, Jacobsen, D'Amico, Devescovi, Andonova, Herron, Lu, Pechmann, Pleh, Wicha, Federmeier, Gerdjikova, Gutierrez, Hung, Hsu, Iyer, Kohnert, Mehotcheva, & Bates, 2004; Szekely, D’Amico, Devescovi, Federmeier, Herron, Iyer, Jacobsen, Arevalo, Vargha, & Bates, 2005; Szekely, D’Amico, Devescovi, Federmeier, Herron, Iyer, Jacobsen, & Bates, 2003; Bates, D’Amico, Jacobsen, Szekely, Andonova, Devescovi, Herron, …& Tzang, 2003). Stimuli for the picture experiments included 40 black-line drawings of common objects and actions. Each drawing elicited a single noun and verb label, in English, with 80% or better agreement, according to norms from the IPNP (Szekely et al., 2004; 2005; 2003; Bates et al., 2003). Each of the 40 drawings, per condition, were assigned an incongruent and congruent primer. Each incongruent label occurred at least three trials following the congruent primer. Incongruent primers were rated by a professional focus group comprised of two experienced teachers, two speech language pathologists, and two research assistants. The group determined that the incongruent labels were not phonologically or semantically related to the picture-noun or picture-verb using a 5-point Likert scale (1 = unrelated; 5 = highly related). An average score for phonemes of 1.37 and an average score for relatedness 1.21 was obtained. Additionally, there were 20 control words that were presented twice with the correct label on each presentation to deter pattern learning in each experiment (a total of 40 control words). A manual response is not required from participants to elicit the N400 ERP component. However, to ensure engagement participants were asked to press a button when they heard the incongruent label. Word labels
presented with the picture stimuli were recorded using a Zoom H1 Digital Recorder. Word labels were edited and pure tones for the oddball paradigm were created and edited in Adobe Audition CC 2018 at 44.1 kHz with a 16-bit sampling rate. Stimuli were recorded in a sound attenuated booth. The average intensity for stimulus items was set at 80 dB SPL, which was consistent with previous literature (Friedrich & Friederici, 2004; 2006; Haebig et al., 2018).

Stimuli for the auditory oddball paradigm were 1000Hz and 1500Hz pure tones, each 100ms in duration. The standard tone was 1000Hz. The target tone, or oddball tone, was 1500 Hz. Participants heard a total of 130 randomized trials utilizing the E-Prime Psychological Software. Participants heard 104 trials, or 80% of trials, of the standard tone. Twenty-six trials, or 20% of trials, were target tones. A manual response is not required to elicit the P3b ERP component. However, to ensure engagement participants were asked to press a button when they heard the target tone.

**Procedure**

Once the informed consent and assent process was completed, participants began the screening process. Each participant was administered a hearing (ASHA Guidelines, 2017) and vision screener. After passing the hearing (ASHA Guidelines, 2017) and vision screening procedures, participants were administered the CELF-P2 and PPVT. While participants were assessed, parents were asked to complete demographic questionnaires and complete the noun and verb home usage surveys.

Following screening measures, testing had three components. Participants entered a sound attenuated booth and were administered one of the three components: 1) oddball tone
monitoring task, 2) noun-picture task, and 3) verb-picture task. Tasks were counterbalanced across participants to eliminate any presentation order effects.

Each participant completed a simple oddball tone monitoring task in which low (1000Hz) and high (1500Hz) pure tones, each 100 ms in duration, were presented continuously spanning 500 ms. The probability of standard versus target tones were 80% versus 20%. Participants were instructed to listen to the tones presented. One hundred and thirty randomized trials comprised this task, ~6 minutes in duration. Continuous EEG were recorded at the scalp during this task. This is further described in the Recording and Apparatus section.

Each participant completed the noun-picture experiment. Each trial included a crosshair (+) presented for 500 ms, which was then replaced by a picture of a common object. The object remained on the computer screen for 1000 ms. Following 500 ms of picture onset, a native English speaker named the picture congruently or incongruently. Words were either correct names of the pictured objects or names of other objects, that is, either congruous or incongruous to the picture. Incongruous words were not semantically or phonologically related to the pictured objects (e.g. house–sheep or apple–speaker). Congruous and incongruous words stated to the same picture always differed in their first phonemes and spanned by at least 3 trials. This experiment had a total of 120 trials and was ~7 minutes. Continuous EEG was recorded during this task as described in the Recording and Apparatus section.

Participants were administered the verb-picture task. This experiment began with a crosshair (+) presented for 500 ms, replaced by a picture of a subject performing a common action. The picture remained on the computer screen for 1000 ms. Following 500 ms of picture onset, a native English speaker named the action congruently or incongruently. Words were either correct actions or incorrect actions, that is, either congruous or incongruous to the picture-
subject. Incongruous words were not semantically related to the pictured objects (e.g. hug–spy or look–hide). Congruous and incongruous words stated to the same picture always differed in their first phonemes and spanned by at least 3 trials. This experiment had a total of 120 trials and was ~7 minutes. Continuous EEG was recorded during this task as described in the Recording and Apparatus section.

**Recording and Apparatus**

A stationary, cushioned chair and stool, to minimize excessive foot movements, were provided for each participant to sit in, and an additional chair was provided for legal guardians. Legal guardians were encouraged to sit with participants in the sound attenuated booth to reduce anxiety and ensure procedural compliance. Each participant sat in a sound-attenuating booth facing a 19-inch monitor. Pictures and visual stimuli were presented on a computer screen inside the booth. Maximum onscreen height and width of pictures measured ~15 centimeters. Viewing distance was ~60 cm. E-prime (Psychological Software Tools, Version 2.0 Professional) controlled the experiment. Words and pure tones were presented through insert earphones using disposable earbuds.

Each participant wore a neoprene Quik-Cap (Compumedics, 2018) fitted with 64 active recording electrodes positioned following the International 10-20 system (Klem et al., 1999; see Figure 1). Electrodes were referenced to the REF site during recording and the averaged mastoid electrodes M1 and M2 offline. Two bipolar-referenced vertical electro-oculograph (VEOG) electrodes, and two bipolar-referenced horizontal electro-oculograph (HEOG) electrodes, recorded electro-ocular activity. EEG was recorded continuously from the scalp at a sampling rate of 1000 Hz, controlled using Curry software, Version 7.12.2 (Compumedics, Neuroscan,
Electrode impedance was 20 kOhm or less at all cites. Continuous EEG data were low-pass filtered at 30 Hz and high pass filtered at .5 Hz offline.

**Continuous EEG Data Analysis**

Continuous EEG data were preprocessed in the Curry 7 analysis suite (Compumedics, Charlotte, North Carolina) before being analyzed in MATLAB (The MathWorks & Simulink, Natick, MA, USA). Data were analyzed using the ERPLAB plugin (Luck & Lopez-Calderon, 2010) to the EEGLAB toolbox (Delorme & Makeig, 2004) for MATLAB. Trials containing ocular artifacts were rejected if the peak-to-peak voltage between -100 and 400 ms exceeded 100μV for either of the EOG channels or 150μV for any of the EEG channels.

**EEG-to-ERP Reduction.** The continuous EEG record of each participant for the noun picture task, verb picture task, and for the simple tone judgment task, were segmented into epochs. Each epoch comprised of EEG data recorded from each electrode during presentation of the tone or label on each trial, after stimulus onset. To retain as many trials as possible (Picton et al., 2000), a Principal Component Analysis (PCA)-based (Bell & Sejnowski, 1995), ocular artifact correction procedure (Glass, Frishkoff, Greenwood, McCune, Kaminski, McConnell, & Atwater, 2004) was implemented. Accepted EEG trials were averaged together, separately for each condition. For the amplitude and latency data, no fewer than 14 artifact-free trials were accepted into the set of ERP averages for each participant in each experiment (Picton et al., 2000).

ERP grand average waveforms and individual subject data for each experiment were reviewed prior to statistical analysis. Grand average ERP waveforms are shown for each Group (HEA vs LEA), for each Tone Type (Standard, Target), and Noun and Verb condition (Congruent, Incongruent).
Analysis

**P300 Analysis.** The EEG epochs related to standard and target tones in the auditory oddball paradigm were sorted by ERPLAB, and epochs for each channel and condition were averaged. We anticipated observing a positive peak between 300 and 700 ms, most prominently in the posterior parietal channels for both conditions (Standard, Target) but a more positive peak for the target tone condition. This time window has been previously explored and reported in the literature (Courchese, 1977; Ladish & Polich, 1989; Polich, Ladish, & Burns, 1990). Next, a difference wave (Target ERPs minus Standard ERPs) was computed within ERPLAB to attenuate activity unrelated to the P300, as described by Luck (1998). Peak amplitudes were extracted at 28 targeted sites. The 28 electrodes included for analysis were combined by Laterality and Region of Interest: F7, FC3, FC5, FC1 (Left Frontal); T7, C5, C3, CP1 (Left Central); P5, P3, P1, O1 (Left Parietal); Fz, Cz, Pz, Oz (Midline); F4, FC2, FC4, FC6 (Right Frontal); C4, C6, T8, CP2 (Right Central); and P6, P4, P2, O2 (Right Parietal). A four-way mixed ANOVA with Group entered as a between-subjects factor (HEA, LEA), with Condition (Standard, Target), Laterality (Left, Right), and Region (Frontal, Central, Parietal) as the within-subjects factor was calculated. An additional, separate analysis of Midline electrodes was carried out. Statistically significant interactions were followed-up with Bonferroni-corrected pair-wise comparisons.

