Parental Reflective Functioning and Children’s Emergent Reading Skills:

ERP and longitudinal behavioral measures

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ABSTRACT

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The current study examined the correlations between parental reflective functioning and children’s phonological awareness and reading-related neural development (measured via a phoneme-processing experiment using EEG), and its utility as a predictor of children’s reading skills one year later when they have begun literacy education.

Fourteen pre-readers’ (mean age 4.51 years) phonological awareness and their parents’ reflective functioning skills were assessed, along with their EEG responses in a phoneme-processing task. Children’s phonological awareness and emergent reading skills were assessed again 12-15 months later, at the start of First Grade.

Left-lateralized neural indices were observed to be correlated with parental reflective functioning (PRF) and children’s later reading-related skills. Specifically, scores on measures of PRF: Interest & Curiosity were positively correlated with the N2 amplitude in the left temporal cortex ($p = 0.049$), and the P2 amplitude in the left temporal cortex was also correlated with children’s Phonological Awareness scores ($p = 0.004$) and with their Basic Reading scores ($p = 0.002$) one year later. Multiple linear regression analyses also revealed that scores on measures of PRF: Interest and Curiosity significantly predicted children’s future phonological awareness ($p = 0.014$) and basic reading skills ($p = 0.002$). This study is the first of its kind to identify correlations between parental engagement and neural indices of children’s pre-reading skills, and to reveal parental reflective functioning as a strong predictor of children’s later reading abilities.
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Dedication

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1. Introduction

Advances in today’s communication and social technology require a certain level of reading proficiency on a day-to-day basis; yet reading disorders are amongst the most common developmental disorders in America, affecting 5-17% of school-aged children (Shaywitz, 1998; Lyon, Shaywitz, & Shaywitz, 2003). Though there are different theories of the manifestations of reading disorders like dyslexia (discussed further below), reading scientists and interventionists generally agree that identifying children who are at risk for reading difficulty may help provide optimal intervention for them as early as possible. Parental history of reading difficulty is one of the strongest predictors of dyslexia, but little is known about why having a parent with dyslexia is associated with increased risk of developing reading difficulties (Guttorm et al., 2005; Leppänen et al., 2002; Lyytinien et al., 2004). Although advances in molecular genetics have identified candidate genes associated with dyslexia (Grigorenko, 2001; Nöthen et al., 1999; Taipale et al., 2003), other studies have found that the heritability of dyslexia does not depend on genetics alone, but it is influenced by gene and environmental interactions like parental education level and reading background (Pennington et al., 2009).

One theory that explores parental influences on reading suggests that parents transfer knowledge to their children based on their own reflection of what the child needs/wants (Fonagy, Steele, Steele, Moran & Higgitt, 1991; Slade, 2007). This reflective functioning skill is the ability to perceive other’s and one’s own behaviors in meaningful and predictable context based on past experiences (Fonagy, Target, Gergely, Allen, & Bateman, 2003). Parental reflective functioning skills are often derived from parents’ interpretation of their children’s behaviors and mental states, and their children inherit similar reflections based on their interactions with their parents. For example, if a caregiver has a reading difficulty that influences them to engage in a less facilitative reading style with their child, it is possible that the child in turn will not obtain the interest or requisite skills for learning to read proficiently (Bus & van IJzendoorn, 1988; Karrass & Braungart- Rieker, 2005; Sénéchal, Cornell, & Broda, 1995; Sénéchal & LeFevre, 2001). However, there has yet to be any study conducted specifically to examine parental reflective functioning and its influences on children’s reading and neural development.
While many studies attempt to investigate causes or find treatments for reading disorders like dyslexia, it is difficult for researchers to come to a general agreement on the underlying mechanisms of this reading disorder (e.g., Bishop, 2002; Valdois, Bosse, & Tainturier, 2004; Olulade, Napoliello, & Eden, 2013; Ramus et al., 2003; Ramus, White, & Frith, 2006; Goswami, 2000; Stanovich, 2017). However, there is a growing consensus among researchers that deficits in phonological awareness and phoneme processing may be causal factors in dyslexia (e.g., Goswami, 2000; Goswami, 2011; Ramus, 2003; Ramus, Marshall, Rosen, & van der Lely, 2013; Shaywitz, 1996; Snowling, 1998). Neuroimaging studies have also shown that children and adults with dyslexia exhibit atypical bilateral or right-lateralized reading circuitry in the brain while carrying out reading-related tasks, such as phonological processing (Dehaene & Cohen, 2011; Goswami, 2011; Pugh et al., 2013; Tanaka et al., 2011).

This study investigated the relationships between parental reflective functioning skills, children’s pre-literacy skills (such as phonological awareness), and the development of children’s neural reading circuitry. The current study used the event-related potential (ERP) method to investigate whether young children whose parents have higher reflective functioning exhibit a typical left-lateralized neural response to a phoneme processing task, compared to peers with parents whose reflective functioning is scored lower. Parents’ reflective functioning skills and children’s phonological awareness scores were analyzed, in addition to ERP data, to determine whether they are predictive of children’s behavioral reading outcomes one year later, when children have begun their exposure to formal literacy education.

This dissertation is structured as follows: Chapter 2 provides an introduction to theories of attachment and parental reflective functioning and how they relate to pre-reading development. It also reviews background literature on the neural reading circuitry of typically-developing pre-readers and those at risk for dyslexia, based on studies using various neuroimaging methods. Chapter 3 outlines the research questions, hypotheses and expected outcomes of the study. Chapter 4 summarizes the design and experimental methods, including data acquisition methods for the study, the event-related potential (ERP) technique, and the ERP data processing and brain-behavior statistical analysis procedures. Chapter 5 discusses the results and presents conclusions. Chapter 6 summarizes the discussion and interpretation of the results, as well as the limitations, delimitations, and future directions of the study.
2. Background

2.1 Familial Risk and Deficits in Pre-reading Skills

Familial history of reading disorders has long been established as one of the most important predictors of a child’s reading outcome. Studies have shown that 30-50% of children who have a family history of dyslexia will develop a reading disorder (Pennington, 1990, 1991). Prospective studies of dyslexia include familial risk as a predictor, as symptoms of dyslexia are hard to measure and observe before a child learns to read (e.g., DeFries, Fulker & LaBuda, 1987; Hallgren, 1950; Lyytinen et al., 2004; Pennington et al., 1991; Pennington & Lefly, 2001). Such studies provide an opportunity to examine behavioral differences between children who have a familial history of reading difficulty (at-risk children) and children who do not. In addition, prospective studies that look at familial risks have allowed researchers to determine that the risk of developing dyslexia due to family history of reading difficulties is not discrete, but rather exists on a spectrum (e.g., Elbro et al., 1998; Pennington & Lefly, 2001; Snowling et al., 2003; Snowling et al., 2007). For example, Elbro et al. (1998) found that even though not all children who have a family history of dyslexia developed reading disorders, at-risk children without dyslexia still performed worse on measures of articulation, phonological processing, and letter-word identification when compared to typically-developing peers. Snowling et al. (2003, 2007) and Pennington and Lefly (2001) also showed that children who have a parent with a reading disorder will perform on the lower end of the reading proficiency spectrum, even if they are not diagnosed with a reading disorder. Not only did these studies show that children with a family history of reading disorders have a higher chance of developing dyslexia themselves, but they also suggest that at-risk children have poorer pre-literacy skills when they begin to learn reading.

What these studies fail to address, however, is why there exists such a wide spectrum of familial influences. Why are some children with familial risks diagnosed with dyslexia, while others are resilient enough to read at a more proficient level? Elbro et al. (1998) did not find any significant differences in parents’ own reading habits or in reading levels between the dyslexic and non-dyslexic groups. Likewise, Snowling et al. (2003, 2007) and Pennington and Lefly (2001) did not find any differences in parental reading habits and home literacy environments (e.g., how often parents read to their children) between at-
risk children who were and were not diagnosed with dyslexia. It remains an unsolved mystery as to why familial risk has such a strong impact on children’s future reading outcomes when there seem to be very few measurable differences in the home literacy environments of children with and without significant risk factors.

While the studies above focused on parental reading history and home literacy environment, they did not explore the relationships between parents and their children or how these relationships may facilitate children’s pre-literacy learning at home. Studies that did focus on parent-child relationships found that there is a potential for reading behaviors and habits of the parents to be passed on to their children during their daily interactions (e.g., Bus et al., 1997; discussed further below).

2.2 Parental Involvement and Pre-literacy Skills

Parental influence is known to be critical for the development of pre-literacy skills because these skillsets are typically acquired at home, as most children spend much of their early years modeling their own behaviors after those of their caregivers (Englund, Luckner, Whaley & Egeland, 2004; Fonagy et al., 1991; Miedel & Reynolds, 1999; Stams, Juffer, & van IJzendoorn, 2002). In particular, parental involvement in teaching children about reading and writing is strongly predictive of a child’s performance in school. For example, Sénéchal and LeFevre (2002) showed that children whose parents actively read to them develop stronger pre-literacy skills, such as phoneme decoding (mapping letters onto sounds). Not only did these skills predict children’s reading outcomes at the end of first grade, they were also correlated with overall academic performance two years later. Other studies have provided evidence to support the view that children develop and consolidate pre-literacy skills much more efficiently when their parents provide adequate prompting and feedback during reading time (e.g., Arnold, Zeljo, Doctoroff & Ortiz, 2008; Bus, van IJzendoorn & Pellegrini, 1995; Karras & Braungart-Rieker, 2005; Ortiz, Stowe & Arnold, 2001; Sénéchal, Cornell, & Broda, 1995; Sénéchal, Thomas, & Monker, 1995; Wood, 2002).

For example, Sénéchal et al. (1995) found that not only were four- and five-year-old children able to acquire new vocabulary after exposure to a single book-reading session, but children who participated in the book-reading sessions actively were also able to comprehend and produce more words than
children who passively listened to the story. Children who were actively engaged in the reading sessions had more interactions with their parents, in which the parents pointed to illustrations of the novel words, helped label the novel words, and prompted and answered questions that helped children understand the novel words. Another study conducted by Hargrave and Sénéchal (2000) found that four-year-old children who had poor expressive vocabulary skills showed improvement on vocabulary scores following participation in this type of facilitative reading instruction. Hargrave and Sénéchal (2000) recruited 36 four-year-old children with poor expressive vocabulary skills for an intervention study, in which half (n = 18) of the children’s parents were told to read to their children at least twice a week in the customary fashion over the course of 4 weeks, while the other half of the children’s parents were taught to read to their children in an engaging and facilitative manner. At the end of 4 weeks, children whose parents facilitated an active reading style showed improvements in their expressive vocabulary skills equivalent to those that would otherwise occur normally over 4 months, whereas children whose parents read to them passively did not make significant gains on their vocabulary skills (Hargrave & Sénéchal, 2000). The results of these studies suggest that children’s (pre)literacy skills development (such as expressive vocabulary skills) benefit from active and facilitative book-reading sessions with their parents.

Children’s pre-literacy development is highly correlated with parental interest in their children’s preschool life, and positive parental relationships with their children’s teachers (e.g., Arnold et al., 2008; Weigel, Martin & Bennett, 2006). Arnold et al. (2008), in a study of 163 preschool children, found that caregiver involvement and interest in a child’s preschool activities is highly predictive of the child’s later reading success even after controlling for other important factors (e.g., socio-economic status, single-parenthood). One possible explanation of why parental involvement plays an important role in children’s early literacy development involves the social aspect of parent-child interactions. Kuhl, Tsao and Liu (2003) conducted an experiment with 28 nine-month-old American infants who were read a story in a foreign language (Mandarin Chinese) over the course of 12 sessions to see if they would retain the phoneme discrimination skills necessary to process and recognize that foreign language. Infants are capable of discriminating phonetic units of languages that are both native and foreign to them, but this ability disappears between 6-12 months of age (Kuhl et al., 2003). However, Kuhl et al. (2003) found that
the 13 infants who were read to by a real person in a foreign language (Mandarin Chinese) were able to retain the phoneme discriminating skills necessary to distinguish between the different lexical tones that are used in Mandarin Chinese, whereas the 15 infants who were exposed to a video recording of the same story in the same language for the same number of sessions did not retain the same skills. These findings suggest that there is an important social and interactive aspect to early language learning.

Not only is the social aspect of parent-child interaction key to child development, but the quality and type of interactions between caregivers and their children also seem to influence learning. For example, Bus et al. (1995) conducted a meta-analysis of 29 studies that investigated parent-preschooler reading as one of the variables in predicting children’s later reading outcomes. Even accounting for variations in methods and languages, they found that parent-child reading patterns (such as reading frequency and reading style) strongly correlated with children’s language growth, emergent literacy and reading achievement (Bus et al., 1995). Parent-preschooler book-reading behavior accounted for more than 8% of the variance in these reading outcome measures, and this parent-child reading behavior is not dependent on the family’s socioeconomic status. The observations from Bus et al.’s (1995) meta-analysis show that even in lower socioeconomic families with low levels of literacy, book-reading frequency between the parent and the child affects the child’s literacy development. The results of the studies described here offer evidence to support the movement in several countries to implement parent-preschooler reading programs, particularly for families from low socioeconomic backgrounds (Bus et al., 1995).

A common finding from the 29 studies in Bus et al.’s (1995) meta-analysis is that a more engaged book-reading interaction style between parents and their children seems to foster book-reading interest in young children. Ortiz, Stowe and Arnold (2001) recruited 25 pairs of preschoolers and their parents to participate in a book-reading intervention in an attempt to increase children’s interest in reading. Twelve pairs of parent-child dyads participated in a one-week intervention program that taught parents how to read to their children in an engaging and facilitative manner designed to promote children’s inquisitiveness (e.g. by getting the child actively involved during book-reading sessions, using positive feedback, prompting the child to ask questions). Compared to the control group, parents who participated
in the intervention not only adopted a more engaging style when reading with their children, but their children responded more positively to book-reading sessions and sought to participate more frequently in interactive reading behaviors with their caregivers (Ortiz, Stowe & Arnold, 2001). While the authors did not follow up with the children’s later reading outcome, their results support Bus et al. (1995)’s findings, in that a more engaging parent-child relationship in reading was shown to foster children’s interest in books and their literacy development.

To understand why parents and caregivers have such a significant influence on children’s reading outcomes, it is helpful to consider theoretical frameworks that attempt to clarify the nature of parenting and its role in child development. Especially in early childhood, parents and caregivers are often the role models from whom children learn. Infants and young children receive information about their world through the people who take care of them, and children develop a response to their surroundings through their interactions with their caregivers (a situation referred to as “Parental Affect Mirroring”, Gergely & Watson, 1996, discussed further below). It is through what Gergely & Watson (1996) described as mothers exaggerating realistic emotional expressions to their very young infants (in which the infants’ emotional states are being re-presented back to them by their mothers), that children first learn to understand and present affect. If children experience predictable behavior from their parents (e.g. they are fed when hungry, or they receive comfort when scared), they will develop a sense of security with their caregivers and thus interact with their surroundings in a more secure way (Fonagy et al., 2002). But if children experience inconsistent and chaotic behavior from their caregivers (e.g. parents respond to infants’ distress with their own distress, or infants are neglected when they need attention), they are likely to develop insecurity towards their caregivers, and these experiences can foster fear and anxiety when facing the rest of the world (Fonagy et al., 2002).

The development of a reflective stance continues after infancy, and this again greatly depends upon the caregiver’s capacity to enter what Winnicott (1965, 1971) refers to as the “Transitional Playspace”; that is, the caregiver’s ability to bridge and separate “playing” and “reality” using language. This not only teaches children to differentiate between reality and play so that they do not become overwhelmed with the “realness” of imaginative play, but the use of language and symbols also
introduces children to the world of communication (Fonagy et al., 2002; Winnicott, 1965, 1971; Slade, 2005). Thus, parental involvement is crucial not just in relation to the infant’s survival, but also in terms of the young child’s self-awareness, interaction with other people and with their environment, and other aspects of cognitive development.

The notion that parental reflective ability affects children’s later social and cognitive development has been studied for decades (e.g., Ainsworth, Bell & Stayton, 1974; Borelli, Crowley, David, Sbarra, Anderson & Mayes, 2010; Fonagy, 1999; Schore & Schore, 2008). The Attachment Theory (Ainsworth, 1979; Bowlby, 1977) has been used as a basis for many investigations into aspects of child development; however, not many studies have been conducted to directly investigate possible relationships between attachment and reading. The study of attachment and its potential influence on reading development seems a natural course for developmental science, because most children learn the fundamental pre-reading skills (such as oral language) at home from their caregivers. But in order to understand more about how parent-child attachment may influence reading development, we must first consider the research that has supported Attachment Theory.

2.3 Attachment Theory and Development

2.3.1 Attachment Theory.

Contemporary psychodynamic theory relies strongly on Bowlby’s and Ainsworth’s Theory of Attachment when it comes to analyzing parent-child interactions (Ainsworth, 1979; Bowlby, 1977). The Attachment Theory was proposed after World War II to explain how the formation of relationship between an infant and their primary caregiver would influence later social and emotional bonding (Ainsworth, 1979; Bowlby, 1977). The Attachment Theory posits that children (except for those who experienced severe neglect during their early childhood) engage in varying patterns of attachment with their primary caregivers—referred to as “attachment styles” (Ainsworth, 1979; Bowlby, 1977).

2.3.2 Attachment Styles.

Current attachment researchers have identified four main attachment styles: secure attachment, anxious-insecure attachment, avoidant-insecure attachment, and disorganized-insecure attachment. Ainsworth (1979) was a pioneer with respect to the experimental aspect of the Attachment Theory, and
developed an experimental protocol, the “Strange Situation”, to objectively test and identify a child’s attachment style with their caregiver. The Strange Situation is comprised of a separation and reunion phase, and the reactions of the targeted infant are observed during the two phases (Ainsworth, 1979). First, a primary caregiver is alone in a room with the child, and then an adult stranger (the experimenter) enters. Shortly after the experimenter arrives in the room, the caregiver leaves the child and exits the room (known as the “Separation Phase”) while the experimenter interacts with the child. After a short period of time, the caregiver re-enters the room (known as the “Reunion Phase”) and interacts with the child again.

During the Separation Phase, most securely-attached children would feel highly distressed when their caregivers leave the room, and this distress is not easily soothed by the experimenter. On the other hand, insecurely-attached children, especially disorganized-insecure infants, would not always exhibit this behavior, instead behaving indifferently to their caregivers’ departure, or attempting to attract the attention of experimenter. Though there are some distinctive behaviors during the Separation Phase that can help researchers understand a child’s underlying attachment mechanisms, it is the Reunion Phase that is informative of a child’s attachment style to their caregiver. For example, securely attached infants would be reassured upon their caregivers’ return, but insecurely attached infants almost always react in a very different manner (Ainsworth, 1979). Some insecure infants would be soothed upon the arrival of their caregivers, but they may also exhibit anxiety or even fear of their caregivers, by hypothesis because they have repeatedly undergone similar experiences of abandonment before. Disorganized-insecure infants often appear ambivalent upon their caregiver’s arrival, and attachment researchers have speculated that this could be due to application of the infants’ coping mechanisms to their caregivers’ unpredictable parenting behaviors (Ainsworth, 1979).

Ainsworth’s observations of infant attachment styles are closely linked to Erikson’s theory of the “Eight Developmental Stages of Men” (Erikson, 1959). Within Erikson’s framework, the first developmental stage revolves around the concept that an infant’s basic needs are met and provided by their parents, particularly through social interaction (Erikson, 1959). An infant first develops trust for others and for oneself through interactions with the caregiver. If a caregiver provides physical and
emotional warmth, care and affection in a dependable and predictable manner, the child is able to develop a sense of trust for their surroundings, as well as confidence to explore the unknown. By contrast, if a caregiver’s behavior is critical and undependable, the infant will cease to develop a sense of trust in the world, as well as a sense of self-trustworthiness (Erikson, 1959). The lack of self-trust has an intimate connection with Erikson’s second and third developmental stage: autonomy versus shame/doubt, and initiative versus guilt. In the second stage of psychosocial development (autonomy versus shame/doubt), Erikson emphasized the importance of caregivers’ role in maintaining a balance between control and support for their children between the ages of 18 months and 3 years (Erikson, 1959). During this time, children begin to discover that they need to learn many abilities (e.g. shoe-tying), and if given an encouraging environment in which they are allowed to explore these abilities without the fear and shame of failure, children will be able to develop a sense of autonomy and independence. After developing this sense of independence, children move on to the third stage of development in Erikson’s framework: initiative versus guilt. Often, this stage sets apart children aged 3-6 years, a period during which parents’ critical or over-protective behaviors may affect a child’s development of decision-making (Erikson, 1959). Constant criticism of a child’s behavior may lead to a sense of guilt and regressing back to a lack of self-trust and self-awareness. Moreover, an overprotective parenting attitude can hinder a child’s ability to take initiative to engage and explore their surroundings (Erikson, 1959). Parenting behavior and attachment styles, therefore, are crucial in shaping children’s cognitive development.