Next, difference scores were then submitted to a mixed ANOVA with Group as a between-subjects factor with two levels (HEA, LEA), with Laterality and Region as the within-subjects factor as previously described. All significant interactions were followed up with the appropriate statistical test and discussed below.
N400 Analysis. The EEG epochs related to congruent and incongruent conditions in the noun-picture and verb-picture experiment were sorted by ERPLAB, and epochs for each channel and condition were averaged. We anticipated observing a negative peak between 400 and 1000 ms, most prominently in central and parietal channels for both conditions but a more negative peak for the incongruent condition. The peak amplitude and peak latency for congruent and incongruent conditions were calculated separately for each child and for each channel of interest mentioned above using time windows. After consulting the literature, an a priori method of measurement was adopted. Hence, the amplitude and latency at single time points (the peaks) were analyzed using consecutive 200 ms time windows: 400-600 ms, 600-800 ms, and 800-1000 ms. Time windows were determined to be the best method to capture the widely reported slow moving negative wave observed in young children when eliciting the N400 (Friedrich and Frederici, 2004; 2006; Pace, Carver, & Friend, 2013).

To examine whether the amplitudes for each peak were significantly more negative for incongruent than congruent conditions, peak amplitudes for the N400 (noun pictures) and N400 (verb pictures) were entered into separate mixed ANOVAs with Condition (Congruent, Incongruent), Region (Frontal, Central, Parietal), Time (400-600, 600-800, 800-1000) and Laterality (Left, Right) as a within-subjects variable, and Group (HEA, LEA) as a between-subjects variable. For each ANOVA, an alpha value of .05 was used for main effects and interactions. Selection of electrode sites was guided by previous research (Haebig et al., 2018, Friedrich & Friederici, 2006; 2004; Pace, Carver, & Friend, 2013) using match-mismatch paradigms with young children. The 28 electrodes included for analysis were combined by Laterality and Region of Interest: F7, FC3, FC5, FC1 (Left Frontal); T7, C5, C3, CP1 (Left Central); P5, P3, P1, O1 (Left Parietal); Fz, Cz, Pz, Oz (Midline); F4, FC2, FC4, FC6 (Right Frontal).
Frontal); C4, C6, T8, CP2 (Right Central); and P6, P4, P2, O2 (Right Parietal). An additional analysis of Midline electrodes was carried out. Statistically significant interactions were followed-up with Bonferroni-corrected pair-wise comparisons.

**Behavioral Data Analysis**

A t-test was conducted to evaluate differences in performance on the accuracy and reaction time measures of the button press between the HEA and LEA preschoolers. It should be noted that these results should be interpreted with caution and will be subject to further elaboration in the Discussion portion of this paper. Results from the t-test were not entered into the correlational matrix.

**Tone Judgment Task Behavioral Data.** For the simple oddball task, tone judgment accuracy and tone judgment RT were analyzed separately. Tone judgment on each trial was correct if the participant withheld responding to a standard (Low) tone or pressed the button to a target (High) tone within the time-out period (1000 ms). Tone judgment accuracy data were submitted to a t-test analysis to determine if performance differences existed between the HEA and LEA group. Incorrect trials were removed from ERP analysis. Additionally, the time it took participants to press the button was recorded and submitted to a t-test analysis.

**Noun and Verb Picture Task Behavioral Data.** Button press judgment on each trial was correct if the participant withheld responding to a congruent and control picture/label or pressed the button in response to an incongruent picture/label within the time-out period (2000 ms). A t-test analysis was applied to picture judgment accuracy to determine if performance differences existed between the HEA and LEA group. Incorrect trials were removed from ERP analysis. Additionally, the time it took participants to press the button was recorded and submitted to a t-test analysis.
ERP and Behavioral Data Relations

Following the examination of mean performance differences, a correlational matrix examined if neurophysiological and behavioral variables shared significant relations (see Table 3). Relations of interest were performance scores on each behavioral measure (parent surveys, CELF-P2, PPVT) and the amplitude and latency of ERP measures from the tone judgment, noun, and verb experiments. Correlations were calculated among peak latency and peak amplitudes and the behavioral measures (standardized scores of language and vocabulary assessments and parental surveys of home language environment). These correlations enabled us to evaluate the hypothesis that overall amplitude and/or latencies of the N400 relates to word frequency, accuracy, and individual language scores.
Figure 1. The electrode array used for EEG recordings.

Table 2. Electrodes and Regions of interest.

<table>
<thead>
<tr>
<th>Laterality/Region</th>
<th>Electrodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Frontal</td>
<td>F7, FC5, FC3, FC1</td>
</tr>
<tr>
<td>Right Frontal</td>
<td>F4, FC6, FC4, FC2</td>
</tr>
<tr>
<td>Left Central</td>
<td>T7, C5, C3, CP1</td>
</tr>
<tr>
<td>Right Central</td>
<td>T8, C6, C4, CP2</td>
</tr>
<tr>
<td>Left Parietal</td>
<td>P5, P3, P1, O1</td>
</tr>
<tr>
<td>Right Parietal</td>
<td>P6, P4, P2, O2</td>
</tr>
<tr>
<td>Midline</td>
<td>FZ, CZ, PZ, OZ</td>
</tr>
<tr>
<td>Frontal</td>
<td>F7, FC5, FC3, FC1</td>
</tr>
<tr>
<td>Central</td>
<td>T7, C5, C3, CP1, T8, C6, C4, CP2</td>
</tr>
<tr>
<td>Parietal</td>
<td>P5, P3, P1, O1, P6, P4, P2, O2</td>
</tr>
<tr>
<td>Anterior</td>
<td>FZ, CZ</td>
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<tr>
<td>Posterior</td>
<td>PZ, OZ</td>
</tr>
<tr>
<td>Left</td>
<td>F7, FC5, FC3, FC1, T7, C5, C3, CP1, P5, P3, P1, O1</td>
</tr>
<tr>
<td>Right</td>
<td>F4, FC6, FC4, FC2, T8, C6, C4, CP2, P6, P4, P2, O2</td>
</tr>
</tbody>
</table>
CHAPTER THREE: RESULTS

Behavioral Data: Language Scores & Parent Surveys

Language scores did not reveal group differences. The mean standard score on the PPVT-4 for the HEA group was $M = 114.76$, $(SD = 13.15)$, and the LEA group was $M = 105.71$, $(SD = 13.41)$. The mean standard score on the CELF-P2 for the HEA group was $M = 102.76$, $(SD = 9.00)$, and the LEA group was $M = 100.06$, $(SD = 11.15)$. The averaged performance on the PPVT-4, $t(32) = 1.99$, $p = 0.06$, and the CELF-P2, $t(32) = 1.44$, $p = 0.44$, did not significantly differ between the HEA and LEA groups.

PPVT and CELF scores were graphed using a box plot to examine if any outliers were present (i.e., +/- 2 standard deviations). No outliers were present among the CELF scores. However, there were 2 PPVT scores, one from each group, that were outliers. One participant from the HEA group had a standardized score of 154 and one participant from the LEA group had a standardized score of 140. Once both scores were removed from the dataset and group PPVT standardized scores were resubmitted to a t-test, language scores did reveal a significant difference. Without the outliers, the HEA group scored significantly higher ($M = 112.47$, $SD = 8.97$) on the PPVT-4 than the LEA group ($M = 103.20$, $SD = 10.67$), $t(30) = 2.58$, $p = 0.02$.

Parent survey scores did not reveal group differences. The mean standard score on the Noun Parent Survey for the HEA group was $M = 329.00$, $(SD = 41.65)$, and the LEA group was $M = 329.12$, $(SD = 45.85)$. The mean standard score on the Verb Parent Survey for the HEA group was $M = 325.06$, $(SD = 39.89)$, and the LEA group was $M = 310.65$, $(SD = 58.39)$. The
average score on the Noun Parent Survey, $t(32) = -0.01, p = 0.99$, and the Verb Parent Survey, $t(32) = 0.84, p = 0.40$, did not significantly differ between the HEA and LEA groups.

**Tone Judgment Task: P300 Behavioral Data**

**Button Press Accuracy.** Accuracy scores varied among participants from 84.73% to 75.89%. A $t$-test was conducted to determine if HEA and LEA children performed differently during the tone judgment task. The $t$-test revealed that there was no significant difference, $t(21) = 1.97, p = .06$, in button press accuracy between HEA ($M = 84.73, SD = 6.55$) and LEA ($M = 75.89, SD = 14.04$) preschoolers.

**Button Press Reaction Time.** A $t$-test was conducted to determine if button press reaction time differences during the tone judgment task existed between HEA and LEA children. The $t$-test revealed that there was no significant difference, $t(21) = 2.02, p = .06$, in button press reaction times between HEA ($M = 700.34, SD = 87.46$) and LEA ($M = 612.13, SD = 126.83$) preschoolers.

**Tone Judgment Task: P300 ERP Data**

A minimum of 14 target tone trials were needed for analysis. Following EEG-to-ERP reduction methods, 13 HEA and 10 LEA participants’ ERP data were included for the tone judgment task analysis. Grand average ERP waveforms are shown for each Group at the four designated Midline electrodes, the twenty-four electrodes of interest, and by Condition in Figures 2 through 6. Both tones elicited early positive waves within the time window of 300 to 700 ms. As hypothesized, the target tone elicited a greater positive peak than the standard tone in both groups, which is depicted in the figures below.
A mixed ANOVA revealed main effects of Condition \([F(1, 21) = 12.94, p = 0.002, \eta^2 = 0.38]\) and Region \([F(2, 42) = 16.14, p = 0.004, \eta^2 = 0.62]\) were revealed. Greater positive amplitudes were observed primarily over central \((M = 14.98, SD = 2.00)\) and parietal \((M = 13.94, SD = 2.02)\) regions when compared to the frontal region \((M = 12.45, SD = 2.00)\). Positive amplitudes were greater for the target tone condition \((M = 18.69, SD = 3.02)\) than the standard tone condition \((M = 8.89, SD = 1.46)\). The analysis did not reveal any significant interactions of Group by Condition, Laterality, or Region.

Peak latencies associated with the peak amplitudes taken from the 24 electrodes of interest also were submitted to a mixed ANOVA with Group as the between-subjects factor, and Condition, Region and Laterality were entered as the within-subjects factors. The analysis did not reveal any significant main effects or interactions of Group by Condition, Laterality, or Region.

A mixed ANOVA was conducted for the amplitude of Midline electrodes with Group as the between-subjects factor, and Condition (Congruent, Incongruent), and Region (Anterior, Posterior) as the within-subjects factors. The analysis revealed a main effect of Condition \([F(1, 21) = 5.71, p = 0.026, \eta^2 = 0.21]\). There were greater positive amplitudes elicited during the target tone condition \((M = 6.79, SD = 0.90)\) than the standard tone condition \((M = 3.74, SD = 0.99)\). A significant Group x Region interaction \([F(1, 21) = 4.44, p = 0.047, \eta^2 = 0.174]\) was revealed. The estimated marginal means of the significant interaction indicated that the HEA group had greater positive amplitudes in the posterior region during the standard and target tone conditions \((Standard Mean = 8.64, Target Mean = 12.19), p = 0.009\), than the LEA group \((Standard Mean = 3.01, Target Mean = 9.72)\).
Figure 2. Peak amplitudes are greater in the posterior region especially for the target tone condition, with greater amplitudes shown for the HEA group over the posterior region.

Peak latencies associated with the peak amplitudes taken from the Midline electrodes of interest also were submitted to a mixed ANOVA with Group as the between-subjects factor, and Condition, Region and Laterality as the within-subjects factors. The analysis did not reveal any significant main effects or interactions of Group by Condition, Laterality, or Region. The peak amplitude was extracted at these significant sites and a temporal factor was derived that coincided with each peak at 398 ms (hereafter referred to as T398). This time latency was found to be at each maximum peak for both groups.

A difference score (Target minus Standard) was calculated to isolate P300 effects. The total grand average waveforms for both groups and all conditions at the Midline electrode sites are displayed in Figure 4. Difference scores were analyzed to see if a magnitude effect existed
between groups. Scores were not shown to be affected by Group, either as a main effect or interacting with Laterality and/or Region.

Please refer to Appendix J to view grand average waveforms for both groups at 24 electrode sites. In the corresponding paragraphs, the grand average wave forms for each group (HEA, LEA), Midline and Condition (Standard, Target, Difference) are available to view. Upon visual inspection, both groups elicit a positive going wave to the target tone at the Pz electrode around ~400 ms.

The topographic plots display the averaged amplitude at each electrode across the scalp at 398 ms after stimulus presentation in Figure 5. Upon visual inspection, the topographic plots show that during the standard tone condition the HEA group has more positive activity occurring over the left central-parietal region than the LEA group. During the target tone condition, both groups appear to have similar activity patterns with positive amplitudes distributed across the left and right central-parietal regions. The difference wave shows similar patterns between the groups with positive amplitudes distributed over the central-parietal regions, with one slight difference: the HEA group has one small area of positive activity located over the right frontal region of the scalp and the LEA group does not.
Figure 3. Grand average waveforms for the HEA and LEA group during the tone judgment task at the Midline electrodes. The black wave is the Standard (1000 Hz) condition, and the red wave is the Target (1500 Hz) condition.

Figure 4. Group grand average waveforms during the tone judgment task at the Midline electrodes evoked by the Standard (1000 Hz) condition and the Target (1500 Hz) condition.
Figure 5. Topographic plots for both groups at T398 at each electrode site for the HEA and LEA group during the tone judgment task.
Noun-Picture Behavioral Data

**Button Press Accuracy.** Accuracy scores varied among participants from 88.35% to 80.31%. A *t*-test was conducted to determine if HEA and LEA children performed differently during the noun picture task. The *t*-test revealed that there was a significant difference (*t*(25) = 3.89, *p* = 0.047) in button press accuracy between HEA (*M* = 88.35, *SD* = 7.49) and LEA (*M* = 80.31, *SD* = 8.65) preschoolers.

**Button Press Reaction Time.** A *t*-test was conducted to determine if button press reaction time differences during the noun picture task existed between HEA and LEA children. The *t*-test revealed that there was no significant difference, *t*(25) = 1.67, *p* = .11, in button press reaction times between HEA (*M* = 1075.67, *SD* = 109.39) and LEA (*M* = 998.25, *SD* = 131.11) preschoolers.

Noun Picture ERP Data

A minimum of 14 congruent and 14 incongruent trials were needed for analysis. Following EEG-to-ERP reduction methods, there were 15 HEA and 13 LEA participants’ ERP data included for the noun picture task analysis. Grand average ERP waveforms are shown for each Group, the four designated Midline electrodes, the twenty-four electrodes of interest, and by Condition in Figure 7. As previously described, peak amplitudes were extracted from all electrodes of interest and analyzed in three consecutive, 200 ms windows: 400-600 ms, 600-800 ms, 800-1000 ms.

The mixed ANOVA revealed main effects of Condition [*F*(1, 26) = 33.01, *p* < 0.001, η² = 0.56] and Region [*F*(2, 52) = 6.09, *p* = 0.004, η² = 0.33]. These main effects will be qualified in the reporting of the significant interactions. The mixed ANOVA revealed significant
interactions of Group x Time x Condition \( [F(2, 25) = 3.98, p < 0.032, \eta^2 = 0.24] \), Condition x Laterality x Region \( [F(2, 25) = 3.76, p = 0.037, \eta^2 = 0.23] \) and Condition x Time \( [F(2, 25) = 7.25, p = 0.003, \eta^2 = 0.34] \).

The Condition x Region x Laterality interaction indicated that during the congruent condition there were greater positive amplitudes observed over the left hemisphere, especially in the left parietal region \((M = 27.51)\). During the incongruent condition larger negative amplitudes were observed in the left hemisphere especially over the left central region \((M = -24.32)\) and even more so over the left frontal region \((M = -22.80)\).

![Figure 6. Condition x Laterality x Region interaction graphical representations for noun picture task.](image)

The mixed ANOVA discussed above revealed a significant Group x Condition x Time and interaction. At the 400-600 ms time window, the HEA group had greater negative amplitudes \((M = -31.20), p = 0.024\), than the LEA group \((M = -18.27)\) during the incongruent condition. Furthermore, the HEA group had greater positive amplitudes during the congruent condition \((M = 19.65), p = 0.041\), than the LEA group \((M = 14.56)\). At the 600-800 ms time window, the HEA group had greater negative amplitudes \((M = -21.57), p = 0.001\), than the LEA group.
group (\(M = -16.85\)) during the incongruent condition. However, the LEA group had greater positive amplitudes (\(M = 18.46\)), \(p = 0.002\), than the HEA group (\(M = 17.73\)) during the congruent condition. At the 800-1000 ms time window, the LEA group had greater negative amplitudes (\(M = -13.66\)), \(p = 0.049\), than the HEA group (\(M = -11.00\)) during the incongruent condition. However, the HEA group had greater positive amplitudes (\(M = 19.77\)), \(p = 0.007\), than the HEA group (\(M = 14.44\)) during the congruent condition.

![HEA Group Noun Picture Amplitude](image)

![LEA Group Noun Picture Amplitude](image)

**Figure 7.** Group x Time x Condition graphical representations for noun picture task.

A mixed ANOVA with Group as the between-subjects factor and Condition (Congruent, Incongruent), Region (Anterior, Posterior), and Time (400 – 600 ms, 600 – 800 ms, 800-1000 ms)
ms) as the within-subjects factors was conducted for the Midline electrodes. The mixed ANOVA did not reveal any significant interactions of Group by Condition and/or Time. There was a main effect of Condition \( [F(1, 26) = 26.56, p < 0.001, \eta^2 = 0.51] \) indicating more negative amplitudes were observed during the incongruent condition \((M = -23.32)\) than the congruent condition \((M = 15.30)\).

A difference score (Target minus Standard) was calculated to isolate N400 effects. The total grand average waveforms for both groups and all conditions are displayed in Figures 7 and 8. Scores were not shown to be affected by Group, either as a main effect or interacting with Laterality and/or Region. Topographic plots by condition (Congruent, Incongruent, Difference score) for both groups are displayed in Figure 9.