2.3.3 Attachment and cognitive development.

Compared to insecurely-attached children, children who have a secure attachment relationship with a primary caregiver are often more willing to explore and investigate new situations, persist through challenges, and seek and accept assistance from their caregivers (e.g., De Ruiter & Van IJzendoorn, 1993). The idea that securely-attached children are capable of seeking and accepting help is important, because it shows that there exists a healthy flow of information between children and caregivers in a secure attachment relationship. In order to recognize and face challenges, a child must acquire the ability to be aware of their own skillset (or lack thereof) (Bergin & Bergin, 2009). It is more likely that securely-attached children exhibit higher levels of such awareness and regulation of cognition (or metacognitive...
processes), because the internal working models of a secure attachment are coherent and consistent. This sense of stability allows children to predict and understand their surroundings (van IJZendoorn, Dijkstra, & Bus, 1995; West et al., 2013). Successful metacognitive monitoring is also important in learning other cognitive skills, as children acquire new knowledge by understanding their own capabilities, and when to seek help and new information from their caregivers (e.g., McCormick, Qu, & Telzer, 2016; van IJZendoorn et al., 1995).

By contrast, insecure-disorganized children have been observed to experience verbally dysfunctional communication relationships with their caregivers (e.g., Main, Kaplan, & Cassidy, 1985). Insecurely attached children are hypothesized to have an unstable internal working model because their relationship with their primary caregiver was built on unpredictable and inconsistent behaviors (Ainsworth, 1979). Such children are expected to be more fearful and nervous about exploring new environments, probably because they are unable to predict what new situations may entail based on the inconsistent outcomes they had experienced previously. In addition, insecurely attached children tend to exhibit constantly changing behaviors towards their caregivers (e.g. they may be clingy at times, but express an indifferent attitude at others), because they have also experienced inconsistent and changing responses from their caregivers in the past (Ainsworth, 1979). Thus, it is less likely for insecurely attached children to view their caregivers as a secure base or a source for stability when they encounter challenges, and so they are expected to engage in independent exploration without seeking help and new information from others (van IJZendoorn et al., 1995; West et al., 2013).

In many cases, having a consistent adult attachment figure is important in the early stages of language development (e.g., Fonagy et al., 2002; Winnicott, 1965). Knowledge transfer often occurs when a caregiver is reliably present to talk to and to listen to their child, and a child can be dependent on the caregiver as a source of new information and emotional support as they encounter novel challenges. But as important as it is for children to have a stable caregiving figure, parents also change their behavior in response to their children’s reactions. In this sense, attachment relationships are bi-directional, such that a child’s attitude towards their parent elicits specific responses from the caregiver based on the nature of the attachment relationship (Fonagy et al., 1991, 2002; George & Solomon, 1996). The ability of
parents and caregivers to reflect on their own (and their children’s) state of mind is referred to as “Parental Reflective Functioning”, and this ability is often observed and measured in parent-child studies (Fonagy et al., 1991, 2002). As previously mentioned, parent-child reading studies have shown that parents who read in a more interactive manner elicit more positive and engaging responses from their children (e.g., Bus et al., 1997; Ortiz et al., 2001; Sénéchal & LeFevre, 2001; Wood, 2002). In turn, the positive behaviors of the children stimulate parents to continue to employ an engaging reading style more frequently. Parents who exercise this type of facilitative reading are able to infer their children’s mental states about reading and conduct reading activities in a way that more effectively arouses their children’s interest in books (Bus & van IJzendoorn, 1988; Bus, Belsky, van IJzendoorn & Crnic, 1997; Sénéchal & LeFevre, 2001; Weigel, Martin & Bennett, 2006). Caregivers who have higher reflective functioning skills tend to have more securely attached relationships with their children, and thus their children respond more positively during book-reading sessions (characteristic of securely-attached children) (e.g., Bateman & Fonagy, 2010; Bus et al., 1997; Ortiz et al., 2001; Wood, 2002). Thus, contemporary attachment researchers are not only focusing on children’s attachment styles, but they are also interested in how parental reflective functioning comes into play in terms of early childhood development (Fonagy et al., 1991; Fonagy & Target, 1997; Slade, Sadler, & Mayes, 2005; Schore & Schore, 2008).

2.4 Parental Reflective Functioning

Reflective functioning (or mentalization) is mentioned in works dated back to Descartes’ theory of mind-body dualism (1641), but the term was not fully explored and defined until Fonagy et al. (1991) began to investigate the properties of reflective functioning in relation to attachment. Reflective functioning is defined as “the process by which we make sense of each other and ourselves, implicitly and explicitly, in terms of subjective states and mental processes” (Bateman & Fonagy, 2010, p. 11). Bateman and Fonagy (2010) proposed that the ability to mentalize is intimately connected to the theory of attachment, because a caregiver’s ability to understand a child’s emotional experience, as well as the ability to internalize and provide manageable feedback to the child, allows the child to model after the caregiver in a similar manner. By hypothesis, we are born with the ability to develop mentalization skills; still, it is our earliest relationships that create the foundation on which we build an understanding of the
ment states of ourselves and of others (Fonagy et al., 2002). Infants do not yet have the ability to recognize and communicate affective states at the time of birth. Rather, the experience and understanding of affective and mental states is usually first instantiated through Parental Affect Mirroring (Gergely & Watson, 1996). The Parental Affect Mirroring theory suggests that caregivers tend to express an exaggerated version of their young infant’s affect display, and through mirroring this exaggerated display of emotion, the infant would reflect similar display of the affect back to their caregiver. It is believed that through this transmission of affective presentation, infants become able to recognize these emotions in themselves and in others (Gergely & Watson, 1996; Slade, 2005). For example, when a parent tries to elicit signs of happiness from their infant, they may tickle the baby while laughing in an exaggerated manner. Through these repeated interactions, the baby comes to recognize that laughter is associated with feelings of happiness, and eventually laughs in order to express this affective state (Gergely & Watson, 1996). Of course, parental affect mirroring also depends on the parent’s ability to recognize the infant’s mental state (Fonagy et al., 2002). If a parent believes that their infant’s signs of distress (e.g. crying to be picked up) are a form of manipulation in order to get attention, they may respond by constantly ignoring the infant’s cries. In this case, the infant’s representation of distressed feelings may be distorted, because the infant could form the association between distress and a neglectful response. This may lead to the child mislabeling emotional states, because the child was not exposed to the corresponding response to that would soothe distress (Fonagy et al, 2002). Due to the nature of this transmission framework, attachment researchers believe that a child’s ability to reflect upon their own self and to regulate their emotions in response to the mental states of others is likely to affect the development of a secure attachment relationship in which the primary caregiver exercises proficient functioning mentalizing abilities (Bateman & Fonagy, 2010).

While this framework of transgenerational processes may appear rigid, it is important to keep in mind that history does not equal destiny. There is evidence that adults with a history of deprivation, neglect and/or abuse have been found to be more likely to experience difficulty in all stages of their family life, but many of these individuals are able to become effective parents (Fonagy et al., 1994; Frommer & Shea, 1973; Kaufman & Zigler, 1989). Clinical and epidemiological data have shown that
many parents’ past experiences of neglect, abandonment and abuse do not necessarily imperil their bond with their children (Cowen, Wyman, Work, & Parker, 1990; Kaufman & Zigler, 1989). Intelligence, positive school experiences, socioeconomic status, strong religious affiliations, a positive network of friends in childhood and adulthood, support from spouse, and a strong sense of belonging to a community are common factors that are observed in resilient parents who suffered abusive and neglectful relationships in the past (Cowen et al., 1990; Kaufman & Zigler, 1989; Fonagy et al., 1994). In addition to the features above, another important protective factor that is observed in resilient parents is their capacity for parental reflective functioning (Fonagy et al., 1994, 2002). Fonagy and colleagues (2002) argue that parental reflective functioning may have the potential of being one of the more important factors contributing to resilience from transgenerational adversity, and it may also have the potential to mediate other protective factors as well. In a longitudinal study, Steele et al. (1991, 1999) examined whether adults’ attachment styles and reflective functioning ability could predict their future children’s bond with them. The study recruited 96 mothers who were pregnant at their first visit when their attachment style was evaluated using the Adult Attachment Interview (a measure developed by George, Kaplan & Main (1985) to assess an adult’s attachment style to their primary caregiver). Later, their infants’ attachment bonds with the mothers were assessed using the Strange Situation paradigm when the infants were 18 months old. The study revealed intergenerational transmission of insecure attachment, as 2/3 of the mothers who had insecure attachment relationships with their parents also formed insecure-avoidant bonds with their infants (Steele, Steele, Fonagy, & Higgitt, 1991; Steele, Steele, Croft, & Fonagy, 1999). But the authors argue that the more informative aspect of this result is why 1/3 of insecure mothers in this study were resilient to the effects of intergenerational transmission of insecure attachment bonds. The authors developed a series of interview questions (later known as the Parental Reflective Functioning Questionnaire) to examine the different protective factors that might help mothers had previous neglectful or abusive relationships form secure bonds with their infants. Fonagy et al. (1993) hypothesized that perhaps an individual’s ability to invoke one’s own mental state constructs (e.g. feelings, beliefs, conflicts) would allow the individual to anticipate and understand others’ mental states as well. Thus, the authors believe that the awareness of mental states (reflective functioning) would allow an insecure parent
to organize, develop and maintain secure attachment relationships with their child (Fonagy et al., 1993). Indeed, when Fonagy et al. (1993) reanalyzed the 96 mother-infant dyads using the parental reflective functioning interview questions, they found that 52% of the mothers who had secure attachment bonds with their infants also had high reflective functioning skills, compared to only 10% of the mothers who had insecure attachment relationships with their infants (Fonagy et al., 1993). When the results were examined further, the authors observed that 100% (10 out of 10) mothers who were deprived as children but had high reflective functioning skills formed secure attachment bonds with their infants. Their infants showed fewer avoidant behaviors and more physical contacts with their mothers during the Strange Situation paradigm. On the other hand, only 1 mother (out of 17) who had neglectful relationships as a child but did not have high reflective functioning skills was able to form a secure attachment bond with her infant (Fonagy et al., 1993). Other factors previously found to be significant in protecting against transgenerational adversity (like marital satisfaction, self-esteem, self-efficacy, previous experience with child care) became non-significant once parental reflective functioning skills were controlled for, which suggests that reflective functioning may enhance and even predict the power of other protective factors mentioned above (Fonagy et al, 1993). While the study does not permit the certain conclusion that reflective functioning acts as a mediator for protective factors against transgenerational insecurity attachment, the results are consistent with the notion that parental reflective functioning skills contribute to parent attachment style (Fonagy et al., 1993).

In the reflective functioning interview, Fonagy et al. (1993) noted that parents who scored highly on the parental reflective scale also provided narratives that reflected a more coherent mental representation of their own caregivers’ psychological and emotional states (from the past), and of themselves as adults (from the present) and as children (from the past). They almost always demonstrated a willingness and ability to contemplate psychological states and motivations, and even address conflicts between beliefs and desires. By contrast, parents on the lower end of the parental reflective scale rarely included references to mental states, either their own or those of others; when they did, it was in platitudinous terms (e.g. “one must walk in another’s shoes”). They also appeared to confuse their own psychological states with those of other people, perhaps indicating a lack of awareness that others’
mentalities are different from their own (Fonagy et al., 1993). Fonagy et al. (1993) recognized the similarities between parental reflective functioning and Theory of Mind research, as it seems that there is commonality between cognitive developmental psychology research into self-awareness and the traditional psychoanalytic approaches to reflective-self capacity (e.g., Whiten & Byrne, 1991; Hobson, 1991; Mayes, Cohen & Klin, 1993). Thus, Fonagy et al. (1993, 2010) further developed their parental reflective interview into a tool that would allow researchers to investigate the reflective functioning skills of caregivers, and the ways in which they may potentially inform interventions in transgenerational risk.

Because it is very difficult to measure reflective functioning skills in infants and young children, research has focused on the ways in which caregiver reflective functioning may be representative of that of their children (e.g., Bateman & Fonagy, 2010; Rutherford, Goldberg, Luyten, Bridgett & Mayes, 2013; Rutherford et al., 2015; Schore & Schore, 2008; Slade, 2005). The notion that a child’s mentalizing ability could be influenced by parental reflective functioning is strongly reminiscent of Bowlby’s (1977) proposal that internal working models develop most effectively within secure attachments. A child develops perceptions of feelings, motivations, expectations, and beliefs about self and others by relating to their own past experiences. If a caregiver is able to understand and positively respond to a child’s distress, the child comes to be able to experience a positive perception of the self (as worthy of being loved), of others (as reliable and trustworthy), and of the world (as predictable and safe) (Bowlby, 1977). The child can then respond and behave towards others (including the caregiver) in a similar manner.

Clinical case studies have found that both the parents and children in an insecure attachment relationship have greatly benefitted from a 20-week long attachment-based intervention that focused on the parents’ reflective functioning towards themselves and their children (Marvin, Cooper, Hoffman & Powell, 2002). Not only did the parents exhibited better self-reflective skills and higher sensitivity and accuracy to what their children’s behavior, their children also displayed more behaviors characteristic of secure attachment relationships (such as more engagement with parents, seeking for comfort from parents). Another treatment study that focused on enhancing parental reflective functioning on high-risk parents also found that substance-abusing mothers developed higher sensitivity and more accurate responses to their children’s emotions, better caregiving abilities, and overall more coherent and stable relationships with
their children after a 12-week long intervention (Suchman et al., 2010). These studies suggest that attachment relationships might not be as rigid as they were first assumed, and that improving reflective functioning skills could enhance the quality of parent-child relationships. Therefore, attachment relationships are bidirectional – the caregiver’s interactions with the child provide the foundation for the child to form an attachment relationship, and the attachment styles of a child can influence and even change how caregivers interact with the child. In this sense, parental reflective functioning skills play a key role in forming attachment relationships between caregivers and children.

2.5 Evidence of Parental Influence on Pre-reading

Parental reflective functioning is still a relatively new idea in reading developmental research, as most developmental research that involves the measure of parental reflective function is focused on children’s affective, social and cognitive development. However, some research on parental book-reading behavior has shown that parents’ reflective functioning skills may potentially influence children’s pre-reading development (e.g., Bus, Belsky, van Ijzendoom, & Crnic, 1997; Ortiz, Stowe, & Arnold, 2001; Bus & van IJzendoorn, 1988).

Book-reading sessions between caregivers and their children provide a valuable opportunity for observing how parental reflective functioning can elicit attachment responses. Bus et al. (1997) and Ortiz et al. (2001), in studies on parental reading styles and their children’s responses, found that children whose parents engaged in book-reading using more interactive methods (e.g., eliciting children’s responses to the stories by asking questions) also responded more positively towards their parents. The child participants exhibited behaviors associated with secure attachment styles, in that they expressed more curiosity and interest in the books during the reading sessions. On the other hand, children whose parents read in a more passive manner (e.g. reading the books word-for-word with no additional interaction with the children) tended to have a shorter attention span and exhibited more disruptive behaviors during book-reading sessions. They also displayed behaviors more characteristic of insecure attachment styles, such as being less attentive and less interested in their parents’ reading, seeking attention from their parents or being distracted by other objects in the room (Bus & van IJzendoorn, 1988; Bus et al., 1997; Ortiz et al., 2001). Many parenting studies, including the ones mentioned above, have
shown that parenting practices and parent-child relationships are the single most important predictors of performance on oral language skills like phonological processing in early childhood (e.g., Bus et al., 1997; Molfese, DiLalla, & Bunce, 1997; Share, Jorm, Maclean, & Matthews, 1984). Although these studies did not use measures of parental reflective functioning in particular, it is evident that young children’s pre-literacy development is highly influenced by their caregivers’ interactions.

While there is little research on parental reflective functioning and its influence on children’s literacy development, even less is known about parental influence on children’s neural development as they begin to learn to read. However, the need for such research is quickly becoming apparent, as recent neuroimaging studies have found that parents have a direct impact on their children’s cognitive processes during reading. For example, Ohgi, Loo and Mizuike (2010) measured functional changes in the frontal cortex of the brain using near-infrared spectroscopy (NIRS) when young children were being read to by their mothers, compared to passive viewing of a video recording of someone reading the same picture book. The study revealed that frontal areas showed higher levels of oxygenated hemoglobin – indicative of increased neural activity – when the children were being read to, consistent with the idea that interpersonal book-reading between caregiver and child fosters learning.

Because the acquisition of reading skills is so complex, it is difficult to isolate specific factors that might influence reading development. However, phonological awareness is a pre-literacy skill on which many studies have focused, not only because it is a skill that is generally thought to be first acquired in the home, but also because it is also highly predictive of a child’s future reading outcomes (e.g., Brady & Shankweiler, 2013; Castles & Coltheart, 2004; Hulme et al., 2002; Snow, 1991).

2.6 Importance of Phonological Awareness in Reading

Before children receive formal literacy instruction at school, they must have a set of pre-literacy skills and experiences that prepare them for the complex task of learning to read, including rhyming skills, the ability to break words and sentences down into their component parts, and sensitivity to the sounds, or phonemes, within words (i.e., phoneme awareness) (e.g., Hulme et al., 2002). While dyslexia is correlated with poorer performance in many pre-literacy skills, phonological awareness is one of the pre-literacy skills that most strongly predict future reading outcomes and academic achievement (e.g.,
Brady & Shankweiler, 2013; Castles & Coltheart, 2004; Hulme et al., 2002; Pennington & Lefly, 2001; Snow, 1991). Although consensus has yet to be reached regarding any specific cause of developmental dyslexia, there exists a well-established body of literature suggesting that deficits in phonological awareness can limit one’s ability to establish accurate mappings between written language and phonology, thus resulting in reading difficulty (e.g., Bradley & Bryant, 1983; Snowling, Goulandris, Bowlby, & Howell, 1986; Stanovich, 1986).

Prospective studies conducted with children at risk for dyslexia have shown that deficits in phonological processing and phonological awareness are often already present before they start learning to read. For example, Caravolas et al. (2012) followed 523 children from four different countries (the United Kingdom, Spain, Czech Republic, and the Slovak Republic) over the course of three years to try to identify any common predictors of reading skill or disability (Caravolas et al., 2012). Even though the trajectory of reading development is different in English compared to Spanish, Czech and Slovak (which are languages with more transparent orthographies than English), children from all four language backgrounds who had poorer phonological awareness skills showed more difficulty in learning to read and were more likely to have developed dyslexia within three years (Caravolas et al., 2012).

While deficits in phonological awareness may not be obviously causally linked to dyslexia, some treatment studies have shown that supporting phonological processing skills may help a sub-group of children with dyslexia to perform better on reading tasks. For example, Warmington and Hulme (2012) found that children’s performance on paired verbal-visual learning tasks was indicative of their ability to read both real words and pseudo-words. In a follow-up treatment study, they found that pre-readers and emergent readers with poor verbal skills greatly benefitted from a phoneme-based reading intervention (Fricke, Bowyer-Crane, Haley, Hulme & Snowling, 2013). After 20 weeks of intervention, 152 children with poor verbal skills improved in letter-sound knowledge and phonological awareness, which directly predicted the progress of their overall reading skill 5 months later.

Presumably, skilled reading requires the integration across modalities of information from speech and print, at both behavioral and neural levels. Functional convergence across spoken and printed modalities has been shown to correlate with the ability to decode words, as well as the development of
neural pathways associated with skilled reading (e.g., Preston et al., 2016). This multi-modal approach to understanding the development of reading and reading disabilities will be discussed next.