Please refer to Appendix K to view grand average waveforms for both groups at 24 electrode sites. In the corresponding paragraphs, the grand average wave forms for each group (HEA, LEA), Midline and Condition (Congruent, Incongruent, Difference) are available to view. Upon visual inspection, both groups elicit a negative going wave to the incongruent condition at the Fz electrode around ~500 ms.

The topographic plots display the averaged amplitude at each electrode across the scalp at 510 ms after stimulus presentation in Figure 10. Upon visual inspection, the topographic plots show that during the congruent condition the HEA and LEA group had positive activity occurring over the left and right parietal region of the scalp. During the incongruent condition, the HEA group appears to have more negative activity over the frontal-central regions than the LEA group. The difference wave shows that the HEA group has greater widespread negative activity across the scalp than the LEA group. The LEA group has negative amplitudes distributed over the left central region.
**Figure 8.** HEA grand average waveforms during the noun picture task at Midline electrodes evoked by the congruent (Match), incongruent (Mismatch), and difference condition during the noun picture task. Negative is plotted down.

**Figure 9.** LEA grand average waveforms during the noun picture task at Midline electrodes evoked by the congruent (Match), incongruent (Mismatch), and difference condition during the noun picture task. Negative is plotted down.
Figure 10. Topographic plots for both groups at T510 at each electrode site for the HEA and LEA group during the noun picture task.
Verb Picture Behavioral Data

**Button Press Accuracy.** Accuracy scores varied among participants from 81.99% to 71.89%. A *t*-test was conducted to determine if HEA and LEA children performed differently during the verb picture task. The *t*-test revealed that there was a significant difference (*t*(28) = 2.56, *p* = 0.02) in button press accuracy between HEA (*M* = 81.99, *SD* = 8.75) and LEA (*M* = 71.89, *SD* = 12.55) preschoolers.

**Button Press Reaction Time.** A *t*-test was conducted to determine if button press reaction time differences during the verb picture task existed between HEA and LEA children. The *t*-test revealed that there was no significant difference, *t*(28) = 0.61, *p* = .55, in button press reaction times between HEA (*M* = 1053.84, *SD* = 151.48) and LEA (*M* = 1011.64, *SD* = 215.43) preschoolers.

Verb Picture ERP Data

A minimum of 14 congruent and 14 incongruent trials were needed for analysis. Following EEG-to-ERP reduction methods, 15 HEA and 15 LEA participants’ ERP data were included for the verb picture task analysis. Grand average ERP waveforms are shown for each Group, the 4 designated Midline electrodes, the 24 electrodes of interest, and by Condition in Figure 17. As previously described, peak amplitudes were extracted from all electrodes of interest and analyzed in three consecutive, 200 ms windows: 400-600 ms, 600-800 ms, 800-1000 ms.

The mixed ANOVA of the 24 electrodes of interest revealed main effects of Condition [*F*(1, 28) = 18.62, *p* < 0.001, *η²* = 0.40], Time [*F*(2, 27) = 5.55, *p* = 0.010, *η²* = 0.29] and Region [*F*(2, 27) = 17.70, *p* < 0.001, *η²* = 0.59]. These main effects will be qualified in the
description of the significant interactions below. The mixed ANOVA of amplitudes revealed significant interactions of Region x Time x Condition x Laterality $[F(4, 25) = 3.53, p = 0.020, \eta^2 = 0.36]$ and Region x Time $[F(4, 25) = 9.46, p < 0.001, \eta^2 = 0.60]$. During the congruent condition, and with respect to laterality, there was significantly greater positive amplitudes over the right parietal region. Additionally for the incongruent condition, there were greater negative amplitudes observed at the 400-600 ms ($M = -8.51$), $p = 0.032$, that were diminished at the 600-800 ms ($M = -3.14$) time windows and again for the 800-1000 ms time window ($M = -0.66$) except for the parietal region. The parietal region had significantly larger positive amplitudes ($M = 4.13$), $p = 0.005$ than the frontal ($M = -9.08$) and central ($M = -7.42$) region during the congruent condition. The frontal ($M = 4.13$), $p = 0.005$, and central ($M = 4.13$), $p = 0.005$, regions had significantly larger negative amplitudes than the parietal ($M = -9.08$) region during the incongruent condition. For the congruent condition, during the 400-600 ms, 600-800 ms, and 800-1000 ms time windows the right hemisphere, especially over the parietal region, experiences the greatest activation. For the incongruent condition, during the 400-600 ms, 600-800 ms, and 800-1000 ms time windows the left hemisphere, especially over the left frontal and central regions, experiences the greatest activation. These effects were quantified by the large effect size observed, $\eta^2 = 0.60$, in our Region x Time interaction.

A mixed ANOVA was conducted for the Midline electrodes with Group as the between-subjects factor, Condition (Congruent, Incongruent), Region (Anterior, Posterior), and Time (400 – 600 ms, 600 – 800 ms, 800-1000 ms) entered as the within-subjects factors. There was a main effect of Condition $[F(1, 28) = 23.43, p < 0.001, \eta^2 = 0.46]$ and Region $[F(1, 28) = 13.80, p = 0.001, \eta^2 = 0.33]$. These main effects will be qualified in the description of the significant interactions below. The mixed ANOVA revealed significant interactions of Group x Condition x
Time [\(F(2, 27) = 4.43, p < 0.05, \eta^2 = 0.25\)] and Region x Time [\(F(2, 27) = 7.06, p < 0.05, \eta^2 = 0.34\)]. The HEA group had significantly larger positive amplitudes during the congruent condition (\(M = 6.51, SD = 1.42\)) and larger negative amplitudes during the incongruent condition (\(M = -9.54, SD = 4.27\)), \(p = 0.007\), than the LEA group (Congruent \(M = 5.11, SD = 1.57\); Incongruent \(M = -6.50, SD = 1.68\)). More amplitudes were observed over the anterior region (\(M = -2.72\)), \(p = 0.029\), when compared to the posterior region (\(M = 0.49\)). The HEA group had greater negative amplitudes than the LEA group during the incongruent condition at the anterior region of the scalp, which was especially evident at the 400-600 ms time window.
Figure 11. Condition x Laterality x Region x Time graphical representations in verb picture task.
A difference score (Target minus Standard) was calculated to isolate N400 effects. The total grand average waveforms for both groups and all conditions are displayed in Figure 13 and 14. Scores were not shown to be affected by Group, either as a main effect or interacting with Time, Laterality, and/or Region.

**Figure 12.** Region x Time graphical representation in verb picture task.

**Figure 13.** HEA grand average waveforms during the verb picture task at Midline electrodes evoked by the congruent (Match), incongruent (Mismatch), and difference condition during the verb picture task. Negative is plotted down.
Figure 14. LEA grand average waveforms during the verb picture task at Midline electrodes evoked by the congruent (Match), incongruent (Mismatch), and difference condition during the verb picture task Negative is plotted down.
Figure 15. Topographic plots for both groups at T535 at each electrode site for the HEA and LEA group during the verb picture task.
Correlational Analysis

A correlational matrix was conducted to examine if neurophysiological and behavioral variables shared significant relations (see Table 3). Relations of interest were performance scores on each behavioral measure (parent surveys, CELF-P2, PPVT) and the amplitude and latency of ERP measures from the tone judgment, noun and verb experiments. ERP amplitudes were calculated using difference score’s peak latency and peak amplitudes at significant Midline electrodes. The PZ electrode was used to derive peak amplitudes and their latencies, for both groups, during the tone judgment task, and the CZ electrode was used during the noun and verb picture task. These ERP scores and behavioral measures were used to calculate overall and group correlations.

Results indicated a moderate positive relationship between CELF-P2 and PPVT scores ($r(32) = .44$), verb and noun picture latencies ($r(27) = .44$), and noun and verb picture amplitudes ($r(27) = .51$). A strong positive correlation found between parent noun and verb surveys ($r(32) = .89$). A moderate negative correlation was found between noun picture amplitude and PPVT scores ($r(28) = -.36$), noun picture amplitude and CELF-P2 scores ($r(28) = -.39$), noun picture amplitude and tone judgment amplitudes ($r(22) = -.57$), and verb picture amplitude and tone judgment amplitudes ($r(21) = -.50$).
Table 3. Correlations among the behavioral and ERP measures

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<th>PS Verb</th>
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Note. * indicates p < 0.05*, indicates p < 0.01**

N Amp = Noun amplitude, V Amp = Verb amplitude, TJ Amp = Tone Judgment amplitude, PS Noun = Parent Survey Noun, PS Verb = Parent Survey Verb, N Lat = Noun Latency, V Amp = Verb Latency, TJ Lat = Tone Judgment Latency
CHAPTER FOUR: DISCUSSION

The current study aimed to answer specific questions pertaining to the vocabulary knowledge and neural processing of language while preschoolers from varied socioeconomic backgrounds listened to names of familiar pictured nouns and verbs. Specifically, we sought to investigate whether HEA and LEA: 1) processed non-linguistic stimuli similarly; 2) processed familiar nouns and verbs similarly; and 3) whether their neural processes relate significantly to behavioral measures (i.e., PPVT, CELF-P2, and Parent Survey scores)?

To investigate these aims, 17 HEA and 17 LEA children participated in the current study. It should be noted that 41 children were recruited to participate in this study. However: 1) prior to beginning the study 3 LEA families did not provide informed consent, and 2) following informed consent procedures, 1 HEA and 3 LEA children did not provide verbal assent and refused to proceed with the study. Additional unexpected obstacles were transportation challenges and difficulty recruiting LEA families. These potential biases and possible solutions are discussed in Limitations.

Children’s vocabulary and language knowledge were assessed using the PPVT and the Core Language Index subtests of the CELF-P2. We provided parents with a home language environment survey asking specifically how often they heard their children producing the stimulus words at home. Derived scores were utilized for the correlational analysis.
Neural Processing & Behavioral Responses of Nonlinguistic Stimuli

In the current study, there were not any significant group differences between HEA and LEA preschoolers’ performance on the standardized assessments or in the findings of the parent surveys. However, after graphing language scores and parent surveys onto boxplots to determine if any outliers were present, two outliers were identified in the PPVT-4 scores. Even when these scores were removed and the data were reanalyzed, averaged standard scores were above the normative mean of 100. Although, the HEA group scored significantly higher on the standardized measure for vocabulary when compared to their LEA peers, such high scores were not expected for the LEA group. This finding is consistent with Hart and Risley’s 30 Million Word Gap (1995) and previous literature (Hoff and Tian, 2005; Torgesen, 2002; Burger, 2010; Westerlund and Lagerberg, 2008). Young children who come from SES backgrounds with greater resources tend to perform better and know more vocabulary words than young children who come from SES backgrounds with fewer resources.

Next, behavioral button responses were analyzed. The HEA group exhibited a trend towards more accurate tone judgment responses, while the LEA group trended towards faster tone judgment response times. Both HEA and LEA children demonstrated greater positive amplitudes to the target tone condition than the standard tone condition. These positive peaks occurred in the central and parietal regions of the scalp. These findings are in accordance with Courchesene (1977), Ladish and Polich (1989), and Ladish, Polich, and Burns (1990). The authors reported that when young children heard target tones in an auditory oddball paradigm, greater positive peaks were elicited compared to standard tones. These peaks occurred primarily in the parietal region of the scalp. The absence of significant group differences, at the 24 electrodes of interest, contradicts the findings of Willner, Gatzke-Kopp, Bierman, Greenberg,
and Segalowitz (2015). The authors reported that low SES kindergartners demonstrated attenuated P3b amplitudes when compared to their high SES counterparts. This reported difference may be due to the different experimental tasks utilized in the Willner and colleagues (2015) study and our smaller sample size. Willner and colleagues (2015) utilized a go/no go task with different stimuli items adding to the complexity of the task. Additionally they recruited over 200 urban, low-income kindergarteners to participate in their study. Perhaps in future studies, this variation of the task could be taken into consideration and be implemented.

Upon visual inspection, there appears to be subtle differences in the topographic distribution of the P3b effect between HEA and LEA preschoolers, but these differences were not significant.

At midline, both groups displayed greater positive amplitudes during the standard and target tone conditions over the posterior region than the anterior region. The HEA group demonstrated significantly larger positive amplitudes over the posterior region than the LEA group. This may suggest that the two groups recruit different neural resources to categorize non-linguistic auditory stimuli. These results were unexpected as differences are not typically observed between groups during a tone judgment task, even in disordered populations (Maxfield et al., 2016). The tone judgment task appeared to be arduous for both groups, but particular more so for the LEA group. These dissimilarities may be due to sustained attention differences reported in SES literature, indicating that children from lower SES backgrounds experience difficulty sustaining attention to stimuli items, or it could be due to age effects. These P3b differences may be subtle but are supported by previous research Willner and colleagues (2015) and Stevens, Lauinger, & Neville (2009).
Finally, a difference score was calculated to determine if a magnitude effect existed between groups. No differences were detected between groups. The results of the tone judgment task partially support our hypothesis. The data suggests that HEA and LEA children judge non-linguistic stimuli similarly. The tone judgment Group x Region interaction may indicate that the two groups utilize different regions to process non-linguistic stimuli.

**Neural Processing & Behavioral Responses of Nouns**

A significant behavioral difference in accuracy was detected in the noun picture task. The HEA group was significantly more accurate than the LEA group. There was not a significant difference in noun picture judgment time, but the LEA group trended toward faster reaction times. This finding may be suggestive of a speed-accuracy trade off, which has been documented previously in the literature (Wickelgren, 1977; Dickman & Meyer, 1988; Foster, Higgins, & Bianco, 2003; Bogacz, Wagenmakers, Forstmann, & Nieuwenhuis, 2010). These authors reported that in tasks requiring participants to press a button, following instructions to respond as quickly as possible, accuracy significantly decreased. Conversely, when participants were instructed to highlight accuracy, reaction times increased, as they took longer to respond. Both groups were provided the same set of automated instructions. Perhaps, LEA preschoolers were eager to respond and fixated on responding quickly, while HEA preschoolers adopted a strategy of accuracy.

Visual inspection of the topographic plots demonstrates differences in amplitude across regions of the scalp between Groups. Specifically, the HEA group had greater positive amplitudes during the congruent condition at the 400-600 ms and 800-1000 ms time windows than the LEA group. The HEA group had greater negative amplitudes during the incongruent condition, exhibiting evidence of the semantic incongruity effect, at the 400-600 ms and 600-800
ms time windows when compared to the LEA group. Conversely, the LEA group had greater positive amplitudes during the congruent condition at the 600-800 ms time window and greater negative amplitudes during the incongruent condition at the 800-1000 ms time window when compared to the HEA group. This indicates that the LEA group was slower to process the noun picture stimuli than the HEA group, and the LEA group demonstrated attenuated N400 effects. These attenuated N400 effects observed in the LEA group may be indicative of a shallower processing of the noun stimuli than the HEA group, meaning the LEA group may not have a complete mastery of object label when compared to the HEA group.

The N400 effects were primarily observed over the left hemisphere. These results agree with previous findings of modulated N400 effects between varied SES backgrounds (Varnum, Na, Murata, & Kitayama, 2012; Varnum, 2016). Varnum and colleagues’ (2012) reported an attenuated N400 amplitude from participants whose parents received a high school education, when compared to the N400 amplitudes of participants whose parents received a college degree or better. Additional analysis results from the current study revealed the HEA group demonstrated a later, more robust positivity in the 800-1000 ms window, which may be indicative of late positive component (LPC) activity and a more developed mental lexicon (Haebig et al., 2018).

In addition to the group differences, there was an overall Region x Condition interaction effect. During the congruent condition there were greater positive amplitudes that occurred over the central and parietal regions of the scalp. Conversely, during the incongruent condition greater negative amplitudes were observed over the frontal and central regions of the scalp. This frontal negativity is consistent with the N400 semantic incongruity effect (Kutas & Van Petten, 1988; McPherson & Holcomb, 1999; Kutas & Federmeier, 2011). Friedrich and Friederici (2004;
2006) and McPherson and Holcomb (1999) reported unrelated, or incongruent mismatch, with picture stimuli evoking the N400 primarily in the frontal and central regions of the scalp. They reported highly lateralized left hemisphere activity in response to the noun picture stimuli. With these results in mind, the data support our hypothesis that HEA and LEA preschoolers process noun picture stimuli differently at a neural level; specifically, that HEA preschoolers process familiar nouns more robustly and quicker than LEA preschoolers.

**Neural Processing & Behavioral Responses of Verbs**

A significant behavioral difference in accuracy was detected in the verb picture task. The HEA group was significantly more accurate than the LEA group. There was not a significant difference in verb picture judgment times, but the LEA group trended towards faster reaction times. These results may be attributed to the speed-accuracy trade off described, and cited, in the previous section.

Upon visual inspection of the topographic plots, there are subtle differences in the amplitudes distributed across the scalp between the HEA and LEA groups during the congruent and incongruent conditions. The most noticeable difference can be seen in the Difference topographic plot. The HEA group appears to have a more robust N400 effect in the parietal region of the scalp when compared to the LEA group. However, the analysis of the Difference scores did not reveal significant differences in neural activity between the groups.

Additional analysis revealed greater positive amplitudes during the congruent condition over the left parietal and left central regions of the scalp at the 400-600 ms and 600-800 ms time windows. During the incongruent condition there were greater negative amplitudes that occurred over the left frontal and left central regions of the scalp at the 400-600 ms and 600-800 ms time windows. The greatest N400 effect occurred primarily in the 400-600 ms time window at the left
frontal region of the scalp (Kutas & Van Petten, 1988; McPherson & Holcomb, 1999; Kutas & Federmeier, 2011). These topographic results are consistent with the noun picture findings discussed in the previous section. The absence of group differences, in the analysis of the 24 electrodes of interest, suggests that the two groups processed the verb stimuli similarly.

During the congruent condition, there was a subset of participants from both groups (4 HEA, 6 LEA) showing some negative amplitudes over the frontal and central regions of the scalp and positive amplitudes over the parietal regions. However, the more robust negative response in the incongruent condition is in agreement with previous findings. This anomaly may be because verbs require more neural activity to process than nouns. Therefore, both groups required more neural activity to process actions depicted in the pictures than objects (Gomes, Ritter, Tartter, Vaughan Jr, & Rosen, 1997; Maguire, Abel, Schneider, Fitzhugh, McCord, & Jeevakumar, 2015). This excess neural recruitment may have contributed to the negative wave patterns observed during the congruent condition at the frontal and central regions in the verb picture task, but not in the noun picture task.