2.7 Hemispheric Lateralization in Reading Circuitry

2.7.1 Hemispheric lateralization in skilled and dyslexic readers.

The network of brain regions involved in skilled reading includes multiple left-lateralized hemispheric regions, including the dorsal or temporoparietal circuit (especially the left inferior occipital regions and the inferior frontal gyrus (IFG)) and the ventral or occipitotemporal circuit (including the supramarginal gyrus, inferior parietal lobe and the superior temporal gyrus (STG)) (e.g., Dehaene & Cohen, 2011; Diehl et al., 2014; Hoef et al., 2007; Pugh et al., 1996, 1997, 2000). People with dyslexia have been shown to exhibit hypoactivation in these circuits in the left hemisphere (e.g., Dehaene, 2009; Hoef et al., 2011; Norton, Beach, & Gabrieli, 2015; Paulesu et al., 2000, 2001; Raschle, Zuk, & Gaab, 2012). The universality of the neurobiology of dyslexia has been a topic of debate, because the number of cases of dyslexia in some countries (like France and Italy) are much less than in English-speaking countries (Dehaene, 2009). However, Paulesu and colleagues identified universal hypoactivation in left hemispheric regions across people with dyslexia from different language backgrounds (Dehaene, 2009; Paulesu et al., 2000, 2001). Paulesu et al. (2000, 2001) proposed that the prominence of dyslexia is the same in all countries, but the symptoms of dyslexia are much more conspicuous in countries with orthographically opaque languages because the processing of opaque orthographies relies to a greater extent on the brain circuitry that maps visual words to word sounds (Dehaene, 2009; Paulesu et al., 2000, 2001). Paulesu et al. (2000, 2001) found that people of different language backgrounds who have dyslexia also share a similar hypoactivation in the left temporal lobe despite the fact that speakers of Italian with dyslexia (Italian is a shallow orthographic language) performed better on reading and phonological tasks than their dyslexic counterparts in the U.K. and France. Positron emission tomography revealed significantly reduced activation in the middle and inferior regions of the left temporal lobe for the dyslexic groups in all three countries compared to typically-reading comparison participants (Paulesu et al., 2001). Thus, even though there might be behavioral differences among dyslexics with different
language backgrounds, it is suspected that there could be a universal underlying anomaly in the neural circuitry of people with dyslexia that is activated during reading (Paulesu et al., 2001).

Similarly, children with dyslexia have also shown a hypoactive pattern in the left hemisphere during reading (e.g., Shaywitz, 1998; Shaywitz et al., 2004). Before they engage in formal literacy education, a bilateral activation pattern is often seen in typically-developing children as they are carrying out reading-related activities (Dehaene & Cohen, 2011; Preston et al., 2016). As they begin to learn to read, this bilateral activation appears to gradually shift leftward, eventually approximating to the activation pattern seen in normal adult readers (Pugh et al., 1996, 1997, 2000; Shaywitz et al., 2004). By contrast, children with dyslexia show a more bilateral (with a slight lateralization to the right hemisphere) and greater frontal neural activation during reading than their typically-developing peers (Dehaene & Cohen, 2011; Hoeft et al, 2007, 2011; Pugh et al., 1996, 1997, 2000; Shaywitz, 1998; Shaywitz et al., 2004). Studies have shown that dyslexia in children is associated with hypoactivation in left hemisphere reading circuitry, with a corresponding hyperactivation in right temporoparietal and occipitotemporal regions, as well as in the prefrontal cortex, when reading and performing other reading-related tasks (Hoeft et al., 2011; Shaywitz et al., 2002; Temple et al., 2001).

Children with dyslexia may maintain this bilateral activation while typically-developing children shift to a more left-lateralized neural circuitry as they become more skilled at reading (e.g., Dehaene & Cohen, 2004, 2011; McCandliss, Cohen, & Dehaene, 2003). Skilled adult readers activate fast visual processing that appears to be fine-tuned for words or word-like strings; such activation is critical for recognizing, categorizing and identifying visual stimuli in order to develop expertise in reading (Dehaene & Cohen, 2004; Maurer et al., 2005, 2006; Palmeri et al., 2004). While most of the studies mentioned above used MRI as their primary imaging technique, Maurer et al. (2005, 2006) used an event-related potential (ERP) paradigm to study the rapid neural response to “print-tuning”, because the processes involved in recognizing and identifying word-like stimuli happen so quickly. Maurer et al. (2006) aimed to investigate how the ERP referred to as the N170 develops in children as they learn to read. In adult readers, an N170 response (increased neurophysiological activity measured by EEG between 140 and 200ms in the left occipitotemporal lobe) is observed during word reading (Bentin et al., 1999; Maurer et
The N170 is also believed to be associated with visual categorization in fields of expertise and automaticity; for example, larger N170 amplitudes were elicited from bird watchers in response to pictures of birds compared to pictures of dogs (Tanaka & Curran, 2001). Similarly, as children begin to learn to read proficiently, they show an N170 ERP; this becomes more left-lateralized as reading expertise increases (Maurer et al., 2006). However, this N170 component is not seen in kindergarteners who have yet to receive literacy education. Thus, Maurer et al. (2006) argue that the N170 is an important early ERP component that reflects left-lateralization as a function of increasing automaticity in the visual recognition of printed words. The amplitude of the left-lateralized N170 component has been observed to be reduced in both children and adults with dyslexia (Helenius et al., 1999; Kast, Elmer, Jancke, & Meyer, 2009).

Current research is beginning to show that bilateralized neural activity and even hypoactivation in the left hemisphere may appear in children who are at risk for reading difficulty before they begin to learn reading (Preston et al., 2016; Pugh et al., 2013). While Maurer et al. (2006) suggest that pre-readers may not yet exhibit a lateralized reading pattern when viewing words or letter-strings, their experimental paradigm only evaluated children’s neural responses to visual word cues, but not words presented in other modalities that may reflect their reading-related skills. Their study on the N170 in school-aged children suggested that “print-tuning” is related to word reading frequency (like vocabulary), but not correlated with phonological processing abilities (Eberhard-Moscicka, Jost, Raith, & Maurer, 2014; Maurer et al., 2006). The authors suggested that their experimental paradigm and assessments did not capture the critical aspects of phonological processing previously found to be highly associated with visual word activation (Eberhard-Moscicka et al., 2014; Shaywitz et al., 2004). By contrast, some studies have shown that a lateralized reading pattern may be observed even in beginning readers engaged in pre-reading tasks involving speech perception (Frost et al., 2009; Preston et al., 2016; Pugh et al., 2013). In particular, poor phonological awareness appears to be associated with hypoactivation in the left hemisphere, similarly to reading in individuals with dyslexia, and not only does poor phonological awareness predict worse reading outcome in the future, it may also correlate with hypoactivity in the left brain in at-risk pre-readers (Frost et al., 2009; Preston et al., 2016).
2.7.2 Phonological awareness and hemispheric lateralization.

Multiple treatment studies have shown that children with reading deficits often have difficulty manipulating the phonological units of language, and that reading ability can improve after phonology-based interventions (Alexander, Andersen, Heilman, Voeller, & Torgesen, 1991; Eden et al., 2004; Hoeft et al., 2011; Lovett et al., 1994; Schneider, Roth, & Ennemoser, 2000; Shaywitz et al., 2004). These studies also found that phonology-based interventions are associated with a shift from right-lateralized to left-lateralized activation in some dyslexic readers (Eden et al., 2004; Hoeft et al., 2011; Shaywitz et al., 2004). Thus, there appears to be a connection between good phonological awareness skills and later reading success, as well as the development of a typical left-lateralized reading network.

Indeed, phonological awareness skills are positively correlated with the degree of activation observed in the left-hemisphere reading network, including the left inferior frontal gyrus (IFG), left superior temporal gyrus (STG) and occipito-temporal regions, when processing visual and auditory real words and pseudowords (Frost et al., 2009). In this fMRI experiment, Frost et al. investigated the relation between phonological awareness and printed words via a cue-target experimental paradigm in which 43 beginner readers (aged 6-10 years) identified whether words (presented auditorily or visually) matched images. They found that better phonological awareness in beginning readers predicts more overlap in left STG regions activated when processing visual and auditory words. These findings reflected the notion that phonological awareness is not only correlated with and useful in speech perception (i.e. listening to spoken words), but it is also crucial for the beginning stages of reading acquisition. Frost et al. (2009) argued that phonological awareness and reading have a reciprocal relationship, in which phonological awareness influences reading achievement (decoding), which further enhances the development of phonological awareness (Frost et al., 2009; Perfetti et al., 1987; Wagner et al., 1994).

To evaluate whether there is reciprocity between reading and phonological awareness, Preston et al. (2016) conducted a follow-up study with 68 second-graders using the same cue-target fMRI paradigm. They examined a reading network previously identified by Pugh et al. (2013) in their work related to the predictive value of print-speech convergence for reading outcomes. This network consists of the bilateral inferior frontal gyrus (IFG; pars opercularis and pars triangularis), temporoparietal regions including STG.
(anterior and posterior), inferior parietal cortex (IPC; inferior parietal lobule and supramarginal gyrus), and the fusiform gyrus, which contains the occipitotemporal region. Preston et al. (2016) found that those beginning readers who showed co-activation in the left hemisphere reading regions (including the IFG and inferior parietal cortex) during both speech and print word processing tasks achieved better reading scores and better phoneme-processing skills 2 years later. By contrast, poorer eventual reading outcomes and poorer phonological awareness were associated with greater co-activation in the right hemisphere (specifically right IFG) during both task modalities (speech and print). These findings suggest that children who experienced poorer reading trajectories over two years not only showed weaker activation in the left IFG and stronger activation in the right IFG during reading, but they also experienced the same neural pattern during spoken word processing (Preston et al., 2016). The predictive power for reading outcomes of examining print-speech coactivated regions was not only stronger than the predictive power of using either modality alone, but the print-speech coactivation effects also accounted for later reading variance, even when initial reading ability was controlled (Preston et al., 2016; Pugh et al., 2013). This finding therefore suggests that an atypical right-lateralized reading pathway characteristic of dyslexia is not necessarily specific to print-word reading tasks but may also impact other fundamental pre-reading skills like phonological awareness.

Given that reading acquisition is strongly associated with phonological processing skills, it is hypothesized that a left-lateralized reading pathway characteristic of skilled-reading might already be present in pre-readers who have good phonological awareness (Preston et al., 2016; Pugh et al., 2013). While there are not many studies in the current literature that have investigated hemispheric lateralization of phonological awareness in preliterate children, some ERP studies that investigated the rapid cognitive and sensory processes used during phoneme-processing tasks found significant asymmetry in adults with dyslexia (Blau, van Atteveldt, Ekkebus, Goebel, & Blomert, 2009; Boets et al., 2013; Eden et al., 2004).

2.7.3 Early ERP components and lateralization.

Landi et al. (2012) used ERP to investigate reading in teenagers whose mothers were cocaine users during pregnancy, and found that they tended to have more reading difficulties and even reading disorders compared to their peers born to non-addicted mothers. Landi et al. recruited 107 thirteen-year-
old teenagers who were prenatally cocaine-exposed (PCE) and 46 non-drug exposed (NDE) to participate in a phoneme-processing ERP task. In the ERP task, the participants listened to one auditory stimulus (i.e., /gibu/) repeatedly for one block, and listened to the same stimulus interspersed with another novel stimulus (i.e., /bidu/). They observed that the PCE group exhibited greater amplitude for the N2 ERP component when they listened to the novel stimulus compared to their NDE counterparts (Landi et al., 2012). The N2 is one of the more widely studied ERP components in the context of phoneme processing, especially in the pediatric population, because the N2 can be easily and readily measured in children. This component (also found to be related to another ERP component called the Mismatch Negativity, or MMN) is found to be associated with early sensory processes of auditory stimulus categorization – the cognitive ability to distinguish whether one auditory stimulus is the same or different from another (e.g., Breton, Ritter, Simpson, & Vaughan, 1988; Connolly, Stewart, & Phillips, 1990; Hagoort, 2008; Maurer, Bucher, Brem, & Brandeis, 2003; Näätänen et al., 1997; Näätänen, Paavilainen, Rinne, & Alho, 2007).

However, unlike the MMN (usually generated in the frontal region of children’s brains) which is sensitive to tone and frequency changes in speech, the N2 (generated in temporal areas) has been shown to be more related to the earliest aspects of phonological processing in spoken words (i.e. pre-lexical access) (Hagoort, 2008; Korpilahti & Lang, 1994; Schulte-Körne, Deimel, Bartling, & Remschmidt, 1998). Left-lateralization of the N2 was found to be positively associated with phonemic discrimination tasks in infants and in children, which supports the hypothesis that a left-lateralized neural network might facilitate reading development (Molfese & Molfese, 1985; Preston et al., 2016; Pugh et al., 2013; Taylor, 1993). Contrastingly, pre-readers with low pre-literacy skills (including poor phonological awareness) were observed to exhibit a more bilateral N2 pattern even when doing a non-reading-related task, suggesting that children with poor pre-literacy skills require the engagement of a more distributed network (Molfese et al., 2008). While N2 over the temporal lobe is often found to be most prominent in young children, the amplitude of the N2 appears to diminish with age in typical development (e.g., Bishop & Macarthur, 2005; Bonte & Blomert, 2004; Taylor, 1993). This observation is consistent with the notion that as children learn to read, the process of phoneme processing becomes more automated, and thus the amplitude of the N2 appears to attenuate as less effort is needed to decode phonemes (Bishop &
Such an interpretation can be applied to Landi et al. (2012)'s findings: teenagers prenatally exposed to cocaine have more reading difficulties, and their N2 amplitudes are more pronounced (a pattern observed in very young children) because their phoneme-processing is not as automated as that of their typically-developing counterparts.

In addition to the N2, Landi et al. (2012) also investigated the P2 ERP component in the left and right temporal cortex, as well as the N1/P2 ERP complex in the medial central cortical region, as these two ERP components have been found to reflect spectral and temporal cues in spoken language crucial for speech perception (Näätänen & Picton, 1987; Ostroff, Martin, & Boothroyd, 1998; Whiting, Martin, & Stapells, 1998; Woods & Elmasian, 1986). In particular, the N1/P2 complex was found to be sensitive to training-induced changes in speech perception; for example, Tremblay et al. (2001) found that after being exposed to a training session to distinguish between two synthetic variants of the syllable /ba/, young adults were able to correctly identify the two different variants of this phoneme and their N1/P2 amplitude in response to the novel variants increased significantly. As well, a heightened N1/P2 amplitude has been shown to be associated with phoneme decoding tasks in skilled readers but not in people with dyslexia, thus suggesting that the N1/P2 might be a key component associated with expertise or increased awareness in phonological processing (Kutas & Van Petten, 1994; Kutas, Van Petten, & Kluender, 2006).

Currently, there is no existing literature on the P2 in preliterate children, but the few studies that investigated P2 in literate adults suggest that there might be a lateralization pattern for the P2 in phoneme decoding, similar to findings from fMRI studies (e.g., Kutas & Van Petten, 1994; Kutas, Van Petten, & Kluender, 2006; Landi et al., 2012). For instance, Landi et al. (2012) suggested that the reduced P2 in the left temporal lobe observed in the cocaine-exposed group may be related to reduced activity in the left STG and IFG, as previously implicated in fMRI studies of the correlation between phonological awareness and left temporal activity (Fiez, Raichle, Baltota, Tallal, & Peterson, 1996; Preston et al., 2016; Price et al., 1996; Pugh et al., 2013).
2.8 The Current Study

Given the large gap in the neuroimaging literature on phonological processing in preliterate children, there is little information available concerning the effects of parental function on pre-reading skills such as phonological awareness. To address this gap, the current study investigated relationships between parental reflective functioning skills and specific indices of children’s pre-literacy skills and later reading outcomes. Even though many studies have shown a correlation between parent-child attachment relationships and pre-reading development, no studies have attempted to identify specific relationships between parental reflective functioning and neural indices of children’s pre-reading skills as they prepare for formal literacy education.

The study design of this project was correlational in nature, because reading is a continuum of abilities and not a set of discrete bimodal skills (Shankweiler et al., 1999). It was predicted that children whose parents showed higher reflective functioning skills would show higher phonological awareness abilities, and that they would exhibit a more typical left-lateralized ERP responses when carrying out a phoneme-processing task. On the other hand, children whose parents had lower reflective functioning skills were expected to have lower phonological awareness scores, and were not expected to exhibit typical left-lateralization ERP responses during a phoneme-processing task. The parents’ reflective functioning scores, children’s phonological awareness scores, and their ERP data were also analyzed to see if they correlated with their later phonological awareness skills and reading outcomes one year later, after the start of their exposure to formal literacy education. In the next chapter, specific research questions and associated hypotheses and predictions are spelled out for the current study.
3. Research Questions and Hypotheses

The current study aims to investigate the influence of parental reflective functioning on children’s pre-literacy skills and reading outcome measures using behavioral and ERP tasks. Previous studies that used the same ERP experimental paradigm found that the peak amplitudes of three ERP components (the N1/P2 complex, N2, P2) were associated with reading-related tasks, especially phonological awareness and phoneme processing (Harwood, 2015; Landi et al., 2012; Molfese, Morse, & Peters, 1990). However, given the fact that our pediatric sample is on the younger side, it is likely that our EEG data will encompass more background noise. Hence, as an attempt to extract the most robust ERP signals from potential background noise, the current proposed project examined the adaptive mean amplitudes and peak latencies of these three ERP components and their relationships to children’s (pre)literacy assessment scores (Clayson, Baldwin & Larson, 2013). These data were also examined with respect to parental responses to questionnaires evaluating parental reflective functioning and parent reading history.

3.1 Research Question #1:

Do children’s neural responses (specifically, the event-related potentials referred to as the N1/P2 complex, the N2 and the P2) to a phonological processing task correlate with behavioral measures of phonological awareness before they are exposed to literacy instruction, and with their reading outcomes one year later?

Hypothesis: Phonological awareness is a fundamental skill that is foundational to, and highly predictive of, a child’s later reading success. Thus, a child’s neural responses to a phonological processing task provide a window into phonological awareness and later behavioral measures of reading progress.

Prediction: Based on this hypothesis, it was predicted that the N1/P2 (over medial-parietal cortical region (mPC)), N2 and P2 (over the left temporal cortex (LTC)) adaptive mean amplitudes in response to a novel pseudoword would be significantly correlated with phonological awareness scores at two time points, before and after the start of literacy instruction, as well as with basic reading scores at the second time point. Specifically, the amplitudes of the N1/P2 and P2 components were predicted to be positively correlated with all reading-related measures at both time points, since Landi et al.’s (2012) study found that teenagers who performed worse on language and reading measures also had smaller
N1/P2 and P2 amplitudes in the same ERP task. However, even though Landi et al.’s (2010) results showed that teenagers who performed worse on reading measures had a larger N2 amplitude during the phoneme-processing ERP task, this result could be attributed to the notion that poor readers’ reading circuitry is more similar to that of young children because reading is not yet an automated skill (Taylor, 1993). For the current study, the sample population consisted of young children who did not yet read at a proficient level, so an increased N2 amplitude was expected as they participated in a phoneme-processing task. Thus, it was predicted that children who exhibit larger amplitudes in the three ERP components during a phonological processing task would also likely achieve higher scores on measures of phonological awareness and basic reading skill. However, the prediction of the association between the peak latencies of these three ERP components and (pre)literacy skills remained exploratory due to the lack of literature on this subject.

3.2. Research Question #2:

Do children’s neural responses correlate with measures of parental reflective functioning?

*Hypothesis:* Parents’ mentality towards their relationship with their children influences the development of the neural circuitry associated with reading. If a parent has good reflective functioning skills, it is likely that the child will form a secure attachment with this parent and will feel more confident and interested in engaging reading-related activities with the parent. Having this secure relationship with a caregiver also allows a child to be exposed to reading on a more frequent basis, thus shaping their brain in preparation for literacy education.

*Prediction:* Based on this hypothesis, it was predicted that the adaptive mean amplitudes of the three ERP components would be positively correlated with measures of parental reflective functioning. However, the issue of whether peak latencies of the three ERP components would have any associations with parental reflective functioning remained exploratory, due to the lack of literature in this field.

3.3. Research Question #3:

Do measures of parental functioning correlate with behavioral indices of children’s phonological awareness and later reading-related abilities?
Hypothesis: Parents’ mentality towards their parent-child relationships influences not only their children’s neural development, but also their behaviors around literacy development (observable through literacy assessments).

Prediction: Based on this hypothesis, it was predicted that parental reflective functioning skills would be positively correlated with children’s phonological awareness skills before and after the onset of literacy instruction, as well as basic reading skills one year later.