To finalize the verb picture analysis, the midline data revealed that the HEA group exhibited greater positive amplitudes in the posterior region of the scalp during the congruent condition, and greater negative amplitudes in the anterior region of the scalp during the incongruent conditions when compared to the LEA group. These effects were observed mostly during the 400-600 ms and 600-800 ms time windows. This pattern of processing is consistent with previous research concerning semantic verb violations and the N400 (Rosler, Streb, & Haan, 2001; Hanna & Pulvermuller, 2018).

With these results in mind, these data partially support our hypothesis that HEA preschoolers would process verb stimuli more robustly and efficiently than LEA preschoolers.
However, the hypothesized group differences were observed only at the Midline electrode sites. Furthermore, the expected differences between nouns and verbs were observed. The absence of group differences for verb processing suggests that perhaps participants required more neural resources to process the verb stimuli, and that the verb condition represents a higher degree of linguistic complexity than the noun stimuli.

**Relationships between Language Scores, Linguistic & Nonlinguistic Neural Processing**

Although neural and behavioral differences were reported in the preceding sections, we wanted to determine if these differences shared significant relations with other behavioral measures (i.e., the PPVT, the CELF-P2, and parent surveys).

Overall group results indicated a strong positive relationship between the noun and verb parent surveys. This means parents who judged their children’s noun home language usage highly, also tended to judge their verb home language usage highly. A moderate positive relationship between CELF-P2 and PPVT scores was observed, which was an expected result. The CELF-P2 and PPVT are standardized clinical assessments (Dunn & Dunn, 2007; Wiig, Secord, & Semel, 2004), which are expected to share similar structural concepts of language and vocabulary, but not to a high degree. Difference scores were calculated to help isolate N400 effects and attenuate noise unrelated to semantic incongruity. Therefore, the greater the negative amplitude, the greater the semantic violation, indicating the participant understood the label did not match the picture. Interestingly, the CELF-P2 and the PPVT shared a moderately negative correlation with noun picture amplitudes. This suggested higher scores on the CELF-P2 and the PPVT shared a moderate relation with greater negative difference score amplitudes on the noun picture task. This finding is in accordance with our findings and previous findings cited in the paragraphs above.
There has been some speculation about neural networks recruited during the processing of nouns and verbs. Our correlational analysis revealed that noun amplitudes and latencies shared a moderate positive relation with verb amplitudes and latencies, meaning preschoolers who tended to display greater negative evoked amplitudes and latencies during the noun task also displayed greater negative evoked amplitudes and latencies during the verb task (and vice versa). These data lend further support to the hypothesis that similar neural constructs are recruited to process nouns and verbs (Maguire et al., 2015). Upon visual inspection of the data, it appears that the LEA group demonstrated attenuated peak amplitudes and longer peak latencies when compared to the HEA group. Closer inspection also reveals that within these groups, there are some children who may be outliers and there are some degrees of variation. One possible explanation for this observation may be due to linguistic maturation effects and/or variability in response to stimuli within groups, which has been documented in the ERP literature (Haebig et al., 2018; Rama, Sirri, & Serres, 2013; Friedrich & Friederici, 2004; 2006). Vocabulary development is a lifelong process (Beck, McKeown, & Kucan, 2013; Bates et al., 1992), and highly correlated to the home language environment. This may help to explain some of the variability observed in the noun and verb amplitudes and latencies.

There were two other significant relations uncovered by the analysis. The tone judgment amplitude scores shared a moderate negative relationship with noun and verb picture amplitudes, meaning participants who tended to display greater evoked positive potentials during the tone judgment task, displayed greater negative amplitude in the noun and verb picture tasks. These results are in accordance with Willner and colleagues (2015) who reported a positive correlation between the magnitude of P3b amplitudes and the vocabulary knowledge of kindergartners and
first graders. They also went on to suggest that children from low SES backgrounds could potentially benefit from attention-driven, language therapies based off this relationship.

When analyzing significant relationships by Group, the HEA and LEA group both demonstrated a strong positive relation between noun and verb parent surveys. Additionally, there was a significant moderate positive relation between verb and tone judgment latencies, suggesting participants who tended to take longer to process incongruent verb stimuli took longer to process target tones.

Consistent with our hypothesis the N400 amplitudes were significantly correlated with the standardized language scores, indicating participants who tended to score higher on the CELF-P2 and PPVT, evoked more negative amplitudes during the noun picture task. Although verb amplitudes were not correlated to the CELF-P2 and PPVT scores, they did share a moderate positive association with noun amplitude, suggesting that they rely on similar neural processes to resolve match-mismatch paradigms in HEA and LEA preschoolers.

**Study Limitations and Future Directions**

This study is the first to group preschoolers by their mothers’ level of education and examine how they discriminate tones and process noun and verb stimuli at a neural level. Although this project is a meaningful contribution to the scientific knowledge base, there are limitations to be discussed. One limitation included an uneven sex distribution between groups. There were more females in the HEA group (13) than the LEA group (7). This is a concern because there have been documented cognitive processing differences between males and females for the P300 and N400 in the adult literature. Conroy and Polich (2007) reported that adult females’ P3b effects were greater and later than those elicited from males. Although our participants were children, and direct comparisons must be made with caution, the unequal sex
distribution between groups did not seem to affect the P3b results as no significant differences were reported in amplitudes or latencies for the tone judgment task, with the exception of the Midline electrode analysis. Additionally, Christakou and colleagues (2010) investigated young children’s neural activation patterns to cognitive responses and reported males tend to recruit the parietal regions of the brain and females tend to recruit the frontal regions of the brain during cognitive tasks. Wirth and colleagues (2007) reported adult females demonstrated earlier and longer lasting N400 effects in the temporal networks (what we labeled our central region) when compared to their male counterparts. These findings did not appear to affect our results as there was a main effect of region for the N400 for both groups. Each group demonstrated greater positive amplitudes at the parietal region of the scalp during the congruent condition, and greater negative amplitudes at the frontal and central regions of the scalp during the incongruent condition.

Another limitation that future research should address is the sample of participants. Our sample size would benefit from more children in each group. Having more children in each group would allow for more reliable ERP effects with a greater number of trials. A generalizability analysis was conducted to help inform future researchers of an appropriate sample size. The analysis revealed that 38 usable participant files, 19 participants per group, would be best to help inform future replications.

Furthermore, although our groups were divided by maternal education, and level of familial education is considered an important factor of socioeconomic status, our LEA group sample included children whose mothers did receive some college education. Future studies should separate groups using a more sensitive criterion. Considerations may include other metrics to capture risk status, including chaos variables and a needs-to-income ratio. Chaos
variables refer to traumatic events that occur within a child’s home environment that may affect their academic success. Determining how chaos variables affect families while factoring in their needs-to-income ratio would provide a more dynamic and accurate assessment of familial socioeconomic status. These considerations in future language development studies would provide useful contributions to the scientific knowledge base for educators and speech language pathologists. Transportation challenges did affect families’ ability to participate in our study. Perhaps future studies could incorporate a public transit reward system (e.g., a bus card, an Uber card, or a subway/metro card) or utilize a portable EEG machine.

Additional factors to consider for future studies are: 1) manipulating the word frequency and word-picture agreement of noun and verb stimuli (Szekely et al., 2004; 2005; 2003; Bates et al., 2003) and 2) conducting a longitudinal study to see how children develop their mental lexicons over time and how external factors affect this development. These questions would allow researchers to study how preschoolers from varied socioeconomic backgrounds develop, acquire, and process words with lower frequency and lower agreement or words with derivational morphology.

Summary and Conclusion

The results of the present study suggest that the recruited sample of HEA and LEA preschoolers scored similarly on language assessments (i.e., the PPVT and the CELF-P2). Additionally, their parents tended to score their use of familiar nouns and verbs in their home language environment consistently. Their button press accuracy and reaction times during a tone judgment task were not significantly different. However, HEA preschoolers were significantly more accurate in noun and verb judgment accuracy than LEA preschoolers. Conversely, LEA preschoolers trended towards faster reactions times in noun and verb judgments. This finding
supports the speed-accuracy trade off principal. Despite multiple reiterations, practice trials, and parent support some children did not demonstrate a clear understanding of the instructions. Therefore, the reliability of these findings is not certain and must be interpreted with caution.

During a tone judgment task HEA and LEA preschoolers processed stimuli similarly at a neural level and showed greater positive amplitudes to a rare target tone over the parietal regions of the scalp, which is indicative of the widely reported P3b, or P300, at the primary electrodes of interest. Conversely, there were significant group differences at Midline electrodes observed during the tone judgment task. HEA preschoolers exhibited greater activation over the posterior region than the LEA group. This result was unexpected as group differences are not typically observed in groups with communication disorders.

Furthermore, HEA preschoolers demonstrated greater negative amplitudes in response to incongruent labels to picture stimuli than LEA preschoolers, indicating a more robust and enhanced semantic processing of familiar nouns. The difference between Groups may be explained by different levels of vocabulary mastery (Beck et al., 2103), differences in neural processing of nouns, or fatigue effects (when young children have lost interest in participating in a study protocol). Previous studies have investigated SES in adults and other cognitive processes, but there has been limited evidence to suggest there are differences in N400 processing between young children who come from middle and low SES backgrounds (Pakulak, Sanders, Paulsen, & Neville, 2005; Demir & Kuntay, 2014; Varnum et al., 2012; Varnum, 2016).