The next chapter describes the design and experimental methods that were used to address these research questions.
4. Research Design and Methods

Electroencephalography (EEG) is a non-invasive neuroimaging technique that measures the continuous electrical activity of the brain via scalp electrodes. EEG measures voltage fluctuations caused by the influx and efflux of ions through ion channels in the postsynaptic terminals of neurons, particularly pyramidal cells since they are multipolar neurons that are oriented in parallel (Luck & Kappenman, 2012; Öllinger, 2009). These postsynaptic potentials (PSPs) generated by single neurons are too small to be detected by electrodes; instead, the electrodes on the scalp pick up the summed PSPs from groups of spatially aligned neurons that are active simultaneously (Luck & Kappenman, 2012). The EEG system used for this study is the Electrical Geodesics, Inc. (EGI) 128 electrode high-density system with HydroCel Geodesic Sensor nets (Electrical Geodesics; Tucker, 1993). The EGI electrodes are encased in plastic substrates and arranged in a predictable geodesic configuration held together by a fine elastomer. These electrodes record precise voltage deflections at the scalp, quantified relative to a reference electrode placed at the center of the scalp (vertex). When time-locked to the onset of experimental stimuli and averaged across multiple instances, these voltage variations are called event-related potentials (ERPs) and represent neural response patterns that are correlated with specific sensory or cognitive activities.

There are several reasons that ERPs are advantageous for neurolinguistic studies in young children. First, ERPs have been widely used in language research, and many ERP components have been found to be associated with specific cognitive processes that support language comprehension (such as lexical, semantic, and syntactic processing; this vast field of study is summarized in, for example, Luck & Kappenman, 2011). In addition, EEG recording has excellent temporal resolution, allowing brain responses to be tracked with millisecond accuracy. Fine temporal resolution is critical when evaluating linguistic processes, because many
subcomponents of language processing are executed very rapidly (e.g., Barde & Thompson-Schill, 2002; Friederici, 2012).

Finally, EEG is ideal to use with children because the technique is non-invasive, tolerates some movement, and is more comfortable for participants than some other neuroimaging methods.

4.1 Design

This dissertation study was correlational in nature, with the aim of investigating associations between measures of parental functioning and their children’s pre-literacy and early literacy skills, evaluated via neurophysiological and behavioral means. The study had a longitudinal design, in which participants visited the lab at 2 different time points (12-15 months apart). During the first time point (Time 1), participants completed an ERP task and a battery of pre-literacy assessments. The participants’ caregivers also completed questionnaires about their parenting background, their children’s demographic information, and familial background. Twelve to fifteen months later (after exposure to formal literacy education at school), participants visited the lab again at the second time point (Time 2) and completed a battery of pre-literacy and reading assessments.

4.2 Participants

Seventeen children between the ages of 3 years 8 months to 5 years 9 months ($M = 4$ years 5 months, $SD = 6.18$ months) were recruited for this study. In addition to the current study, these participants went on to participate in a larger 4-year ongoing study at Haskins Laboratories funded by the National Institutes of Health. All participants were recruited from the New Haven, Connecticut community and neighboring areas through flyers, recruitment booths at museums and city events, and local daycare facilities. Children who were bilingual, exposed to formal literacy education, did not live with at least one biological parent, had a confounding medical or
psychological diagnosis, or had cognitive or developmental delays were excluded from this study. Three participants who had too few usable EEG trials were also excluded from further analysis. Only data from the remaining 14 participants were used in the final analysis.

Informed consent was obtained from a parent or a legal guardian of all participants at the beginning of the first testing session. Verbal assent was also attained from all child participants prior to the beginning of the study. Participants and their families were assured that their participation was voluntary, and that they retained the right to terminate their participation at any point of the study without penalty. Parent questionnaires and self-report measures were completed by the participants’ parents or guardians during their first visit. Participating families received monetary compensation ($25/hr) from the Research Project Grant (R01) funded by the National Institutes of Health. All procedures were carried out with the approval of the Yale University Human Investigation Committee and the Yale Medical School’s Institutional Review Board (HIC#: 1208010711) and by Teachers College, Columbia University Institutional Review Board (Protocol#: 18-494). Both letters of approval are attached in Appendix A.

None of the participants reported any history of neurological or developmental disorders, or any use of psychiatric medications. All participants had normal vision (with corrective lenses) and normal hearing range appropriate for their age group. Note was taken of existing diagnoses of dyslexia in the participants’ parents. Participants’ demographic information is summarized in Table 1 below.
Table 1

Summary of Demographic Information

<table>
<thead>
<tr>
<th>Subject ID</th>
<th>Age at Time 1</th>
<th>Gender</th>
<th>Number of Parents with Dyslexia</th>
</tr>
</thead>
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</tr>
<tr>
<td>401187</td>
<td>5.75</td>
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</tr>
</tbody>
</table>

Mean 4.51

SEM 0.15

4.3 Screening Assessments

4.3.1 Visual acuity screening.

All participants completed a visual acuity screening using the Kindergarten Eye Test Chart (Precision Vision Inc.), which consists of symbols (heart, star, circle, plus sign, boat, cup, moon, hand, and flag) that get progressively smaller in size as one proceeds down a row. This visual test is high contrast for accurate testing of preliterate children. The stimuli were placed 20 feet away from participants, who named the objects they saw starting from the top row until they could not identify the symbols anymore. All children who participated in the study had at least 20/40 vision (with corrective lenses if necessary).
4.3.2 Auditory acuity screening.

An Ambco 1000+ Pure Tone Audiometer was used to evaluate hearing acuity, as it is capable of screening sequentially and automatically using the OTO-SCREEN mode. Participants placed the headset over their heads with the receivers completely covering their ears. They were instructed to respond to the tone presented by the audiometer by pressing a button using their dominant hand. As per standard school testing procedures, the OTO-SCREEN mode was tested at the 10-35 dB range, screening at 1000, 2000 and 4000 Hz frequencies in the right and then the left ear sequentially. All participants in this study had normal hearing and responded at 10-20dB across all frequencies (Niskar et al., 1998).

4.3.3 Intelligence Quotient (IQ).

The participants’ full-scale intelligence quotient (FSIQ) was obtained using the Wechsler Preschool and Primary Scale of Intelligence IV (WPPSI-IV; Wechsler, 2012). This test provides a reliable and representative measure of general intellectual functioning, including measures of verbal IQ, performance IQ, processing speed and global language functioning. The FSIQ is a standard score with a mean of 100 and a standard deviation of 15. All participants in this study had an FSIQ above 70 (this threshold is two standard deviations below average and represents a cutoff for children considered clinically intellectually delayed; American Psychiatric Association, 2013).

4.4 Parental Questionnaires.

Every participant’s primary caregiver completed a series of parental questionnaires at the beginning of their child’s enrollment in the study, as follows.

4.4.1 The Parental Reflective Functioning Questionnaire (PRFQ).

The PRFQ (Luyten, Mayes, Nijssens, & Fonagy, 2017) is an 18-item Likert scale that probes parents’ capacity for understanding the mental states of their children (Fonagy et al.,
The PRFQ was designed for parents with children aged 0-5 years, as communication with young children is often non-verbal, so parents’ understanding of and sensitivity to their children is crucial during the early stages of development (Fonagy et al., 1990; Luyten et al., 2017).

The PRFQ is divided into 3 subscales: Pre-Mentalizing (PM), Certainty about Mental States (CM), and Interest and Curiosity in Mental States (ICM) (Luyten et al., 2017). The PM subscale is associated with malevolent attributions and parental inability to understand their child’s mental states. The CM subscale is related to a parent’s certainty about their child’s mental states; over-certainty may lead to “intrusive hypermentalizing” while under-certainty may be indicative of “hypomentalizing” or lack of awareness. The ICM subscale aims to assess parental interest in and curiosity about their child’s mental and emotional states; low ICM levels would indicate lack of interest, while very high ICM scores may indicate intrusive interest in the child’s mental state. The authors of the PRFQ suggested that the middle scores in the CM and ICM subscales are representative of adaptive parental reflective functioning, whereas the extreme scores on the ends are considered maladaptive (Luyten et al., 2017). Thus, the scores from these two subtests were rescaled during analysis, in that the central values are considered the “highest” score, while scores on either end of the spectrum are considered the “lowest” scores.

4.4.2 The Adult Reading History Questionnaire (ARHQ).

The ARHQ (Lefly & Pennington, 2000) is a 26-item Likert scale questionnaire that probes parents’ attitudes and behaviors around reading and has been used to diagnose dyslexia in adults (see Appendix C).

4.4.3 Additional Questions.

Additional questions related to the participants’ developmental milestones (e.g. speech or motor delays), medical history (e.g. medical or psychological diagnosis), and familial
background and support (e.g. familial income, reading environment at home, language experience and background) were also filled out by parents and guardians (see Appendix D).

4.5 Literacy Assessments

All participants completed a five-hour battery of behavioral testing across two testing sessions. Only the data from the Comprehensive Test of Phonological Processing - Second Edition (CTOPP-II; Wagner, Torgesen, Rashotte, & Pearson, 2013) and The Woodcock Johnson Test of Achievement – Third Edition (WJ-III; Woodcock, Mather, & McGrew, 2001) were reported in this study. The CTOPP-II was administered to the participants at both Time 1 and Time 2 testing sessions, whereas WJ-III was only administered at Time 2 due to the participants’ ages and limited reading ability at their first testing session.

4.5.1 Comprehensive Test of Phonological Processing- Second Edition (CTOPP-II).

The CTOPP-II (Wagner et al., 2013) was included in the present study because it is a norm-referenced test that assesses reading-related phonological processing skills. The reliability and validity of the test are high, with an average internal consistency coefficient for the composite scores of above 0.85, and an average correlation coefficient range of 0.65-0.76 (Wagner et al., 2013).

Participants’ phonological awareness was measured via the Elision, Blending Words and Sound Matching subtests from CTOPP-II. The Elision subtest consists of 34 items, and it measures the ability to omit a specific sound from a word (e.g. say bold without saying /b/). The Blending Words subtest consists of 33 items, and it measures the ability to combine short phonemes to form words (e.g. What word do these sounds make: /t/ - /oy/?). The Sound matching subset consists of 26 items, and it measures the ability to identify words with the same beginning or ending sounds. Administration of each subtest began with an age-appropriate start point to establish a baseline and ended when participants reached a ceiling indicated by three
consecutive incorrect responses, as outlined by the guidelines in the CTOPP-II manual (Wagner et al., 2013).


The WJ-III (Woodcock et al., 2001) was used to measure reading ability, phonemic awareness, reasoning, language development, and overall academic achievement. Scores from this test are used clinically for diagnosis of learning disabilities. In this study, only the Letter-Word Identification and Word Attack subtests were analyzed, as they make up the Basic Reading Skills component of the test.

The Letter-Word Identification subtest consists of 76 items, beginning with simple single letter identification (e.g. “M”) and gradually to increasingly difficult sight word identification (e.g. “therapeutic”). Administration of this assessment began with an age-appropriate start point to establish a baseline, which was measured by the six lowest consecutive correct responses, and a ceiling was identified when the participant made six consecutive incorrect responses (Woodcock et al., 2001).

The Word Attack subtest consists of 32 items, ranging from single letter sound identification items (e.g. “What sound does this letter make?”) to pseudoword identification items (e.g “doitibility”). The items on this subtest gradually increase in difficulty. A performance baseline for this subtest was established by six lowest consecutive correct responses, and as before a ceiling was identified when the participant made six consecutive incorrect responses (Woodcock et al., 2001).

4.6 Experimental Equipment

4.6.1 Stimulus presentation.

The stimuli were presented in free-field at a child-friendly volume of 70-80dB SPL via an overhead speaker positioned two meters from the floor.
4.6.2 EEG acquisition computer.

EEG data were recorded using EGI’s Netstation version 4.5 data acquisition software (EGI Inc.), with an EGI Net Amps 300 high impedance amplifier, sampling at 500hz, running on an iMAC operating on the macOS Sierra (version 10.12).

4.6.3 EEG run room.

All participants completed the ERP experiment at Haskins Laboratories, New Haven, Connecticut. The ERP experiment took place in a sound-attenuated room in the laboratory to ensure an optimal environment for EEG data collection. The EEG run room was lit with dimmable LED lighting and shielded to minimize electrical noise. In order to ensure that young children felt at ease during testing, the experimenter remained in the same room during the EEG experiment. However, the participant and experimenter were separated by a curtain to minimize distraction, and participants were monitored by a webcam placed above their computer screen. Parents waited for the participants in the lab’s waiting area just outside of the EEG run room.

4.7 EEG Experiment

4.7.1 EEG recording and experimental procedure.

For the ERP task, the participant was seated in a sound attenuated and electrically-shielded testing room, with a speaker positioned 2 meters directly overhead for presentation of auditory stimuli. In order to record EEG, a high-density sensor array net with 128 sponged silver chloride plated carbon fiber (Ag/AgCl) electrodes (manufactured by Electrical Geodesics, Inc.) was placed on each participant’s scalp. The participant’s head circumference was measured in order to select the appropriate size net for use. The vertex (center of the head) was then marked using a soluble marker to ensure accurate placement of the net. Prior to the placement of the net on the scalp, the net was soaked in a solution of two teaspoons of potassium chloride (KCl), 3 ccs of baby shampoo, and 1 liter of purified warm water for 5 minutes for optimal conductivity.
The net was then placed on the head of each participant using a standard protocol outlined by EGI Inc. to align the electrodes with pre-determined anatomical landmarks (vertex, nasion, inion, mastoids). Once the appropriate sensor net was placed and adjusted properly on the participant’s head (see below), it was then connected to a calibrated high impedance amplifier (EGI Net Amps 300 Series), and EEG recordings were digitized using EGI’s NetStation (v4.5.4) data acquisition software at a sample rate of 500hz. After the sensor net was connected, electrodes were examined and adjusted to ensure they were in direct contact with the scalp. A 400-microvolt electrical field was fed through each electrode to measure impedance, and any electrodes that showed impedances greater than 40kΩ were lightly hydrated with KCl solution using a small pipette and repositioned to ensure good scalp contact. Raw EEG data were filtered using an analog low-pass filter to prevent antialiasing the signal.

4.7.2 ERP experiment stimuli.

The two experimental stimuli were acquired from Molfese & Molfese (1979)’s study. They were computer-synthesized, consonant-vowel bisyllabic pseudowords in an adult female voice: /gibu/ and /bidu/. Both stimuli were matched in rise and decay times (at 4ms), peak intensity, and duration. Each stimulus had an initial 50ms rapid-frequency transition followed by three steady state formants (60, 90, 120Hz respectively) with a duration of 250ms (Cutting, 1974; Molfese & Molfese, 1979). Previous research with infants, young children, and adolescents has shown that measuring the lateralized neural responses involved in discriminating between these two stimuli can provide information about phonological processing in the brain (Molfese, Morse & Peters, 1990; Harwood, 2015; Landi et al., 2012). The ERP experiment was designed to examine the neural responses in discriminating a new pseudoword from one to which the participants were repeatedly exposed. Thus, these two bisyllabic pseudowords were used because they were matched in manner of articulation, but are different enough (even for young
children and infants) to distinguish (Molfese et al., 1990; Molfese & Molfese 1985, 1997). In particular, Molfese and Molfese (1985) observed that neonates who failed to generate an N2 ERP component in a discriminatory task between the sounds /gi/ and /bi/ were later found to be at risk for language problems. Additionally, the detection of the partial-rhyme between /gibu/ and /bidu/ may potentially elicit ERP components (such as N1/P2 complex, N2, and P2) associated with phonemic and phonological processing (Kutas & Van Petten, 1994; Kutas, Van Petten, & Kluender, 2006). The time duration of each stimulus was 595ms, and the interstimulus interval was either 1800ms or 2800ms (randomly switching to prevent habituation effects).

4.7.3 ERP task.

The experiment consisted of two blocks: the first was the Desensitization Block, in which one stimulus (e.g. /gibu/) was repeatedly presented 50 times so that participants became desensitized to it. The second block was the Novel Block, in which both stimuli (/gibu/ & /bidu/) were presented 50 times each in equal proportion using a pseudo-random pattern in which the same stimulus would not be presented for more than 3 times consecutively to prevent habituation effects. Each token followed by a randomized inter-stimulus interval of either 1800ms or 2800ms. The two blocks were separated by a 20 second break. The desensitized stimulus in the first block was randomly chosen for each participant so that the roles for the two stimuli were counter-balanced across subjects. Figure 1 provides a schematic visualization of the ERP task. The ERP task was presented using E-Prime Extensions for Net Station from E-Prime software v. 2.0.10.353 (Psychology Software Tools; EGI Inc.).

Prior to beginning the ERP task, the participant was instructed to sit still and listen to the stimuli that would be presented in the experiment. The duration of the experiment was approximately 7 minutes.
4.7.4 Number of experimental trials.

The number of trials in the ERP experiment was directly replicated from Landi et al.’s (2012) experiment, with 50 trials in the desensitized condition, and 100 trials in the novel condition. Although a larger number of trials (around 250 trials) are usually recommended for earlier and faster components like N1, a smaller number of trials was more realistic for this experiment due to the pediatric population (Woodman, 2010). Additionally, this study is focused on later and slower components like the N2 and P2, and a smaller number of trials (e.g. 30-60) is typically sufficient to measure these ERP components (Woodman, 2010).
4.8 Experimental Protocol

Participants and their families visited the lab at 2 different time points (12-15 months apart), and each time point consisted of 2 separate visits to reduce participant fatigue or burnout. Participant eligibility was established via a phone interview with the parents to ensure that all participants were monolingual English speakers, had little or no formal literacy education (enrolled in preschool or the first quarter of kindergarten), and had no medical or psychological diagnoses that might confound the study design (e.g. Down Syndrome, Autism Spectrum Disorder). Participants and their parents were then invited to the lab for their first testing session.

4.8.1 First testing session (Time 1).

The first testing session (Time 1) was split into two 3-hour visits separated by no more than two weeks. In the first testing session, participants and their parents were given a tour of the lab and a description of the study. Informed consent was obtained from the participants and their parents prior to any testing procedures. Next, parents completed questionnaires about their children’s demographic information, familial background, and their parenting. Participants were screened to ensure normal vision and range of hearing. They also completed the battery of assessments described above that measured their phonological awareness, phonetic decoding skills, letter and sight word identification, and other pre-literacy skills, as well as the ERP task.

4.8.2 Second testing session (Time 2).

Participants and their families returned to the lab for their second testing session (Time 2) 12 to 15 months later. By this time, participants were either in first grade or later kindergarten, and had at least six months of reading instruction at school. Informed consent was obtained again prior to any testing procedures. The Time 2 session was split into two 2-hour visits separated by no more than two weeks, and consisted of behavioral and literacy assessments only, as described above.
4.9 Data Processing and Analysis

4.9.1 Data pre- and post-processing.

EEG data pre-processing procedures were carried out using EGI NetStation software (v5.4) (Electrical Geodesics Inc.) and followed the steps outlined by Handy, 2005; Luck, 2005; Picton et al., 2007; Handy, 2014. Raw data were filtered using a 0.1 Hz high-pass filter and a 30Hz low-pass filter (FIR Passband Gain: 99.0 % (-0.1 dB), Stopband Gain: 1.0 % (-40.0 dB), Rolloff: 2.00 Hz) (Luck, 2005; Oppenheim & Schafer, 1975; Rabiner & Gold, 1978). EEG data were segmented into epochs 700ms in length, with a 100ms pre-stimulus baseline interval and a 600ms post-stimulus interval.

Once the data were segmented, the epochs were visually inspected and an in-house NetStation automated script will be used to identify “bad” electrodes (>200μV) and eye movement artifacts (>150μV). If an electrode is identified as “bad” for more than 40% of the entire EEG segment, it was marked as a “bad channel”, and its data were replaced by a process of spherical spline interpolation based on data collected at surrounding channels. If an EEG segment contained more than 10 bad channels, then the entire segment was marked “bad” and it was removed from further analysis (Perrin, Pernier, Bertrand, & Echallier, 1989). The EEG segments were then re-referenced to the vertex reference (Cz in the International 10-20 system), and were baseline corrected using the 100ms pre-stimulus baseline interval for each participant.

The pre-processed segments were then averaged within each of the desensitized and novel conditions, and only participants with 20 or more usable trials for each condition were included in further analysis. Due to a large number of unusable trials, 3 participants were excluded from the study (thus only data from 14 participants remained in the final analysis). Finally, data were exported into .csv files for each participant and per each condition, to permit further analyses in additional software packages (see below).
4.9.2 ERP analysis.

ERP data analysis was conducted in RStudio (Version 1.0.153; RStudio Inc., 2016). Previous ERP research on phoneme discrimination has shown that children who exhibit weaker skills in phoneme awareness behaviorally also show ERP amplitude differences over the following regions of interest (ROIs) in the brain: medial-parietal cortical region (mPC), left temporal-parietal (LTP) region, and right temporal-parietal (RTP) region (Landi et al., 2012). These specific regions and their associated channel numbers (where the electrodes are placed on the scalp) are detailed in Table 1 and Figures 2a and 2b below. The channels for each ROI were chosen based on Landi et al. (2012) and on Harwood (2016), both studies that used the same ERP paradigm.

4.9.2.1 Principal Component Analysis (PCA) for time windows. In our pilot study, the time windows for each ERP component were selected based on Landi et al. (2012). However, pilot study analyses suggested that these time windows may not be appropriate for this study sample. Thus, a traditional peak-picking method was applied to visually identify the time-windows for each ERP component from the grand average waveforms (averaged across participants and across channels in each region; see Figures 4a - 4c). Principal component analyses (PCAs) were used as a confirmatory tool to determine whether the pre-selected time windows were appropriate for each of the three targeted ERP components (N1/P2, N2 and P2). The PCAs were conducted in RStudio (Version 1.0.153; RStudio Inc., 2016), on a subset of channels for each ROI and on a subset of time points for each time window. In each PCA, only the first principal component was investigated further, as PCAs transform the original data in such a way that the first principal component represents the linear combination of the channels accounting for the most variance (Dien, 2012; Hastie, Tibshirani, & Friedman, 2013, pp. 534-536). A waveform for each ERP component in each ROI was then reconstructed using only the
first principal component to confirm whether the signal of the targeted ERP component was still captured within the selected time window.

4.9.2.2 EEG Adaptive Mean Amplitudes and Latencies. Following preprocessing, EEG data were imported into RStudio (Version 1.0.153; RStudio Inc., 2016) for statistical analysis. An analysis script was written specifically for this experiment to calculate adaptive mean amplitudes and peak latencies for each ERP component (N1/P2, N2 and P2) using the corresponding time windows (previously confirmed using PCAs) and averaged channel numbers (see Table 2 below).

In the mPC, the combined adaptive mean amplitude of the N1/P2 complex was computed by subtracting the N1 adaptive mean amplitude from the P2 adaptive mean amplitude:

\[ \text{Amplitude}_{N1/P2} = \text{P2 Amplitude} - \text{N1 Amplitude} \]

The combined peak latency of the N1/P2 complex was also computed in the same manner, by subtracting the N1 peak latency from the P2 peak latency.

Table 2

<table>
<thead>
<tr>
<th>ERP Component</th>
<th>Time Window</th>
<th>Region</th>
<th>Channel numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>70-120ms</td>
<td>mPC</td>
<td>60,61,62,66,67,70,71,72,74,75,76,77,78,81,82,83,84,85</td>
</tr>
<tr>
<td>P2</td>
<td>150-250ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N2</td>
<td>110-160ms</td>
<td>LTC</td>
<td>40,41,42,45,46,47,50,51,52,53,58,59,60</td>
</tr>
<tr>
<td>P2</td>
<td>170-220ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N2</td>
<td>120-160ms</td>
<td>RTC</td>
<td>85,86,91,92,93,96,97,98,101,102,103,108,109</td>
</tr>
<tr>
<td>P2</td>
<td>200-230ms</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figures 2a and 2b. The sensor layout of the 128 channel Hydrocel Geodesic Sensor Net. The mPC montage (highlighted electrodes in green in Figure 2a) was used for plotting and analyzing the N1/P2, and the left and right TC montages (highlighted electrodes in green in Figure 2b) were used for plotting and analyzing the N2 and P2.

4.9.3 Behavioral data analysis.

Literacy assessments for phonological awareness (CTOPP-II) and basic reading (WJ-III) were separately standardized and averaged per subtest.

4.9.3.1 Comprehensive Test of Phonological Processing- Second Edition (CTOPP-II).

Phonological awareness was measured using the Phonological Awareness component of the CTOPP-II (Wagner et al., 2013). The Phonological Awareness component was made up of the elision, blending words, and sound-matching subtests.

First, the raw score of each subtest was calculated based on each participant’s performance. Then, a subtest scaled score was computed based on the participant’s age. The
scaled scores of all three subtests were used to compute a standard score for the Phonological Awareness component for each participant at each time point.

4.9.3.2 Woodcock Johnson Test of Achievement – Third Edition (WJ-III). The WJ-III was used to measure basic reading skills (Woodcock et al., 2001). The Basic Reading component was made up of the Letter-Word Identification and Word Attack subtests. The raw score for each subtest was calculated based on each participant’s performance, and the scaled score of each subtest was computed using the raw scores. Finally, a standard score for the Basic Reading component was calculated by combining the scaled scores of both subtests, using the WJ-III scoring software.

4.9.4 Brain-behavior analysis.

4.9.4.1 Permutation Correlation Analysis. All statistical analyses were performed in RStudio (Version 1.0.153; RStudio Inc., 2016). Pearson’s permutation correlation tests and Spearman’s permutation correlation tests were conducted to evaluate the significance of correlations between adaptive mean amplitudes and peak latencies of the three ERP components identified during the novel condition of the EEG experiment and literacy assessments and demographic information. Rather than Pearson’s and Spearman’s correlation tests, permutation correlation analyses were used in an attempt to reduce Type I and Type II errors that might occur due to the many correlations between variables that are under investigation. Each permutation test had an iteration of $N = 10,000$. Pearson’s correlation tests were conducted on scores from the parental questionnaires (parental reflective functioning (PRFQ) and parent reading history (ARHQ)) and reading-related assessments (standard scores of phonological awareness (CTOPP-II) and basic reading scores (WJ-III)), while Spearman’s correlation tests were conducted for family income and for number of books in the household because these are ranked variables.
4.9.4.2 Multiple Linear Regression Analysis. The pilot study that preceded this dissertation study suggested that additional factors (such as number of parents diagnosed with dyslexia and number of reading sessions at home) should also be considered alongside the parental questionnaire scores when considering relationships between home environment and children’s later reading outcomes. Thus, multiple linear regression analyses were conducted in RStudio (Version 1.0.153; RStudio Inc., 2016) to predict Time 2 phonological awareness (standard scores from CTOPP-II) and basic reading skills (standard scores using WJ-III) based on demographic information and scores on parental questionnaires (parental reflective functioning (PRFQ) and parent reading history (ARHQ)).
5. Results

5.1 Behavioral Results

All participants showed normal visual acuity (with correction) as measured by the Kindergarten Eye Test Chart, and a normal range of hearing based on the hearing screen administered on the first day of testing. All participants in this study had an FSIQ above 70 (this threshold is two standard deviations below average and represents a cutoff for children considered clinically intellectually delayed; American Psychiatric Association, 2013) with a mean score of 106.14 (± 3.05). The literacy assessment and parental questionnaire results are summarized in Table 3 below. The phonological awareness (PA) scores at Time 1 are significantly correlated with scores at Time 2 ($r = 0.58; p = 0.03$), and the group means for PA at both time points are not significantly different ($df = 26; t = 1.58; p = 0.127$). This suggests that the participants’ PA scores did not change after exposure to formal literacy education.
### Table 3

**Summary of Demographic Information and Behavioral Assessments**

<table>
<thead>
<tr>
<th>Subject ID</th>
<th>Age at Time 1</th>
<th>Gender</th>
<th>IQ Standard Score</th>
<th>Reading History</th>
<th>PRFQ: PM</th>
<th>PRFQ: CM</th>
<th>PA at Time 1</th>
<th>PA at Time 2</th>
<th>Basic Reading at Time 2</th>
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<tbody>
<tr>
<td>401031</td>
<td>4.50</td>
<td>Female</td>
<td>94</td>
<td>0.09</td>
<td>1.50</td>
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<td>6.33</td>
<td>103</td>
<td>94</td>
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<td>6.67</td>
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</tr>
</tbody>
</table>

*Mean 4.51, SEM 0.15*  

**Notes:** Demographic information and behavioral assessments of 14 participants, including: age, gender, intelligence quotient (IQ) standard scores, (pre)literacy assessment standard scores (PA – phonological awareness from CTOPP-II; Basic Reading score from WJ-III), parent reading history score, and parental reflective functioning questionnaire (PRFQ: PM- Pre-Mentalizing Modes, CM- Certainty about Mental States, ICM- Interest and Curiosity) scores.

### 5.2 EEG Results

#### 5.2.1 Principal Component Analysis (PCA).

As described in the previous chapter, principal component analyses (PCAs) were used as a confirmatory tool to determine whether the pre-chosen time windows were appropriate for each of the three ERP components. A waveform for each ERP component in each ROI was then reconstructed using only the first principal component to confirm whether the signal of ERP
component was still captured within the pre-chosen time window. As illustrated in most cases below, the reconstructed waveform is very similar to its original ERP waveform. This observation is likely a result of the two-step averaging procedure (averaging signals across participants and across channels to get a grand average signal in one ROI), indicating that this averaging procedure is an effective denoising method. However, for future analyses on these data, it should be noted that PCA could be more effectively used as a denoising tool by applying the PC projection to individual subject data prior to determining the amplitudes and latencies of ERP components.

Fourteen out of the 17 total recruited participants had enough useable EEG trials (60% or more); hence, only the EEG data of these 14 participants were used in the data analysis. There was no correlation between participants’ age and the number of useable trials ($r = -0.002; p = 0.995$), thus ruling out any potential age-related effects. PCAs were conducted in RStudio (Version 1.0.153; RStudio Inc., 2016), on a subset of channels for each ROI and on a subset of time points for each time window. The PCAs for each region are summarized below.

**5.2.1.1 MPC - N1 ERP component.** To confirm the validity of the selected time window for the N1 ERP component over the medial-parietal cortex (mPC), a PCA was computed over a time window of 50ms to 200ms (visually identified from the grand average waveform using a traditional peak-picking method). Figure 3a below depicts the original N1 ERP waveform over the medial-parietal cortex (mPC) and the reconstructed waveform derived from only the first principal component (proportion of variance = 0.9072) over the selected time window. The reconstructed waveform suggests that there is an identifiable negative peak between 70-120ms (peaking at around 98ms). Thus, the time window for the N1 ERP component over the mPC region was shifted to 70ms-120ms.
Figure 3a. Original N1 ERP waveform over medial-parietal cortex and the reconstructed waveform derived from the first principal component (which represents 90.72% of signal variance over this ROI in this time window). Further analysis of the N1 in the mPC was conducted using the new time window of 70-120ms (indicated by the vertical dashed lines).

5.2.1.2 MPC - P2 ERP component. To confirm the validity of the selected time window for the P2 ERP component over the MPC, a PCA was computed over a time window of 174ms to 274ms (visually identified from the grand average waveform). Figure 3b below depicts the original P2 ERP waveform over the medial-parietal cortex (mPC) and the reconstructed waveform derived from only the first principal component (proportion of variance = 0.8231). The reconstructed waveform shows a positive peak between 150-250ms (peaking around 205ms). Hence, the time window for the P2 in the mPC was shortened to 150-250ms in order to conduct more conservative analyses of the data.
Figure 3b. Original P2 waveform over medial-parietal cortex and the reconstructed waveform derived from only the first principal component (which represents 82.31% of signal variance over this ROI in this time window). Further analysis of the P2 in the mPC was conducted using the new time window of 150-250ms (as indicated by the vertical dashed lines).

5.2.1.3 LTC - N2 ERP component. To confirm the validity of the selected time window for the N2 ERP component over left temporal cortex (LTC), a PCA was computed over a time window of 124ms to 200ms (visually identified from the grand average waveform). Figure 3c below shows the original N2 ERP waveform over the left temporal cortex (LTC) and a reconstructed waveform derived from only the first principal component (proportion of variance = 0.7192). The reconstructed waveform shows that there is a second negative peak between 110ms and 160ms (peaking around 120ms). The N2 ERP component shown in the reconstructed waveform in Figure 3c appears to peak earlier than the findings reported by Landi et al. (2012). For example, Landi et al. (2012) found their second negative (N2) ERP mean amplitude in the
time window of 152-200ms, while the reconstructed waveform in figure Xc suggests that the current study sample’s N2 ERP amplitude peaks at around 120ms. This could be due to differences in sample demographics (e.g. age, reading exposure, prenatal drug exposure). Based on the reconstructed waveform, the time window of the N2 in the LTC was adjusted to 110-160ms for further analyses.

![Reconstructed N2 in LTC](image)

*Figure 3c.* Original N2 waveform over left temporal cortex and the reconstructed waveform derived from only the first principal component (which represents 71.92% of signal variance over this ROI in this time window). Further analysis of the N2 in the LTC was conducted using a new time window of 110-160ms (as indicated by the vertical dashed lines).

5.2.1.4 LTC - P2 ERP component. To confirm the validity of the selected time window for the P2 ERP component over the LTC, a PCA was computed over a time window of 200ms to 274ms (visually identified from grand average waveform). Figure 3d below depicts the original P2 ERP waveform over the left temporal cortex (LTC) and the reconstructed waveform derived
from only the first principal component (proportion of variance = 0.707). It is likely that the peak at 180ms shown in the reconstructed waveform in Figure 3d represents signal from the P2 ERP component, whereas the peak at 270ms represents signal contributing to a later ERP component like the P3. This observation of the two peaks suggests that perhaps the previously-chosen time window of 200ms-274ms was too long, and thus the time window for analysis of the P2 was shortened to 170-220ms.

![Reconstructed P2 in LTC](image)

**Figure 3d.** Original P2 waveform over left temporal cortex and the reconstructed waveform derived from only the first principal component (which represents 70.66% of all signal variance). Further analysis of the P2 in the LTC was conducted using a new time window of 170-220ms (as indicated by the vertical dashed lines).

### 5.2.1.5 RTC - N2 ERP component

To confirm the validity of the selected time window for the N2 ERP component over the right temporal cortex (RTC), a PCA was computed over a time window of 124ms to 200ms (visually identified from grand average waveform). Figure 3e
below shows the original N2 ERP waveform over the right temporal cortex, and the
reconstructed waveform derived from only the first principal component (proportion of variance
= 0.7232). The reconstructed waveform shows a second negative peak at around 135ms, which is
similar to the early activation pattern observed in the N2 component over the left temporal
cortex. A new time window of 120-160ms was therefore applied for further analysis of the N2
ERP component over the RTC.

**Figure 3e.** Original N2 waveform over right temporal cortex and the reconstructed
waveform derived from only the first principal component (which represents 72.32% of
all signal variance). Further analysis of the N2 in the RTC was conducted using a new
time window of 120-160ms (as indicated by the vertical dashed lines).

**5.2.1.6 RTC - P2 ERP Component.** To confirm the validity of the selected time window
for the P2 ERP component over the RTC, a PCA was computed over a time window of 200ms to
274ms (visually identified from grand average waveform). Figure 3f below depicts the original
P2 waveform over the right temporal cortex, and a reconstructed waveform derived from only
the first principal component (proportion of variance = 0.8797). The reconstructed waveform shows two positive peaks, one at around 220ms and the other around 250ms. Similar to the P2 ERP component observed in the left temporal cortex, it is possible that the peak at 220ms shown in Figure 3f includes signal from the P2 ERP component, whereas the peak at 250ms represents signal contributing to a later ERP component like the P3. This observation suggests that perhaps the previously-chosen time window of 200ms-274ms was too long, and thus the analysis time window for the P2 in the RTC was shortened to 200-230ms.

![Reconstructed P2 in RTC](image)

*Figure 3f*: Original P2 waveform over right temporal cortex and the reconstructed waveform derived from only the first principal component (which represents 87.97% of all signal variance). Further analysis of the P2 in the RTC was conducted using a new time window of 200-230ms (as indicated by the vertical dashed lines).
5.2.2 Adaptive mean amplitudes.

Figures 4a,b,c below depict the grand average ERP waveforms in the desensitized and novel conditions for all 14 participants. Pairwise t-tests were conducted on the adaptive mean amplitudes of each ERP component in the medial-parietal cortical region (mPC), left temporal cortex (LTC), and right temporal cortex (RTC). There were no significant differences between the desensitized and novel conditions in the N1/P2 amplitude in mPC (t (26) = 0.378; p = 0.709), in the N2 amplitude in LTC (t (26) = 0.238; p = 0.814) and RTC (t (26) = 1.770; p = 0.089), or in the P2 amplitude in LTC (t (26) = 0.437; p = 0.666) and RTC (t (26) = 2.028; p = 0.053). The pairwise t-tests are summarized in Table 4 below.

5.2.3 Peak latencies.

Pairwise t-tests were also conducted on the peak latency of each ERP component in each region of interest. There are no significant differences between the desensitized and novel conditions in the N1/P2 peak latency in mPC (t (26) = -0.661; p = 0.515), in the N2 peak latency in LTC (t (26) = -1.498; p = 0.146) and RTC (t (26) = -0.518; p = 0.609), or the P2 peak latency in LTC (t (26) = -0.979; p = 0.336) and RTC (t (26) = 0.664; p = 0.513). The pairwise t-tests are summarized in Table 4 below.

The lack of significant difference between the two conditions are likely due to the high variance in the data (as illustrated by the standard deviation (lighter shaded areas around the grand average waveforms)). One reason that these data are highly variable is that the pediatric sample is very young and so the data are subject to higher noise levels. Another reason might be due to individual variability in neural activities during phoneme-processing in pre-readers. Recent neuroimaging studies have shown that poor readers often have significantly more variable auditory responses than typically-developing readers, and the variance in this current dataset might be partially attributable to this phenomenon since the current sample consists of
pre-readers with a family history of dyslexia and weak pre-literacy skills (Hornickel & Kraus, 2013; Hancock, Pugh & Hoeft, 2017; Malins et al., 2018).

Additionally, while the current study did not investigate the P300 ERP component, visual inspection of the grand average waveforms suggests that there might be a condition effect in the P300 (peaking at around 350ms post-stimulus) in the medial-parietal cortex. It is likely that the novel condition elicited a larger P300 effect over the parietal and temporal regions, as the P300 is often associated with detection of new or “oddball” targets (Linden, 2005; Li, Gratton, Yao & Knight, 2010; van Dinteren, Arns, Jongsma & Kessels, 2014). These points are considered further in the Discussion.

**Figure 4a.** EEG waveforms measured over the medial-parietal cortex (mPC) 100ms before and 400ms after stimulus onset. The ERP waveform in blue represents responses to the desensitized stimulus, and the ERP waveform in orange represents responses to the novel stimulus. The lighter shaded areas around the waveforms illustrate the standard deviation, and the darker shaded areas around the waveforms illustrate the standard error of the mean. The new time-windows for N1 (70-120ms) and P2 (150-250ms) determined using PCA are labeled.
Figure 4b. EEG waveforms measured over the left temporal cortex (LTC). The new time-windows for N2 (110-160ms) and P2 (170-220ms) determined using PCA are labeled.

Figure 4c. EEG waveforms measured over the right temporal cortex (RTC). The new time-windows for N2 (120-160ms) and P2 (200-230ms) determined using PCA are labeled.
Table 4

Summary of Paired-Samples T-Tests between Conditions

<table>
<thead>
<tr>
<th>ERP</th>
<th>Adaptive Amplitude/ Peak Latency</th>
<th>Region</th>
<th>t</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1/P2</td>
<td>Amplitude</td>
<td>mPC</td>
<td>0.378</td>
<td>26</td>
<td>0.709</td>
</tr>
<tr>
<td></td>
<td>Latency</td>
<td></td>
<td>-0.661</td>
<td>26</td>
<td>0.515</td>
</tr>
<tr>
<td>N2</td>
<td>Amplitude</td>
<td>LTC</td>
<td>0.238</td>
<td>26</td>
<td>0.814</td>
</tr>
<tr>
<td></td>
<td>Latency</td>
<td>RTC</td>
<td>1.770</td>
<td>26</td>
<td>0.089</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LTC</td>
<td>-1.498</td>
<td>26</td>
<td>0.146</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RTC</td>
<td>-0.518</td>
<td>26</td>
<td>0.609</td>
</tr>
<tr>
<td>P2</td>
<td>Amplitude</td>
<td>LTC</td>
<td>0.437</td>
<td>26</td>
<td>0.666</td>
</tr>
<tr>
<td></td>
<td>Latency</td>
<td>RTC</td>
<td>2.028</td>
<td>26</td>
<td>0.053</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LTC</td>
<td>-0.979</td>
<td>26</td>
<td>0.336</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RTC</td>
<td>0.664</td>
<td>26</td>
<td>0.513</td>
</tr>
</tbody>
</table>

Note. Summary of paired-samples t-tests evaluating adaptive mean amplitudes and peak latencies differences between the novel and desensitized conditions in the N1/P2 (70-120ms/150-250ms), N2 in left temporal cortex (110-160ms), N2 in right temporal cortex (120-160ms), P2 in LTC (170-220ms), and P2 in RTC (200-230ms).