During the verb picture task, at the primary electrodes of interest, the absence of Group differences suggested HEA and LEA preschoolers processed stimuli similarly. The significantly greater negative amplitudes exhibited at the left frontal and left central regions during the incongruent condition during the 400-600 ms and 600-800 ms time windows, is evidence of the
N400 semantic incongruity effect. The presence of group differences at the Midline analysis revealed that HEA preschoolers demonstrated greater negative amplitudes at the anterior region of the scalp than LEA preschoolers. The group differences observed at Midline electrodes were part of our predicted hypotheses. The lack of group differences at the primary electrode sites were unexpected. One potential explanation for these results is that verbs are more linguistically complex than nouns and require more neural resources and activity to process when compared to noun stimuli.

English is a “noun friendly” language. Nouns are often described as a hierarchical word class, meaning that an object’s label can be shared with another (e.g., baseball, ball, basketball, etc.) or share thematic relationships (e.g., finger, hand, nose, body parts) which can accelerate the neural mapping of a language (Maguire, Brier, & Ferre, 2010).

Verbs have been historically harder to learn than nouns but are the root to developing the foundational network of robust oral language skills (Waxman, Fu, Arunachalam, Leddon, Geraghty, & Song, 2013; Fleischman & Roy, 2005). As previously cited, additional neural activity related to motor processing is required to process verb stimuli (Maguire et al., 2015). To process verbs, we must first understand how the action sequence is imposed on the noun. Some studies have suggested that motor processing is required to decipher this process and have some referent. For example, a person must understand the motoric principle of walking (i.e., putting one foot in front of the other) to understand that a noun (e.g., a girl) is performing the action (e.g., “The girl is walking”). This may explain the lack of differences we expected to see between groups, indicating that verbs were equally difficult to process for both groups. Or it may be the groups lack the extensive background knowledge to decipher the complexity of verbs and the different contexts in which they can occur.
Finally, the correlational analysis indicated that the CELF-P2 and PPVT share moderate relations with noun picture amplitudes. Noun and verb amplitudes, along with their latencies were moderately correlated. These results open the question of the potential sensitivity of neurophysiological measures of language processing.

Although one may ponder whether using EEGs and ERPs as assessment tools is not ideal, this method represents a first step in identifying biological neural markers that could potentially index levels of vocabulary knowledge in at-risk preschoolers. This method may have potential as a more sensitive pre-and post-test measure for more subtle cognitive linguistic changes in future language interventions. The current findings of this study are significant because they have contributed to the scientific knowledge base of linguistic processing in preschoolers who come from varied SES backgrounds, which was the overarching aim of this project. Furthermore, we hope these findings positively contribute to the field of developmental language and help to inform our interventions for at-risk populations.
REFERENCES


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APPENDIX A: IRB Letter of Determination

2/5/2019

Wendy Olsen,
Communication Sciences and Disorders

RE: Expedited Approval for Continuing Review
IRB#: CR1_Pro00034055
Title: Do Preschoolers elicit an N400 during a story listening activity?

Study Approval Period: 2/22/2019 to 2/22/2020

Dear Dr. Olsen:

On 2/3/2019 8:21 PM, the Institutional Review Board (IRB) reviewed and APPROVED the above application and all documents contained within including those outlined below.

Approved Item(s):
Protocol Document(s):
Protocol Version #2 07/30/18 Clean
Protocol Version #2 07/30/18 Tracked

Consent/Assent Document(s)*:
Combined Parental Permission & Parent Version # 3, 12_20_18 Clean.docx.pdf
Combined Parental Permission & Parent, Version #2, 7/31/18 Clean.pdf

*Please use only the official IRB stamped informed consent/assent document(s) found under the "Attachments" tab on the main study's workspace. Please note, these consent/assent document(s) are valid until they are amended and approved.

The IRB determined that your study qualified for expedited review based on federal expedited category number(s):
(4) Collection of data through noninvasive procedures (not involving general anesthesia or
sedation) routinely employed in clinical practice, excluding procedures involving x-rays or
microwaves. Where medical devices are employed, they must be cleared/approved for
marketing.

(7) Research on individual or group characteristics or behavior (including, but not limited to,
research on perception, cognition, motivation, identity, language, communication, cultural
beliefs or practices, and social behavior) or research employing survey, interview, oral history,
focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

As the principal investigator of this study, it is your responsibility to conduct this study in
accordance with USF IRB policies and procedures and as approved by the USF IRB. Any
changes to the approved research must be submitted to the IRB via an Amendment for review
and approval. Additionally, all unanticipated problems must be reported to the USF IRB within
five (5) business days.

We appreciate your dedication to the ethical conduct of human subjects research at the
University of South Florida and your continued commitment to human research protections. If
you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

[Signature]

Melissa Sloan, PhD, Vice Chairperson

USF Institutional Review Board
Consent to Participate in Research & Parental Permission for my Child to Participate in Research

Pro #00034055

The following information is being presented to help you and your child decide whether or not you would like to be a part of a research study. Please read this information carefully. If you have any questions or if you do not understand the information, we encourage you to ask the researcher.

We are asking you to take part, and to allow your child to take part, in a research study called: Is an N400 Elicited in Preschoolers while Listening to a Story?

The person in charge of this research study is Wendy Olsen, M.S., CCC-SLP. This person is called the Principal Investigator. However, other research staff may be involved and can act on behalf of the person in charge. She is being guided in this research by Howard Goldstein, PhD, CCC-SLP.

The research will be conducted at USF’s Tampa Campus, Building PCD, ROOM 3005.

Purpose of the study:
The purpose of this study is to find out how preschoolers understand academic vocabulary used in a story. We plan to study this is to invite you to the laboratory and ask your child questions about what happened and the vocabulary used in the story. We will also ask your child to wear a special cap that records their brain waves.

Why are you & your child being asked to take part?
We are asking you and your child to take part in this research study because he/she is a preschooler. This study is trying to determine vocabulary understood by preschoolers at a neural level.

Study Procedures:
Your child will be asked to participate in this study, and we will ask you, the legal guardian, to fill out some forms asking about the home environment.
If you and your child take part in this study, you will be asked to:
• Children will be asked to answer some vocabulary and language questions before the study begins. They will also be administered a vision and hearing screening. Following the screenings, children will be asked to wear a special cap that records their brainwaves while listening to a story that has 2 five minute parts. After the child hears each part, they will be asked 8 questions about the story.

• Parents/legal guardians will be asked to fill out surveys and questionnaires asking about the home environment (e.g., How many children live in the household?).

• Participants will make a one-time visit to the USF Tampa campus. The expected duration of the study is 1-1.5 hours.

• The research will be conducted at USF’s Tampa campus, CSD Building, PCD, Room 3005.

• During the study, children will be required to look at pictures on a computer screen, and hear a story using headphones. We will ask them to pay attention because we will ask questions about the story later.

• You are free to stop participating, at any time, for any reason, without consequence, by letting the researcher know.

**Total Number of Participants**

About 50 individuals will take part in this study at USF.

**Alternatives / Voluntary Participation / Withdrawal**

If you decide not to let your child take part in this study and you do not participate, that is okay. Instead of being in this research study you and your child can choose not to participate.

You and your child should only take part in this study if both of you want to. You or your child should not feel that there is any pressure to take part in the study to please the study investigator or the research staff.

**If you or your child decide not to take part:**

- You will not be in trouble or lose any rights you would normally have.

- If you decide to withdraw after the study has begun, you will be given half credit, $12.50, on a WalMart gift card.

You can decide after signing this informed consent form that you no longer want your child or yourself to take part in this study. We will keep you informed of any new developments which might affect your willingness to participate or allow your child to continue to participate in the study. However, you and your child can decide to stop taking part in the study for any reason at any time. If you and/or your child decide to stop taking part in the study, tell the study staff as soon as you can.

**Benefits**

We do not know if you or your child will gain any benefits by taking part in this study.

**Risks or Discomfort**

The following risks may occur:
• Your child may become tired in between tasks. The researcher will ask if he/she wants to take a break.
• You or your child may need a drink of water. Please let the researcher know, so we can get you a bottle of water.
• Please know that your confidentiality is of the upmost concern to us. We will safeguard all personal information and a subject ID number will be provided to all sensitive documents to ensure your family’s privacy.

Compensation
You will receive a $25 Walmart gift card for compensation towards the travel expenses associated with taking part in this study.

Cost
It will not cost you anything to participate and to let your child take part in the study.

Conflict of Interest Statement
The researcher does not present with a conflict of interest.

Privacy and Confidentiality
We will keep you and your child’s study records private and confidential. Certain people may need to see your study records. Anyone who looks at your records must keep them confidential. These individuals include:
• The research team, including the Principal Investigator, study coordinator, and all other research staff.
• Certain government and university people who need to know more about the study, and individuals who provide oversight to ensure that we are doing the study in the right way.
• Any agency of the federal, state, or local government that regulates this research, the Department of Health and Human Services (DHHS).
• The USF Institutional Review Board (IRB) and related staff who have oversight responsibilities for this study, including staff in USF Research Integrity and Compliance.

We may publish what we learn from this study. If we do, we will not include you or your child’s name. We will not publish anything that would let people know who you are.