5.3 Brain-Behavior Analyses

5.3.1 Permutation Correlation Analysis.

Pearson’s permutation correlation tests and Spearman’s permutation correlation tests were conducted to evaluate the significance of correlations between adaptive mean amplitudes and peak latencies of the three ERP components identified during the novel condition of the EEG experiment, demographic information, and scores on literacy assessments. Each permutation test had an iteration of $N = 10,000$. Pearson’s correlation tests were conducted with parental questionnaires and reading-related assessments, whereas Spearman’s correlation tests were conducted only for family income because it represents ranked variables.

5.3.1.1 Adaptive mean amplitudes. Table 5 below shows the p-values of permutation correlation tests ($N = 10,000$) between scores on all behavioral measures and the adaptive mean amplitudes of each targeted ERP component over each ROI.
The adaptive mean amplitude of the N2 ERP component in the left temporal cortex was significantly correlated with scores on the Parental Reflective Functioning Questionnaire: Interest and Curiosity ($p = 0.049$; Figure 5a). The adaptive mean amplitude of the P2 ERP component in the left temporal cortex was significantly correlated with standard scores of phonological awareness ($p = 0.004$) and basic reading skills ($p = 0.002$) at Time 2 (Figure 5b).

Table 5

*Summary of Permutation Correlation Analysis (Adaptive Mean Amplitudes)*

<table>
<thead>
<tr>
<th></th>
<th>Parent Reading History</th>
<th>N1/P2 Adaptive Mean Amplitude (mPC)</th>
<th>N2 Adaptive Mean Amplitude (LTC)</th>
<th>P2 Adaptive Mean Amplitude (LTC)</th>
<th>P2 Adaptive Mean Amplitude (RTC)</th>
<th>P2 Adaptive Mean Amplitude (RTC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parent Reading History</td>
<td>0.063</td>
<td>0.440</td>
<td>0.233</td>
<td>0.756</td>
<td>0.627</td>
<td></td>
</tr>
<tr>
<td>Parental Reflective Functioning (Pre-Mentalization)</td>
<td>0.858</td>
<td>0.883</td>
<td>0.750</td>
<td>0.096</td>
<td>0.403</td>
<td></td>
</tr>
<tr>
<td>Parental Reflective Functioning (Certainty of Mental States)</td>
<td>0.906</td>
<td>0.170</td>
<td>0.093</td>
<td>0.883</td>
<td>0.534</td>
<td></td>
</tr>
<tr>
<td>Parental Reflective Functioning (Interest &amp; Curiosity about Mental States)</td>
<td>0.606</td>
<td>0.049*</td>
<td>0.076</td>
<td>0.348</td>
<td>0.985</td>
<td></td>
</tr>
<tr>
<td>Phonological Awareness (Time 1)</td>
<td>0.290</td>
<td>0.861</td>
<td>0.317</td>
<td>0.320</td>
<td>0.736</td>
<td></td>
</tr>
<tr>
<td>Phonological Awareness (Time 2)</td>
<td>0.931</td>
<td>0.159</td>
<td>0.004**</td>
<td>0.355</td>
<td>0.544</td>
<td></td>
</tr>
<tr>
<td>Basic Reading (Time 2)</td>
<td>0.946</td>
<td>0.110</td>
<td>0.002**</td>
<td>0.179</td>
<td>0.489</td>
<td></td>
</tr>
<tr>
<td>Number of Parent with Dyslexia</td>
<td>0.695</td>
<td>0.138</td>
<td>0.665</td>
<td>0.691</td>
<td>0.938</td>
<td></td>
</tr>
<tr>
<td>Number of Reading Sessions per Week</td>
<td>0.749</td>
<td>0.395</td>
<td>0.138</td>
<td>0.754</td>
<td>0.318</td>
<td></td>
</tr>
<tr>
<td>Family Income</td>
<td>0.295</td>
<td>0.604</td>
<td>0.927</td>
<td>0.578</td>
<td>0.292</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Summary of p-values of the permutation correlation analyses ($N = 10,000$) between adaptive mean amplitudes of N1/P2 (mPC; medial-parietal cortex), N2 (LTC; left temporal cortex, RTC; right temporal cortex) and P2 (LTC, RTC) and scores on parental questionnaires, children’s scores on reading-related assessments, and demographic information. Significant correlations are highlighted in yellow ($p < 0.05$); * indicates a p-value < 0.05; ** indicates a p-value < 0.005.
Figure 5a. N2 adaptive mean amplitude in the left temporal cortex was significantly and positively correlated with scores on the Parental Reflective Functioning Questionnaire – Interest and Curiosity towards Mental States ($p = 0.049$).

Figure 5b. P2 adaptive mean amplitude in the left temporal cortex was significantly correlated with both Phonological Awareness Scores at Time 2 ($p = 0.004$) and with Basic Reading Scores at Time 2 ($p = 0.002$).
5.3.1.2 **Peak Latency.** Table 6 below provides the p-values of permutation correlation tests \((N = 10,000)\) between scores on all behavioral measures and the latencies of ERP component peaks. There were no significant correlations between the peak latencies of ERP components and scores of reading-related assessments or demographic information.

Table 6

**Summary of Permutation Correlation Analysis (Peak Latencies)**

<table>
<thead>
<tr>
<th>Measure</th>
<th>N1P2 Peak Latency in mPC</th>
<th>N2 Peak Latency in LTC</th>
<th>P2 Peak Latency in RTC</th>
<th>N2 Peak Latency in LTC</th>
<th>P2 Peak Latency in RTC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parent Reading History</td>
<td>0.181</td>
<td>0.744</td>
<td>0.116</td>
<td>0.320</td>
<td>0.698</td>
</tr>
<tr>
<td>Parental Reflective Functioning (Pre-Mentalization)</td>
<td>0.696</td>
<td>0.272</td>
<td>0.354</td>
<td>0.918</td>
<td>0.541</td>
</tr>
<tr>
<td>Parental Reflective Functioning (Certainty of Mental States)</td>
<td>0.746</td>
<td>0.160</td>
<td>0.267</td>
<td>0.104</td>
<td>0.995</td>
</tr>
<tr>
<td>Parental Reflective Functioning (Interest &amp; Curiosity about Mental States)</td>
<td>0.471</td>
<td>0.465</td>
<td>0.408</td>
<td>0.392</td>
<td>0.941</td>
</tr>
<tr>
<td>Phonological Awareness (Time 1)</td>
<td>0.198</td>
<td>0.651</td>
<td>0.254</td>
<td>0.301</td>
<td>0.559</td>
</tr>
<tr>
<td>Phonological Awareness (Time 2)</td>
<td>0.168</td>
<td>0.175</td>
<td>0.220</td>
<td>0.241</td>
<td>0.960</td>
</tr>
<tr>
<td>Basic Reading (Time 2)</td>
<td>0.262</td>
<td>0.238</td>
<td>0.665</td>
<td>0.918</td>
<td>0.532</td>
</tr>
<tr>
<td>Number of Parent with Dyslexia</td>
<td>0.805</td>
<td>0.375</td>
<td>0.985</td>
<td>0.753</td>
<td>0.563</td>
</tr>
<tr>
<td>Number of Reading Sessions per Week</td>
<td>0.068</td>
<td>0.273</td>
<td>0.764</td>
<td>0.589</td>
<td>0.162</td>
</tr>
<tr>
<td>Family Income</td>
<td>0.312</td>
<td>0.354</td>
<td>0.196</td>
<td>0.892</td>
<td>0.595</td>
</tr>
</tbody>
</table>

*Note.* Summary of p-values of the permutation correlation analysis \((N = 10,000)\) between peak latencies of N1P2 (mPC; medial-parietal cortex), N2 (LTC; left temporal cortex, RTC; right temporal cortex) and P2 (LTC, RTC) and scores of parental questionnaires, scores of children’s reading-related assessments, and demographic information. There are no significant correlations between peak latencies of any ERP components and the scores of any parental questionnaires, reading-related assessments or demographic information.
5.3.2 Multiple Linear Regression Analysis.

Multiple linear regression analyses were conducted in RStudio (Version 1.0.153; RStudio Inc., 2016) to determine whether phonological awareness skills and reading outcomes at Time 2 could be predicted based on demographic information and parental questionnaires.

5.3.2.1 Phonological Awareness (Time 2)

A significant regression equation was found for phonological awareness at Time 2 ($F_{(6,5)} = 5.594$, $p = 0.039$), with an $R^2$ of 0.870. The equation and summary of the multiple linear regression analysis are stated below.

\[
\text{Phonological Awareness Score}_{(\text{Time 2})} = 100.719 + 10.441 (\text{PRF:ICM}) + 3.146 (\text{Reading Sessions}) \\
+ 2.613 (\text{Number of Parents with Dyslexia}) \\
- 1.543 (\text{Parent Reading History}) - 1.055 (\text{PRF:CM}) + 0.479 (\text{PRF:PM})
\]

The multiple linear regression analysis indicates that scores on the measures of Parental Reflective Functioning: Interest & Curiosity in Mental States ($p = 0.014$) was found to be significantly positively associated with children’s phonological awareness scores in Time 2. A summary of the multiple linear regression analysis can be found in Table 7 below. Figure 6a illustrates the correlation between phonological awareness scores in Time 2 and Parental Reflective Functioning: Interest & Curiosity in Mental States ($r = 0.831; p < 0.0001$).
Table 7

Summary of Multiple Linear Regression (Phonological Awareness)

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>100.719</td>
<td>1.847</td>
<td>54.538</td>
<td>3.92e-08 ***</td>
</tr>
<tr>
<td>Number of Parent with Dyslexia</td>
<td>2.613</td>
<td>2.058</td>
<td>1.270</td>
<td>0.260</td>
</tr>
<tr>
<td>Reading Sessions per Week</td>
<td>3.146</td>
<td>2.138</td>
<td>1.472</td>
<td>0.201</td>
</tr>
<tr>
<td>Parent Reading History</td>
<td>-1.543</td>
<td>2.098</td>
<td>-0.735</td>
<td>0.495</td>
</tr>
<tr>
<td>PRF: Pre-Mentalization</td>
<td>0.479</td>
<td>2.095</td>
<td>0.228</td>
<td>0.828</td>
</tr>
<tr>
<td>PRF: Certainty of Mental States</td>
<td>-1.055</td>
<td>3.026</td>
<td>-0.348</td>
<td>0.742</td>
</tr>
<tr>
<td>PRF: Interest &amp; Curiosity in Mental States</td>
<td>10.441</td>
<td>2.799</td>
<td>3.731</td>
<td>0.014*</td>
</tr>
</tbody>
</table>

Note. The p-values of statistically significant predictors are highlighted in yellow (* indicates a p-value < 0.05).

Correlation of Interest & Curiosity and Phonological Awareness (Time 2)

Figure 6a. Correlation between Phonological Awareness and Parental Reflective Functioning: Interest & Curiosity in Mental States ($p < 0.0001$).
5.3.2.2 Basic Reading Skills (Time 2)

Another significant regression equation was found for Basic Reading at Time 2 ($F_{(6,5)} = 9.412$, $p = 0.013$), with an $R^2$ of 0.919. The equation and summary of the multiple linear regression analysis are stated below.

Basic Reading Score\(_{(Time 2)}\)

\[
= 109.764 + 16.349(\text{PRF:ICM}) - 8.779 \ (\text{PRF:CM}) \\
+ 5.056 \ (\text{Reading Sessions}) - 3.341 \ (\text{Parent Reading History}) \\
+ 1.023 \ (\text{PRF:PM}) - 0.846 \ (\text{Number of Parents with Dyslexia})
\]

Scores on the measures of Parental Reflective Functioning: Interest & Curiosity in Mental States ($p = 0.002$) was found to be significantly positive associated with children’s Basic Reading Scores in Time 2, while scores of Parental Reflective Functioning: Certainty of Mental States ($p = 0.031$) was found to be significantly negatively associated with children’s Basic Reading Scores in Time 2. A summary of the multiple linear regression analysis can be found in Table 8a below.
Table 8a

Summary of Multiple Linear Regression (Basic Reading)

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>109.764</td>
<td>1.794</td>
<td>61.192</td>
<td>2.21e-08 ***</td>
</tr>
<tr>
<td>Number of Parent with Dyslexia</td>
<td>-0.846</td>
<td>1.999</td>
<td>-0.423</td>
<td>0.690</td>
</tr>
<tr>
<td>Reading Sessions per Week</td>
<td>5.056</td>
<td>2.076</td>
<td>2.435</td>
<td>0.060</td>
</tr>
<tr>
<td>Parent Reading History</td>
<td>-3.341</td>
<td>2.038</td>
<td>-1.639</td>
<td>0.162</td>
</tr>
<tr>
<td>PRF: Pre-Mentalization</td>
<td>1.023</td>
<td>2.035</td>
<td>0.503</td>
<td>0.637</td>
</tr>
<tr>
<td>PRF: Certainty of Mental States</td>
<td>-8.779</td>
<td>2.940</td>
<td>-2.987</td>
<td>0.031*</td>
</tr>
<tr>
<td>PRF: Interest &amp; Curiosity in Mental States</td>
<td>16.349</td>
<td>2.718</td>
<td>6.014</td>
<td>0.002**</td>
</tr>
</tbody>
</table>

*Note. The p-values of statistically significant predictors are highlighted in yellow (* indicates a p-value < 0.05; ** indicates a p-value < 0.005)*.

The observation that Parental Reflective Functioning: Certainty of Mental States is negatively associated with children’s reading scores was not initially predicted, because this would suggest that children whose parents who have a good understanding of their mental states would have lower reading skills. However, on examining the direct correlation between children’s Basic Reading scores (Time 2) and Certainty of Mental States, there is a positive (though not significant) correlation ($r = 0.415; p = 0.140$; Figure 6b). This positive correlation suggests that unlike the association seen in the multiple linear regression analysis, parents’ certainty about their children’s mental states is positively related to children’s later basic reading skills.
Figure 6b. Positive (but not statistically significant; \( p = 0.140 \)) correlation between Parental Reflective Functioning: Certainty of Mental States and Basic Reading Scores (Time 2).

This discrepancy is likely a mathematical artifact due to having highly correlated predictors in the same regression model (Bruce & Bruce, 2018, pp. 150-153). While predictor variables in a multiple regression are often related with each other, highly correlated factors may make it difficult to interpret the significance and directionality of regression coefficients.

In order to test whether the coefficient for Certainty of Mental States is a mathematical artifact, a correlation test between Certainty of Mental States and Interest & Curiosity of Mental States was used, revealing that the two variables are highly correlated (\( r = 0.693; p = 0.006 \); Figure 6c).
Figure 6c. Positive and significant ($p = 0.006$) correlation between Parental Reflective Functioning: Certainty of Mental States and Parental Reflective Functioning: Interest & Curiosity of Mental States.

Next, the multiple regression analysis was re-run using all variables and just the Interest & Curiosity of Mental States component of parental reflective functioning. This approach showed that Interest & Curiosity of Mental States is still a significant positive predictive variable for Basic Reading Scores ($F_{(4,7)} = 5.545$; coeff: $10.771$; $p = 0.007$; see Table 8b). Figure 6d below depicts the correlation between basic reading scores and Parental Reflective Functioning: Interest & Curiosity in Mental States ($r = 0.806$; $p < 0.0001$).
Table 8b

Summary of Multiple Linear Regression (PRF: Interest & Curiosity in Mental States)

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>110.110</td>
<td>2.597</td>
<td>42.398</td>
<td>1.06e-09 ***</td>
</tr>
<tr>
<td>Number of Parent with Dyslexia</td>
<td>0.113</td>
<td>2.785</td>
<td>0.040</td>
<td>0.969</td>
</tr>
<tr>
<td>Reading Sessions per Week</td>
<td>3.322</td>
<td>2.750</td>
<td>1.208</td>
<td>0.266</td>
</tr>
<tr>
<td>Parent Reading History</td>
<td>-2.536</td>
<td>2.902</td>
<td>-0.874</td>
<td>0.411</td>
</tr>
<tr>
<td>PRF: Interest &amp; Curiosity in Mental States</td>
<td>10.771</td>
<td>2.886</td>
<td>3.732</td>
<td>0.007**</td>
</tr>
</tbody>
</table>

Note. Interest & Curiosity in Mental States remain positively and significantly associated with Basic Reading scores (Time 2). (* indicates a p-value <0.05; ** indicates a p-value <0.005)

Correlation of Interest & Curiosity and Basic Reading Scores (Time 2)

Figure 6d. Correlation between Basic Reading (Time 2) and Parental Reflective Functioning: Interest & Curiosity in Mental States (p < 0.0001).
On the other hand, when the multiple regression analysis was re-run using all variables and just the Interest and Curiosity of Mental States component of the PRFQ, the directionality and significance changed for Certainty of Mental States as a variable, rendering it now a positive (but not significant) predictor for Basic Reading scores ($F_{(4,7)} = 0.766$; coeff: $2.314$; $p = 0.656$; see Table 8c).

Table 8c

Summary of Multiple Linear Regression (PRF: Certainty of Mental States)

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>110.243</td>
<td>4.428</td>
<td>24.898</td>
<td>4.3e-08 ***</td>
</tr>
<tr>
<td>Number of Parent with Dyslexia</td>
<td>-2.781</td>
<td>4.693</td>
<td>-0.593</td>
<td>0.572</td>
</tr>
<tr>
<td>Reading Sessions per Week</td>
<td>5.625</td>
<td>4.796</td>
<td>1.173</td>
<td>0.279</td>
</tr>
<tr>
<td>Parent Reading History</td>
<td>-0.287</td>
<td>4.831</td>
<td>-0.059</td>
<td>0.954</td>
</tr>
<tr>
<td>PRF: Certainty of Mental States</td>
<td>2.314</td>
<td>4.975</td>
<td>0.465</td>
<td>0.656</td>
</tr>
</tbody>
</table>

*Note.* Certainty of Mental States is now positively but not significantly associated with Basic Reading scores (Time 2).

The results of these two separate multiple linear regression models suggest that when considering other predictive factors of future reading outcome, Interest and Curiosity in Mental States is the only aspect of parental reflective functioning that is positively and significantly associated with children’s Basic Reading scores at Time 2. Therefore, the significant negative association between Certainty of Mental States and Basic Reading scores observed in the initial
regression model was likely a mathematical artifact resulting from the high correlation between the two subtests of parental reflective functioning.

5.4 Results Summary

There were no significant differences between the desensitized and novel conditions of the EEG experiment as indicated by pairwise t-tests across the adaptive mean amplitudes and peak latencies of all three targeted ERP components. The adaptive mean amplitude of the N2 in the left temporal cortex (LTC) was significantly correlated with scores on the Parental Reflective Functioning Questionnaire: Interest and Curiosity in Mental States ($p = 0.049$); and the P2 adaptive mean amplitude in the LTC was significantly correlated with Phonological Awareness scores at Time 2 ($p = 0.004$) and with Basic Reading scores at Time 2 ($p = 0.002$). Multiple linear regression analyses revealed that scores on the measures of Parental Reflective Functioning: Interest and Curiosity in Mental States was a significant predictor of children’s Phonological Awareness scores ($p = 0.014$) and of children’s Basic Reading scores ($p = 0.002$) at Time 2.

In the next chapter, these findings will be considered against the research questions and theoretical frameworks that guided the development of this dissertation.
6. Discussion

This study aimed to investigate parental influences on reading related development in young children, by addressing three questions: 1. Do children’s neural responses (measured using an ERP task) to a phonological processing task correlate with their phonological awareness abilities, and with reading abilities one year later? 2. Do children’s neural responses correlate with measures of parental reflective functioning? 3. Do the measures of parental reflective functioning correlate with children’s later phonological awareness skills and reading abilities?

6.1 Research Question 1

To address the first question, Pearson’s permutation correlation analyses were conducted on the amplitudes of the three ERP components of interest (N1, P1, P2) and the scores on assessments of literacy skills obtained at both Time 1 and Time 2. Results showed that P2 adaptive mean amplitude over left temporal cortex was positively correlated with children’s scores on assessments of phonological awareness ($p = 0.004$) and with basic reading scores ($p = 0.002$) at Time 2. This finding did not hold for the same component measured over right temporal cortex. The observed increased P2 amplitude is consistent with previous research that showed a similar increase in P2 amplitude when hearing phonologically legal stimuli repeatedly (Rugg, Doyle, & Wells, 1995; Rugg & Doyle, 1994; Cheng, Schafer, & Riddell, 2014). A phonological repetition effect characterized by an increased P2 amplitude may be interpreted as an early marker for the P600 ERP component thought to be related to higher-level phonological processes like phonological encoding and retrieval (Molfese & Molfese, 1985; Kutas & Van Petten, 1994; Kutas et al., 2006; Landi et al., 2012). However, this study did not target the P600 component, and literature on the P2 component in response to phonological repetition effects is scarce, so this P2 finding and its possible relationship to phonological repetition effects should be interpreted with caution. Still, the increased P2 amplitude was observed only over left
temporal cortex, which is consistent with results from previous research that found significant P2 amplitude enhancement in left fronto-temporal areas during phonological processing tasks (Cheng et al., 2014). The current observation of P2 amplitude correlating with scores on reading-related measures is in line with this study’s prediction that activation of regions in the left temporal cortex (such as left inferior and/or superior temporal gyri) correlates with reading skills and with performance on reading-related tasks (such as phonological awareness).

In contrast with the study predictions, N2 adaptive mean amplitude over the left temporal cortex did not reach a significant correlation with children’s basic reading scores at Time 2 ($p = 0.110$). Increased N2 amplitude in the left temporal areas in response to phoneme discrimination has been found to be associated with typical or good reading outcomes in young children (Molfese & Molfese, 1985; Kutas & Van Petten, 1994; Kutas et al., 2006; Landi et al., 2012). The present study therefore was expected to reveal a significant correlation between the N2 amplitude in the left temporal cortex and scores of reading-related measures. Perhaps the failure to reach significance is due to the fact that Time 2 reading scores were obtained just as the participants began their formal literacy education. While previous studies (e.g. (Molfese & Molfese, 1985; Kutas & Van Petten, 1994; Kutas et al., 2006; Landi et al., 2012) have found the N2 ERP component to be associated with future reading outcomes in young children, the current study’s Time 2 reading scores assess participants’ reading skills as emergent reading learners but not their later reading ability as proficient readers. Hence, while a significant positive correlation between N2 amplitudes and Time 2 reading scores might be expected, this relationship might not be as strong as predicted.

6.2 Research Question 2

Permutation correlation analyses were also conducted to address the second research question. Children’s neural responses were found to be significantly correlated with all three
measures of parental reflective functioning (Pre-mentalization, Certainty of Mental States, and Interest & Curiosity of Mental States). In contrast with the study prediction that all three aspects of parental reflective functioning would be correlated with ERP components associated with reading development, the only significant correlation found was between Interest & Curiosity of Mental States and N2 adaptive mean amplitude in the left temporal cortex. This result suggests that parenting reflective functioning skills (related to parents’ interest and curiosity in children’s mental states) are correlated with left-lateralized neural activation during a phonological processing task (indexed by N2 amplitudes over left temporal regions). Contrary to the initial study prediction, parental reflective functioning was not found to be significantly correlated with P2 amplitude. As observed above, P2 amplitude was significantly correlated with Time 2 phonological awareness scores, and this result is consistent with other findings that P2 is associated with phonological processing (Cheng et al., 2014). On the other hand, the N2 has been found to be more associated with later reading outcomes (Molfese & Molfese, 1985; Kutas & Van Petten, 1994; Kutas et al., 2006; Landi et al., 2012). The observation of a relationship between parental reflective functioning and N2 amplitude suggests that parental engagement might be correlated with the neural indices that characterize children’s later reading success, regardless of their pre-literacy skills prior to learning reading. This is an important finding for this study, because this aspect of parental reflective functioning is most indicative of parents’ engagement with their children (Luyten et al., 2017). Of all three aspects of reflective functioning, parents’ interest and curiosity in their children’s mental states is thought to be a driving force that influences their intention to interact with their children, their engagement style, and the frequency of parent-child interaction (Luyten et al., 2017). This finding may have implications for understanding how parents’ engagement may be associated with their children’s reading skills as they begin literacy acquisition. This interpretation can be further reinforced by
the results from the multiple linear regression analysis examining the strong positive relation between parental engagement and children’s reading skills at Time 2 (further discussed below).

6.3 Research Question 3

To investigate the third research question, multiple linear regression analyses were conducted to address whether parental reflective functioning skills correlate with children’s phonological awareness and reading skills one year later with respect to other factors that might also influence children’s reading development. The factors that were included in the regression model were: PRF - Interest & Curiosity of Mental States; PRF - Certainty of Mental States; PRF - Pre-mentalization; number of reading sessions at home per week; parents’ reading history; and the number of parents diagnosed with dyslexia. When considering all these factors, only PRF - Interest & Curiosity of Mental States was a strong predictor of children’s phonological awareness skills ($p < 0.014$) and of their basic reading scores ($p < 0.002$) one year later.

Parents’ reading history, number of reading sessions per week, and number of parents diagnosed with dyslexia as predictors of phonological awareness and reading scores did not reach statistical significance as predictors of phonological awareness scores and reading scores at Time 2. While previous studies have also shown that parents’ own reading habits and home literacy environment do not necessarily differ between the homes of children with dyslexia and those without, intuitively one would expect that not having a parent with dyslexia and having increased exposure and practice to reading sessions at home would provide an environment for children to improve their reading skills (Elbro et al., 1998; Pennington & Lefly, 2001; Snowling et al., 2003). However, the current data suggest that having a parent with dyslexia as well as exposure to reading sessions at home is not as significant a factor as parental engagement. To further investigate if having a parent with dyslexia might different from not having a parental
risk of dyslexia, independent t-tests were conducted to illustrate if children’s basic reading skills and their parents’ Interest & Curiosity scores were significantly different amongst the two groups. Results show that children with a parent with dyslexia do not have significantly different basic reading skills compared to children without a parent with dyslexia (t (26) = 0.649; p = 0.522). As well, parents with and without dyslexia also do not have significantly different Interest & Curiosity scores (t (26) = 1.391; p = 0.176), suggesting that parents’ reflective functioning skills may be independent of their own diagnosis of dyslexia. While this finding might seem counter-intuitive at first, it is actually consistent with results from previous language development studies conducted to investigate the social aspect of language learning in young children. For example, Ohgi et al.’s (2010) findings using fNIRS show that there was more neural engagement when young children were being read to by their mothers compared to watching a video of someone reading the same story. Similarly, results from Kuhl et al.’s (2003) study also suggest that there is an important social aspect to language learning as they observed infants’ ability to retain phoneme discrimination skills for a foreign language, finding that this ability was manifested only when they were being read to by a real adult and not when they were only exposed to videos of the same stories. In both studies, all participants had the same amount of exposure to storybook reading, yet the children who experienced in-person interactions retained the information from their reading sessions or showed neural activation indicative of greater engagement with the reading material. Perhaps the current results are revealing a similar kind of importance to social aspects of interaction when young children are learning reading-related skills. Parents’ interest and curiosity in their children’s mental states may reflect their engagement style and engagement frequency with their children. If parent-child engagement facilitates social aspects of language learning, then it makes sense that parental reflective
functioning would be a strong predictor of children’s later reading outcomes regardless of whether the parents themselves have diagnoses of reading disorders.

Contrary to the study predictions, hemispheric lateralization (indicated by N2 and P2 adaptive mean amplitudes in the left and right temporal cortices) was not found to be associated with phonological awareness measures at Time 1. However, left-lateralized neural activation was observed to be associated with phonological awareness and reading scores at Time 2. This finding suggests that the ERP experimental design may not have been sensitive to discriminating phonological awareness skills in pre-readers, but rather was a strong predictor of children’s later phonological skills and emergent reading abilities. Another possible interpretation is that children’s early phonological processing skills may not be fully represented by behavioral assessments but may have instead been captured by neural indices in our EEG experiment. Thus, the results of this dissertation study suggest that children with certain neural indices (specifically, left-lateralized activation during a phoneme-processing task) tend to have higher phonological awareness and reading scores one year later, regardless of their pre-literacy skills at Time 1.

Another noteworthy finding from this study is the association between parental reflective functioning (especially Interest & Curiosity in Mental States) and children’s neural and reading development. Not only was parental reflective functioning shown to be strongly correlated with children experiencing left-lateralized neural activation during a phoneme-processing task, but this was also a strong predictor of children’s later development of reading and reading-related skills. As mentioned earlier, left lateralized neural activation during phoneme-processing may have implications for later reading success. The observation that parental reflective functioning is strongly associated with this left-lateralized pattern may suggest that parental engagement is also associated with later reading success. Indeed, results of the multiple linear regression analyses showed that parental reflective functioning was the strongest predictor of reading skills
of emergent reading learners in this study, even when considering a variety of other factors (such as number of reading sessions at home, and how many parents are diagnosed with dyslexia). One interpretation of this finding could be that social interaction during parent-child engagement facilitates literacy development.

Even though previous studies have shown correlations between parent-child relationships and pre-reading development, the current study is the first of its kind to identify specific relationships between parental reflective functioning and neural indices of children’s pre-reading skills as they prepare for formal literacy education. This study also revealed the predictive power of parental reflective functioning and showed that it is a strong predictor of children’s later reading success as they begin to acquire literacy. While this study was not conducted with a dyslexic sample, some participants of this study have poor pre-literacy skills and are at-risk for developing reading disorders; thus, the results may have implications that could also apply to children with reading difficulty. However, further investigations are needed to determine whether similar results and implications can be yielded from a dyslexic sample population.

6.5 Limitations, Delimitations and Future Directions

In the present study, a key finding is that young children’s phonological awareness and basic reading skills as they begin to learn reading are strongly associated with left-lateralized neural activation observed during a phoneme-decoding task one year prior to their exposure to formal reading education. This left-lateralization pattern and later reading-related skills were significantly correlated with parental reflective functioning skills, suggesting that the quality of parent-child engagement may have a facilitative role in early reading education for young children. However, this study did not explore if children’s neural activity changed as they begin reading education, and thus it is uncertain if parental reflective functioning would still be associated a left-lateralization pattern when children become emergent readers. In order to
address this question, future studies should implement a Time 2 EEG session in order to investigate whether there are any neural changes when children are exposed to formal literacy education in First Grade. Also, it is unclear why parental reflective functioning is associated with children’s future reading skills. Since our findings suggest that parents’ interest and curiosity in their children’s mental states are most strongly correlated with children’s neural and reading development, future studies could further investigate the mechanisms whereby parental reflective functioning may contribute to reading learning. For example, it may be that parents’ interest and curiosity in their children’s mental states result in more and/or higher quality engagement at home, so perhaps gathering additional data regarding parenting style or parent-child interaction frequency may help tease apart why this particular aspect of parental reflective functioning is most strongly correlated with reading outcomes (Luyten et al., 2017).

Another limitation of this study is that the correlation between parental reflective functioning and children’s basic reading skills was only examined after one year, when participating children were first beginning their education in reading. Based on the limited data of this study, it is not possible to conclude that this basic reading skill is predictive of the children’s later reading success and thus it is not certain whether the predictive power of parental reflective functioning might carry over beyond the initial stages of literacy education. A previous study by Sénéchal & LeFevre (2002) showed that even though parental influences have strong contribution to young children’s early language and pre-reading development, these effects seem to be less direct as children learn to read proficiently. However, these studies did not assess specific aspects of parental influences, nor did they examine parental influences on children’s neural or biological development as they learn to read. Future studies could continue to assess children’s later reading outcome and related neural development as they become proficient readers and examine whether the later reading success of older children correlates with different
aspects of parental reflective functioning (along with more detailed factors about parent-child engagements like reading style, parenting style, or frequency of parent-child interactions). If the effects of parental influences (including those of parental reflective functioning) do indeed fade as children grow older, future studies could seek to determine the stage at which parental influences stop contributing to literacy development, and these studies could also determine whether enhancing parental influences could provide a foundation to enhance literacy learning skills. By addressing these questions, we might be able to decide whether or not more social involvement at home might be advantageous in early reading education.

One other criticism of this study stems from the idea that while some studies have reported that Parental Reflective Functioning is associated with the development of secure attachment relationships, there might be exceptions where parents have high reflective functioning but their children do not respond or behave in a way that is characteristic of securely-attached children. Such relationships might yield inaccurate results on the Parental Reflective Functioning Questionnaire (PRFQ), as many of the questions on the questionnaire pertain specifically to parents’ experience with their children. Again, future studies should attempt to gather additional data regarding parenting style, parent-child interactions and parents’ reflective function skills outside of the context of parenting in order to supplement the PRFQ.

While this study examined neural indices that are most characterized by the dyslexic population, the study sample did not include any individual with a diagnosis of dyslexia (mostly because the sample was comprised of pre-readers at Time 1). Thus, findings might not be completely generalizable to children with dyslexia, in part because other factors (such as genetics) should also be considered when investigating a disorder this complex. However, it could be worthwhile to examine whether findings could be replicated in an older sample comprised of children with dyslexia, and children who are at-risk but resilient to familial risks of
dyslexia (while considering other genetic and environmental influences). This could potentially provide some insight into the role of parental engagement as a resilient factor for at-risk children. If future studies also find that increased parental engagement (or social interactions at home) is associated with literacy acquisition even in children with dyslexia, this could provide a motivation for adding a socially-oriented aspect to future reading interventions.

Although initial visual inspection of the grand average waveforms in the desensitized and novel condition suggested that there might be a condition effect in both the N2 and P2 amplitude and latency in the right temporal cortex, pairwise t-tests suggested otherwise. The high variance in the data (as illustrated by the shaded areas in Figures 4a - 4c) offers a likely explanation for the lack of statistical significance. One reason for the high variances in the data is that the study sample is on the young side (mean age: 4.51 years), and young children are more susceptible to fatigue, inattention, movement and other factors that might interfere with data collection during the EEG experiment. Another possible explanation could be an unanticipated habituation effect that occurred for the Novel stimulus, thus resulting in no statistically significant differences between the neural responses of the two different conditions. However, this explanation is less probable due to a visual identification of a P300 ERP component in the Novel condition over the medial-parietal cortex, which is indicative of detection of a novel stimulus regardless of a child’s reading abilities. Thus, the lack of neural differences to a Novel stimulus in reading-related ERP components does not necessarily mean that the participants did not perceive the two stimuli differently, especially given a visual identification of a P300 to the Novel stimulus. However, to ensure that there are no unwanted habituation effects with the Novel stimulus, future analysis could implement a split-half comparison to only include the first half of the Novel trials to remove any habituation effects in the later trials. Another reason why the Novel and Desensitized conditions are not significantly different may be due to the variability in the participants’ reading-
related skills. Recent neuroimaging studies have shown that poor readers and children with reading difficulties often have significantly more variable auditory and reading-related neural responses due to having associated behavioral struggles, such as auditory, linguistic and attention difficulties (Hornickel, Chandrasekaran, Zecker & Kraus, 2010; Honickel & Kraus, 2013; Hancock et al., 2017; Malins et al., 2018). These studies showed that deviations from traditional measures of averaged neural activation may be correlated with children’s variability in reading-related abilities (Malins et al., 2018). Thus, it is possible that some of the variance in the data could be attributed to individual variances in neural responses to processing speech-related auditory stimuli. Individual variability in neural activation would need to be further investigated to determine whether this possible explanation has utility. If it does, further analyses should be applied to quantify trial-to-trial variability in EEG responses from each participant, to investigate whether such measures correlate with observations of reading and reading-related skills.

There are limitations regarding the experimental design of this study. In particular, the stimuli used in the ERP experiment could be improved by regulating their linguistic and acoustic properties in the context of developmental work. The stimuli in this experiment were originally adapted from a similar ERP experiment conducted by Molfese et al. (1990), but the acoustic and linguistic properties of the two stimuli are not identical in that the phonemes are acquired at different stages of development (which is an important aspect of the current study, as our ERP experiment relies on the assumption that children perceive both pseudowords the same way). In future experiments, it would be helpful to develop stimuli that share the same developmental framework to rule out the possibility that there are processing differences between the stimuli.

Additionally, this ERP experiment is passive in nature, meaning that participants’ engagement in the experiment is not assessed or monitored. When young children are completing an experiment that has repetitive presentation of the same stimuli, drifting attention and
disengagement from the ERP task could have been a source of noise in the ERP data. Future improvements could be made, such as employing an oddball paradigm with a response condition, to ensure that participants are attending to the ERP task.

Finally, as mentioned in the Results chapter, principal component analyses (PCA) could be utilized more efficiently as a denoising method in future analyses of this data. In this study, PCAs were used as a confirmatory process to determine whether pre-selected time windows based on participants’ grand average waveforms were appropriate. Even though the results of the PCAs helped explain statistically why some of the time windows might be different from those used in previous studies, results from the PCAs should still be interpreted in the light of additional details that might provide further explanation for these timing differences. For example, Landi et al. (2012)’s time window for N2 in the temporal cortices was 152-200ms, which was 42-32ms later than our defined time window for N2 in our sample group. This could be due to the fact that participants in Landi et al.’s (2012) study were adolescents aged 9-11 years with a wide range of reading abilities, and some of the participants had been prenatally exposed to cocaine. Thus, the difference in age, reading skills, and exposure to prenatal drug use are population variables that could explain why Landi et al.’s (2012) sample and the current study sample experienced average N2 components at different times.

When looking at Figures 3a - 3f, it should be noted that in the majority of cases the reconstructed waveform of each ERP component derived from the first PC is very similar to the original recorded waveform. This could be attributed to the fact that the averaging procedure used after the PC analysis to calculate the ERP signal amplitude in a given ROI is a very good denoising method. However, the denoising effect of the PCA does not really come into play for the selection of meaningful time windows for latency analysis. Future analyses may apply PCA as a denoising tool for the individual EEG signals. One approach would be to first determine the
principal component decomposition for the grand averaged signal and then apply the PC projection to individual participant data before determining adaptive mean amplitudes and peak latencies of interest. This would allow individual EEG signals to be denoised by a PC filter derived from the entire population of study participants. If there is still no condition effect between the Novel and Desensitized conditions using the newly denoised data, perhaps what is considered “noise” in traditional measures of averaged neural activity may be correlated with variability in children’s reading-related skills (Hornickel & Kraus, 2013; Hancock, Pugh & Hoeft, 2017; Malins et al., 2018). Further investigations by quantifying trial-to-trial variances in EEG responses from each participant will be needed to examine any relations between neural variances and variability in reading skills.

Even given the limitations mentioned above, the current study is still the first of its kind to investigate the relations between parental reflective functioning (the capacity to understand and relate to the mental states of oneself and that of their children) and the reading and related neural development of young children as they being to engage with literacy instruction. The study’s findings have potential implications for the significance of parental reflective functioning skills in our understanding of children’s literacy and related neural development, and further research may be able to investigate whether some aspects of parental reflective functioning could be incorporated into reading education or reading intervention programs for children with reading difficulties.


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The International Journal of Psycho-analysis, 77(6), 1181.


Appendices

Appendix A

Letter of Protocol Approval

(Yale University Human Investigation Committee)

Yale University Human Investigation Committee

Telephone: 203-785-4688
Fax: 203-785-2847
http://info.med.yale.edu/hic

To: Kenneth Pugh, Ph.D., M.A.
From: The Human Investigation Committee
Date: 12/10/2012
HIC Protocol #: 1208010711
Study Title: Nature and Acquisition of the Speech Code and Reading

Committee Action: Expedited Approval
HIC Action Date: 12/10/2012
Approval Date: 12/10/2012
Expiration Date: 12/09/2013
Submission Type: Response to Revisions Requested for Initial Protocol Approval

The Human Investigation Committee (HIC) has reviewed your response to the specific minor revisions requested of you by the HIC for the above mentioned initial protocol.

The HIC has determined that these revisions satisfy the request made by the Chair or designated reviewer and therefore approves this research protocol. This review meets approval criteria set forth in 45 CFR 46.111. The approval of this protocol is considered valid through the Expiration Date noted above.

Review Comments:

- The HIC found this study to meet the requirements of 45 CFR § 46.404 in that it presents no more than minimal risk to the minor subjects. Permission of one parent or guardian is sufficient to carry out the study.

- The Committee finds that written informed consent can be waived for this study for recruitment purposes per federal regulation 45 CFR 46.117 (c)(2). This part of the regulations states that the research presents no more than minimal risk of harm to subjects and involves no procedures for which written consent is normally required outside of the research context.

- The HIC acknowledges receipt of the MRRC approval letter dated October 9, 2012.

- Enclosed: Approved HIC protocol application, Adult Compound Authorization/Parental Permission Forms, Parental Permission forms, Adolescent Assents, Child Assents.

- The HIC acknowledges that this protocol is funded through an NIH/NICHD grant #HD001994 provided to Dr. Jay Rueckl at Yale.