You can get the answers to your questions, concerns, or complaints.
If you have any questions, concerns or complaints about this study, call Wendy Olsen at (813) 210-0859.
If you have questions about you or your child’s rights, complaints, or issues as a person taking part in this study, call the USF IRB at (813) 974-5638 or contact by email at RSCH-IRB@usf.edu.
Consent to Participate and Parental Permission for My Child to Participate in this Research Study

I freely give my consent to take part and to let my child take part in this study and authorize that his/her health information as agreed above, be collected in this study. I understand that by signing this form I am agreeing to take part in and to let my child take part in research. I have received a copy of this form to take with me.

Signature of Person and Parent of Child Taking Part in Study  Date

Printed Name of Person and Parent of Child Taking Part in Study

Statement of Person Obtaining Informed Consent

I have carefully explained to the person taking part in the study what he or she can expect from their participation. I confirm that this research subject speaks the language that was used to explain this research and is receiving an informed consent form in their primary language. This research subject has provided legally effective informed consent.

Signature of Person Obtaining Informed Consent  Date

Printed Name of Person Obtaining Informed Consent
APPENDIX B: Noun Pictures

The pictures used were not created by the researcher. They were used in previous research and available online to download for free from the International Picture Naming Project Database (IPNP; Szekely, D'Amico, Devescovi, Federmeier, Herron, Iyer, Jacobsen, Arevalo, Vargha, & Bates, 2005; Szekely, Jacobsen, D'Amico, Devescovi, Andonova, Herron, Lu, Pechmann, Pleh, Wicha, Federmeier, Gerdjikova, Gutierrez, Hung, Hsu, Iyer, Kohnert, Mehotcheva, & Bates, 2004; Székely, D’amico, Devescovi, Federmeier, Herron, Iyer, ... & Bates, 2003; Bates, D’Amico, Jacobsen, Székely, Andonova, Devescovi, ... & Wicha, 2003). The IPNP Database is a psycholinguistic corpus available to researchers to carry out new and exciting research using norm based culturally neutral black line drawings in seven different languages. The articles listed above have stimuli listed at the end of each study that provide frequency and agreement properties. The current study utilized information from this group of researchers to help inform the selection of noun stimulus items.
APPENDIX C: Verb Pictures

The pictures used were not created by the researcher. They were used in previous research and available online to download for free from the International Picture Naming Project Database (IPNP; Szekely, D'Amico, Devescovi, Federmeier, Herron, Iyer, Jacobsen, Arevalo, Vargha, & Bates, 2005; Szekely, Jacobsen, D'Amico, Devescovi, Andonova, Herron, Lu, Pechmann, Pleh, Wicha, Federmeier, Gerdjikova, Gutierrez, Hung, Hsu, Iyer, Kohnert, Mehotcheva, & Bates, 2004; Székely, D’amico, Devescovi, Federmeier, Herron, Iyer, … & Bates, 2003; Bates, D’Amico, Jacobsen, Székely, Andonova, Devescovi, … & Wicha, 2003). The IPNP Database is a psycholinguistic corpus available to researchers to carry out new and exciting research using norm based culturally neutral black line drawings in seven different languages. The articles listed above have stimuli listed at the end of each study that provide frequency and agreement properties. The current study utilized information from this group of researchers to help inform the selection of verb stimulus items.
APPENDIX D: Demographic Survey & Medical Questionnaire

Demographic Intake Form

Please remember any information you chose to share with us will remain confidential and private. Your privacy is very important to us.

**Participant Information**

Participant ID ______________________________

Date of Consent ______________________________

Date of Assent ______________________________

First and Last Name __________________________

Age (months) ________________________________

**Contact Information**

Street ________________________________

Apartment # ______________________________

State and Zip ______________________________

E-mail ________________________________

Parent 1 ________________________________

Parent 2 ________________________________

(If applicable)

Parent 3 ________________________________

Parent 4 ________________________________

How do you prefer to be contacted? (circle one)

- Over the phone
- Text
- In Person
- Other__________________________

What is the best time to contact you? (circle one)

- Morning
- Afternoon
- Evening

Is your child in good health today? (circle one)

- Yes
- No

What hand does your child use to draw, feed themselves, or write? (circle one)

- Right Hand
- Left Hand
- Both Hands
What is your race/ethnicity?

______________________________________________________________________________

How many adults live in your household?

______________________________________________________________________________

What is your occupation?

______________________________________________________________________________

Are you considered full time or part time?

______________________________________________________________________________

Have you ever attended college?    Yes        No
If yes, did you get a degree?    Yes     No
If no to the question above, why not?

______________________________________________________________________________

What is the highest level of education you have received?

______________________________________________________________________________

What is the highest level of education every adult family member, who lives in the home, has received?

______________________________________________________________________________

Please circle the range of your yearly household income.

<$20,000
$20,000 - $30,000
$30,001 - $40,000
$40,001 - $50,000
>$50,000

Do you rent or own your home?

______________________________________________________________________________
How many times have you moved within the last year?
______________________________________________________________________________

How many people live in your household?
______________________________________________________________________________

How many children live in your household?
______________________________________________________________________________
______________________________________________________________________________
If more than one, please list the birth order.
______________________________________________________________________________
______________________________________________________________________________

How many books/magazines do you have in your home?
______________________________________________________________________________
______________________________________________________________________________

Please answer the following questions for the child who is participating in the research today.

How much time, approximately, do you spend throughout the week reading to your child at home?
______________________________________________________________________________
______________________________________________________________________________

How much time does your child watch TV throughout the week?
______________________________________________________________________________
______________________________________________________________________________

How much time does your child use the computer throughout the week?
______________________________________________________________________________
______________________________________________________________________________

How much time does your child use a smart device (e.g., tablet, iPhone, Android, etc.) throughout the week?
______________________________________________________________________________
What is the name of the preschool your child attends?

______________________________________________________________________________

Does your child receive free or reduced lunch? Yes  No

Have you had to change preschools or childcare a lot? Yes  No

Do you own any pets? Yes  No

Do you notice any difficulties your child may be experiencing (e.g., playing with others, speech, counting, etc.)?

______________________________________________________________________________
Neurological Information

1. Does your child see a neurologist? If yes, for what reason?
________________________________________________________________________
________________________________________________________________________

2. Has your child ever experienced a traumatic brain event (e.g., car accident or fall)? If yes, please describe.
________________________________________________________________________
________________________________________________________________________

3. Does your child have any neurological issues (e.g., migraines or epilepsy)? If yes, please describe.
________________________________________________________________________
________________________________________________________________________

4. Does your child have and mood or emotional issues (e.g., anxiety, ADHD, behavioral challenges, etc.)? If yes, please describe.
________________________________________________________________________
________________________________________________________________________

5. Does your child take any medications? If so, what are they?
________________________________________________________________________
________________________________________________________________________

6. Does your child currently receive therapy or services (e.g., physical therapy, speech therapy, behavioral therapy, etc.)? If yes, please describe.
________________________________________________________________________
________________________________________________________________________

7. Is there a history of speech or language difficulties in your family (e.g., stuttering)? If yes, please describe.
________________________________________________________________________
________________________________________________________________________

8. Is there anything you think I should know, that I haven’t asked about? If yes, please describe.
________________________________________________________________________
________________________________________________________________________
9. Has your child ever reported feeling dizzy accompanied with nausea, loss of consciousness, disorientation, or persistent headaches? If yes, how long did it persist?

________________________________________________________________________

10. Have you or your child recently experienced stressful life events (e.g., car accident, loss of a job, loss of a family member, etc.)? If yes, please describe.

________________________________________________________________________
APPENDIX E: Home Language Environment Survey: Nouns

Parent Survey Nouns

Please mark the box that best answers the following question: How often does your child use the following words at home? If you have concerns, please feel free to ask the researcher.

<table>
<thead>
<tr>
<th>Word</th>
<th>A Lot</th>
<th>Fairly Often</th>
<th>Sometimes</th>
<th>Almost Never</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Ball</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Basket</td>
<td></td>
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APPENDIX F: Home Language Environment Surveys: Verbs

Parent Survey Verbs

Please mark the box that best answers the following question: How often does your child use the following words at home? If you have concerns, please feel free to ask the researcher.

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APPENDIX G: Grand Average Waveforms for the Tone Judgement Task

Figure 1. Grand average waveforms for the HEA group during the tone judgment task at left frontal, right frontal, left central, right central, left parietal, and right parietal electrodes evoked by the Standard (1000 Hz) condition and the Target (1500 Hz) condition. Positive is plotted up.

Figure 2. Grand average waveforms for the LEA group during the tone judgment task at left frontal, right frontal, left central, right central, left parietal, and right parietal electrodes evoked by the Standard (1000 Hz) condition and the Target (1500 Hz) condition. Positive is plotted up.
Appendix H: Grand Average Waveforms for the Noun Picture Task

Figure 1. Group (HEA, LEA) grand average waveforms during the noun picture task at all electrodes evoked by the congruent (Match) and incongruent (Mismatch) condition. Negative is plotted down.
APPENDIX I: Grand Average Waveforms for the Verb Picture Task

Figure 1. Group grand average waveforms during the verb picture task at all electrodes evoked by the congruent (Match) and incongruent (Mismatch) condition. Negative is plotted down.