- The HIC notes that submission to external IRBs for approval will occur after approval is obtained by the Yale University HIC. External IRB approval must be obtained using the final version approved by the Yale HIC. Any changes required by the external IRBs would have to be submitted as amendments to the HIC for HIC approval. The HIC must be notified of external IRB approvals before the study is started.
The HIC notes that the PI is sponsoring this multi-center trial and that Yale serves as coordinating center. The Committee reminds the Investigator of their obligations as a sponsor coordinating a multi-center trial. These responsibilities include, but are not limited to, ensuring ongoing IRB approval at other study sites, monitoring adverse events and reporting to the HIC, the FDA, Sponsor, and other bodies that monitor the conduct of the study and retaining copies of this documentation.

- The PI is reminded to submit subject recruitment materials to the HIC for review.
- The HIC has determined that this protocol presents minimal risk to subjects.

It is the investigator’s responsibility to obtain reapproval of ongoing research prior to the Expiration Date. Please submit the request for reapproval at least two months prior to the expiration date to allow for reapproval processing and review.

**Adverse Reactions:** Serious, unanticipated and related adverse events, and unanticipated problems involving risk to subjects or others must be reported within 48 hours to the HIC, using Form 6A.

**Amendments:** If you wish to change any aspect of this study, such as the study procedures or processes, the informed consent document(s), recruitment activities, or wish to add or remove investigators or key study personnel, you must communicate your requested changes to the HIC using the appropriate form located at http://www.yale.edu/hrpp. Any changes in the protocol must be approved by the HIC prior to implementation.

**Request to Close:** When the study procedures and the data analysis are fully complete, the Form #5C must be completed and sent to the HIC requesting that the study be closed. Investigators should attach a copy of the study findings. Abstracts or publications satisfy this findings requirement.

Please keep this memo with your copy of the approved protocol.
Letter of Exempt Study Approval

(Teachers College, Columbia University Institutional Review Board)

Thank you for submitting your study entitled, “Parental Reflective Functioning and Children’s Emergent Reading Skills: ERP and longitudinal behavioral measures;” the IRB has determined that your study is Exempt from committee review (Category 4) on 11/15/2018.

Please keep in mind that the IRB Committee must be contacted if there are any changes to your research protocol. The number assigned to your protocol is 18-494. Feel free to contact the IRB Office by using the “Messages” option in the electronic Mentor IRB system if you have any questions about this protocol.

You can retrieve a PDF copy of this approval letter from the Mentor site.

Best wishes for your research work.

Sincerely,
Dr. Myra Luna Lucero
Research Compliance Manager
irb@tc.edu
Appendix B

Parental Reflective Functioning Questionnaire (PRFQ)

PRFQ
Luyten, Mayes, Nijssens, & Fonagy, 2017

Listed below are a number of statements concerning you and your child. Read each item and decide whether you agree or disagree and to what extent. Use the following rating scale, with 7 if you strongly agree; and 1 if you strongly disagree. The midpoint, if you are neutral or undecided, is 4.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

1. __ The only time I’m certain my child loves me is when he or she is smiling at me.
2. __ I always know what my child wants.
3. __ I like to think about the reasons behind the way my child behaves and feels.
4. __ My child cries around strangers to embarrass me.
5. __ I can completely read my child’s mind.
6. __ I wonder a lot about what my child is thinking and feeling.
7. __ I find it hard to actively participate in make believe play with my child.
8. __ I can always predict what my child will do.
9. __ I am often curious to find out how my child feels.
10. __ My child sometimes gets sick to keep me from doing what I want to do.
11. __ I can sometimes misunderstand the reactions of my child.
12. __ I try to see situations through the eyes of my child.
13. __ When my child is fussy he or she does that just to annoy me.
14. __ I always know why I do what I do to my child.
15. __ I try to understand the reasons why my child misbehaves.
16. __ Often, my child’s behavior is too confusing to bother figuring out.
17. __ I always know why my child acts the way he or she does.
18. __ I believe there is no point in trying to guess what my child feels.
### Appendix C

**Adult Reading History Questionnaire (ARHQ)**

Lefly & Pennington, 2000

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**Adult Reading History Questionnaire**

*PLEASE NOTE: This reading history questionnaire applies to you, and not to your children.*

Please circle the number of the response that most nearly describes your attitude or experience for each of the following questions or statements. If you think your response would be between numbers, place an “X” where you think it should be.

1. Which of the following most nearly describes your attitude toward school when you were a child:

<table>
<thead>
<tr>
<th>Loved school; favorite activity</th>
<th>Hated school; tried to get out of going</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

2. How much difficulty did you have learning to read in elementary school?

<table>
<thead>
<tr>
<th>None</th>
<th>A great deal</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

3. How much extra help did you need when learning to read in elementary school?

<table>
<thead>
<tr>
<th>Help from:</th>
<th>No help</th>
<th>Friends</th>
<th>Teachers/parents</th>
<th>Tutors or special class 1 year</th>
<th>Tutors or special class 2 or more years</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

4. Did you ever reverse the order of letters or numbers when you were a child?

<table>
<thead>
<tr>
<th>No</th>
<th>A great deal</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
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</tbody>
</table>

5. Did you have difficulty learning letter and/or color names when you were a child?

<table>
<thead>
<tr>
<th>No</th>
<th>A great deal</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

6. How would you compare your reading skill to that of others in your elementary classes?

<table>
<thead>
<tr>
<th>Above average</th>
<th>Average</th>
<th>Below average</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

7. All students struggle from time to time in school. In comparison to others in your classes, how much did you struggle to complete your work?

<table>
<thead>
<tr>
<th>Not at all</th>
<th>Less than most</th>
<th>About the same</th>
<th>More than most</th>
<th>Much more than most</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

8. Did you experience difficulty in high school or college English classes?

<table>
<thead>
<tr>
<th>No; enjoyed and did well</th>
<th>Some</th>
<th>A great deal; did poorly</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

9. What is your current attitude toward reading?

<table>
<thead>
<tr>
<th>Very positive</th>
<th>Very negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

10. How much reading do you do for pleasure?

<table>
<thead>
<tr>
<th>A great deal</th>
<th>Some</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>
115

(appendix continued)

11. How would you compare your current reading speed to that of others of the same age and education?

<table>
<thead>
<tr>
<th>Above average</th>
<th>Average</th>
<th>Below average</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

12. How much reading do you do in conjunction with your work? (If retired or not working, how much did you read when you were working?)

<table>
<thead>
<tr>
<th>A great deal</th>
<th>Some</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

13. How much difficulty did you have learning to spell in elementary school?

<table>
<thead>
<tr>
<th>None</th>
<th>Some</th>
<th>A great deal</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

14. How would you compare your current spelling to that of others of the same age and education?

<table>
<thead>
<tr>
<th>Above average</th>
<th>Average</th>
<th>Below average</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

15. Did your parents ever consider having you repeat any grades in school due to academic failure (not illness)?

<table>
<thead>
<tr>
<th>No</th>
<th>Talked about it, but didn’t do it</th>
<th>Repeated 1 grade</th>
<th>Repeated 2 grades</th>
<th>Dropped out</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

16. Do you ever have difficulty remembering people’s names or names of places?

<table>
<thead>
<tr>
<th>No</th>
<th>A great deal</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

17. Do you have difficulty remembering addresses, phone numbers, or dates?

<table>
<thead>
<tr>
<th>No</th>
<th>A great deal</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

18. Do you have difficulty remembering complex verbal instructions?

<table>
<thead>
<tr>
<th>No</th>
<th>A great deal</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

19. Do you currently reverse the order of letters or numbers when you read or write?

<table>
<thead>
<tr>
<th>No</th>
<th>A great deal</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

20. How many books do you read for pleasure each year?

<table>
<thead>
<tr>
<th>More than 10</th>
<th>6–10</th>
<th>2–5</th>
<th>1–2</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

21. How many magazines do you read for pleasure each month?

<table>
<thead>
<tr>
<th>5 or more</th>
<th>3–4 regularly</th>
<th>1–2 regularly</th>
<th>1–2 Irregularly</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

22. Do you read daily (Monday–Friday) newspapers?

<table>
<thead>
<tr>
<th>Every day</th>
<th>Once a week</th>
<th>Once in a while</th>
<th>Rarely</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
(appendix continued)

23. Do you read a newspaper on Sunday?

<table>
<thead>
<tr>
<th>Completely every Sunday</th>
<th>Scan each week</th>
<th>Once in a while</th>
<th>Rarely</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

***Check the most appropriate answer for each of the following questions***

24. To the best of your knowledge, did your parents ever report that either one of them had a problem with reading or spelling?

   ___ Yes
   ___ No
   ___ Not sure

   If yes, please give details: ______________________________________________________

25. To the best of your knowledge, did your brothers and/or sisters ever have a problem with reading or spelling?

   ___ Yes
   ___ No
   ___ Not sure

26. What is the highest educational level that you have attained?

   ___ High school, did not graduate
   ___ High school graduate
   ___ Trade or business school
   ___ Some college, did not graduate
   ___ Junior college graduate, associate's degree (or equivalent)
   ___ College graduate, bachelor's degree (or equivalent)
   ___ Some postgraduate education, no advanced degrees
   ___ Attained 1 or more advanced degrees

**Scoring the RHQ:**

Scores on the RHQ are calculated by totaling the points an individual scores on the first 23 items (the other 3 questions are for informational purposes only) on the questionnaire, and dividing by 92. This should yield a percentage score for that person. Generally, scores greater than .30 are considered to be indicative of a positive history of RD.
Appendix D

Additional Demographic Questions

1. What is your child’s first language?
2. What is the parents’ first language(s)?
3. Are there other languages spoken fluently at home?
4. What is your child’s experience with books and reading?
5. To what extent has there been an emphasis on reading at home?
6. How many times a week do you read to your child?
7. Does your child receive speech-language therapy services? If yes, please specify reason.
8. Does your child have a clinical diagnosis or history of developmental or communication disorders?
9. Has your child experience any developmental delays? (e.g. speech delay, motor-sensory delay)
10. Is there a family history of dyslexia? If yes, please specify which family member (e.g. mother/father, sibling)
11. What is your family’s total annual income level? (<$20k, 20-50k, 50-100k, 100k+)
12. What are the parents educational background?
Appendix E

Results Matrices

Summary of Paired-Samples T-Tests between Conditions

<table>
<thead>
<tr>
<th>ERP</th>
<th>Adaptive Amplitude/Peak Latency</th>
<th>Region</th>
<th>t</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1/P2</td>
<td>Amplitude</td>
<td>mPC</td>
<td>0.378</td>
<td>26</td>
<td>0.709</td>
</tr>
<tr>
<td></td>
<td>Latency</td>
<td></td>
<td>-0.661</td>
<td>26</td>
<td>0.515</td>
</tr>
<tr>
<td>N2</td>
<td>Amplitude</td>
<td>LTC</td>
<td>0.238</td>
<td>26</td>
<td>0.814</td>
</tr>
<tr>
<td></td>
<td>RTC</td>
<td>1.770</td>
<td>26</td>
<td>0.089</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Latency</td>
<td>LTC</td>
<td>-1.498</td>
<td>26</td>
<td>0.146</td>
</tr>
<tr>
<td></td>
<td>RTC</td>
<td>-0.518</td>
<td>26</td>
<td>0.609</td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>Amplitude</td>
<td>LTC</td>
<td>0.437</td>
<td>26</td>
<td>0.666</td>
</tr>
<tr>
<td></td>
<td>RTC</td>
<td>2.028</td>
<td>26</td>
<td>0.053</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Latency</td>
<td>LTC</td>
<td>-0.979</td>
<td>26</td>
<td>0.336</td>
</tr>
<tr>
<td></td>
<td>RTC</td>
<td>0.664</td>
<td>26</td>
<td>0.513</td>
<td></td>
</tr>
</tbody>
</table>

Summary of Permutation Correlation Analysis (Adaptive Mean Amplitudes)

<table>
<thead>
<tr>
<th></th>
<th>N1/P2 Adaptive Mean Amplitude (mPC)</th>
<th>N2 Adaptive Mean Amplitude (LTC)</th>
<th>P2 Adaptive Mean Amplitude (LTC)</th>
<th>N1 Adaptive Mean Amplitude (RTC)</th>
<th>P2 Adaptive Mean Amplitude (RTC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parent Reading History</td>
<td>0.063</td>
<td>0.440</td>
<td>0.233</td>
<td>0.756</td>
<td>0.627</td>
</tr>
<tr>
<td>Parental Reflective Functioning (Pre-Mentalization)</td>
<td>0.858</td>
<td>0.883</td>
<td>0.750</td>
<td>0.096</td>
<td>0.403</td>
</tr>
<tr>
<td>Parental Reflective Functioning (Certainty of Mental States)</td>
<td>0.906</td>
<td>0.170</td>
<td>0.093</td>
<td>0.883</td>
<td>0.534</td>
</tr>
<tr>
<td>Parental Reflective Functioning (Interest &amp; Curiosity about Mental States)</td>
<td>0.606</td>
<td><strong>0.049</strong></td>
<td>0.076</td>
<td>0.348</td>
<td>0.985</td>
</tr>
<tr>
<td>Phonological Awareness (Time 1)</td>
<td>0.290</td>
<td>0.861</td>
<td>0.317</td>
<td>0.320</td>
<td>0.736</td>
</tr>
<tr>
<td>Phonological Awareness (Time 2)</td>
<td>0.931</td>
<td>0.159</td>
<td><strong>0.004</strong></td>
<td>0.355</td>
<td>0.544</td>
</tr>
<tr>
<td>Basic Reading (Time 2)</td>
<td>0.946</td>
<td>0.110</td>
<td><strong>0.002</strong></td>
<td>0.179</td>
<td>0.489</td>
</tr>
<tr>
<td>Number of Parent with Dyslexia</td>
<td>0.695</td>
<td>0.138</td>
<td>0.665</td>
<td>0.691</td>
<td>0.938</td>
</tr>
<tr>
<td>Number of Reading Sessions per Week</td>
<td>0.749</td>
<td>0.395</td>
<td>0.138</td>
<td>0.754</td>
<td>0.318</td>
</tr>
<tr>
<td>Family Income</td>
<td>0.295</td>
<td>0.604</td>
<td>0.927</td>
<td>0.578</td>
<td>0.292</td>
</tr>
</tbody>
</table>
Appendix E

Results Matrices

Summary of Permutation Correlation Analysis (Peak Latencies)

<table>
<thead>
<tr>
<th></th>
<th>NI2 Peak Latency in</th>
<th>NI Peak Latency in</th>
<th>PI Peak Latency in</th>
<th>NI Peak Latency in</th>
<th>PI Peak Latency in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parent Reading History</td>
<td>0.181</td>
<td>0.744</td>
<td>0.116</td>
<td>0.320</td>
<td>0.698</td>
</tr>
<tr>
<td>Parental Reflective Functioning (Pre-Mentalization)</td>
<td>0.696</td>
<td>0.272</td>
<td>0.354</td>
<td>0.918</td>
<td>0.541</td>
</tr>
<tr>
<td>Parental Reflective Functioning (Certainty of Mental States)</td>
<td>0.746</td>
<td>0.160</td>
<td>0.267</td>
<td>0.104</td>
<td>0.995</td>
</tr>
<tr>
<td>Parental Reflective Functioning (Interest &amp; Curiosity about Mental States)</td>
<td>0.471</td>
<td>0.465</td>
<td>0.408</td>
<td>0.392</td>
<td>0.941</td>
</tr>
<tr>
<td>Phonological Awareness (Time 1)</td>
<td>0.198</td>
<td>0.651</td>
<td>0.254</td>
<td>0.301</td>
<td>0.559</td>
</tr>
<tr>
<td>Phonological Awareness (Time 2)</td>
<td>0.168</td>
<td>0.175</td>
<td>0.220</td>
<td>0.241</td>
<td>0.960</td>
</tr>
<tr>
<td>Basic Reading (Time 2)</td>
<td>0.262</td>
<td>0.238</td>
<td>0.665</td>
<td>0.918</td>
<td>0.532</td>
</tr>
<tr>
<td>Number of Parent with Dyslexia</td>
<td>0.805</td>
<td>0.375</td>
<td>0.985</td>
<td>0.753</td>
<td>0.563</td>
</tr>
<tr>
<td>Number of Reading Sessions per Week</td>
<td>0.068</td>
<td>0.273</td>
<td>0.764</td>
<td>0.589</td>
<td>0.162</td>
</tr>
<tr>
<td>Family Income</td>
<td>0.312</td>
<td>0.354</td>
<td>0.196</td>
<td>0.892</td>
<td>0.595</td>
</tr>
</tbody>
</table>

Summary of Multiple Linear Regression (Phonological Awareness)

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>100.719</td>
<td>1.847</td>
<td>54.538</td>
<td>3.92e-08***</td>
</tr>
<tr>
<td>Number of Parent with Dyslexia</td>
<td>2.613</td>
<td>2.058</td>
<td>1.270</td>
<td>0.260</td>
</tr>
<tr>
<td>Reading Sessions per Week</td>
<td>3.146</td>
<td>2.138</td>
<td>1.472</td>
<td>0.201</td>
</tr>
<tr>
<td>Parent Reading History</td>
<td>-1.543</td>
<td>2.098</td>
<td>-0.735</td>
<td>0.495</td>
</tr>
<tr>
<td>PRF: Pre-Mentalization</td>
<td>0.479</td>
<td>2.095</td>
<td>0.228</td>
<td>0.828</td>
</tr>
<tr>
<td>PRF: Certainty of Mental States</td>
<td>-1.055</td>
<td>3.026</td>
<td>-0.348</td>
<td>0.742</td>
</tr>
<tr>
<td>PRF: Interest &amp; Curiosity in Mental States</td>
<td>10.441</td>
<td>2.799</td>
<td>3.731</td>
<td>0.014*</td>
</tr>
</tbody>
</table>
Appendix E

Results Matrices

Summary of Multiple Linear Regression (Basic Reading)

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>109.764</td>
<td>1.794</td>
<td>61.192</td>
<td>2.21e-08 ***</td>
</tr>
<tr>
<td>Number of Parent with Dyslexia</td>
<td>-0.846</td>
<td>1.999</td>
<td>-0.423</td>
<td>0.690</td>
</tr>
<tr>
<td>Reading Sessions per Week</td>
<td>5.056</td>
<td>2.076</td>
<td>2.435</td>
<td>0.060</td>
</tr>
<tr>
<td>Parent Reading History</td>
<td>-3.341</td>
<td>2.038</td>
<td>-1.639</td>
<td>0.162</td>
</tr>
<tr>
<td>PRF: Pre-Mentalization</td>
<td>1.023</td>
<td>2.035</td>
<td>0.503</td>
<td>0.637</td>
</tr>
<tr>
<td>PRF: Certainty of Mental States</td>
<td>-8.779</td>
<td>2.940</td>
<td>-2.987</td>
<td>0.031*</td>
</tr>
<tr>
<td>PRF: Interest &amp; Curiosity in Mental States</td>
<td>16.349</td>
<td>2.718</td>
<td>6.014</td>
<td>0.002**</td>
</tr>
</tbody>
</table>

Summary of Multiple Linear Regression (PRF: Interest & Curiosity in Mental States)

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>110.110</td>
<td>2.597</td>
<td>42.398</td>
<td>1.86e-09 ***</td>
</tr>
<tr>
<td>Number of Parent with Dyslexia</td>
<td>0.113</td>
<td>2.785</td>
<td>0.040</td>
<td>0.969</td>
</tr>
<tr>
<td>Reading Sessions per Week</td>
<td>3.322</td>
<td>2.750</td>
<td>1.208</td>
<td>0.266</td>
</tr>
<tr>
<td>Parent Reading History</td>
<td>-2.536</td>
<td>2.902</td>
<td>-0.874</td>
<td>0.411</td>
</tr>
<tr>
<td>PRF: Interest &amp; Curiosity in Mental States</td>
<td>10.771</td>
<td>2.886</td>
<td>3.732</td>
<td>0.007**</td>
</tr>
</tbody>
</table>

Summary of Multiple Linear Regression (PRF: Certainty of Mental States)

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>110.243</td>
<td>4.428</td>
<td>24.898</td>
<td>4.3e-08 ***</td>
</tr>
<tr>
<td>Number of Parent with Dyslexia</td>
<td>-2.781</td>
<td>4.693</td>
<td>-0.593</td>
<td>0.572</td>
</tr>
<tr>
<td>Reading Sessions per Week</td>
<td>5.625</td>
<td>4.796</td>
<td>1.173</td>
<td>0.279</td>
</tr>
<tr>
<td>Parent Reading History</td>
<td>-0.287</td>
<td>4.831</td>
<td>-0.059</td>
<td>0.954</td>
</tr>
<tr>
<td>PRF: Certainty of Mental States</td>
<td>2.314</td>
<td>4.975</td>
<td>0.465</td>
<td>0.656</td>
</tr>
</tbody>
</table>