ABSTRACT

Title of Document: INFANT SPEECH PERCEPTION IN NOISE AND EARLY CHILDHOOD MEASURES OF SYNTAX AND ATTENTION ABILITIES

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Childhood outcomes in syntactic and attention abilities were measured for 23 children (mean age = 5:3) who, as infants, had either succeeded or failed at identifying their name in the presence of multitalker background noise. Children from the unsuccessful infant group were rated by parents as having significantly more difficulty with attention-related behaviors than children from the successful infant group. The two groups did not perform significantly differently on standardized measures of morphosyntactic ability, but the unsuccessful group was found to have significantly lower MLUs on narrative language samples than the successful group.

INFANT SPEECH PERCEPTION IN NOISE AND EARLY CHILDHOOD MEASURES OF SYNTAX AND ATTENTION ABILITIES

By

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Dedication

To Brad, for supporting, believing, and encouraging. I couldn't have done it without you.

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Chapter 1: Introduction and Literature Review

Introduction

Anyone reading this paper has mastered the fundamentals of a language; yet not one of us can remember exactly how we did so. Despite the fact that the vast majority of humans acquire competency in some form of linguistic communication, our lack of memory of our own early linguistic experiences means that much remains to be known about the acquisition process itself. This much is clear: infants do not enter the world communicating linguistically, but within a few years they are able to understand and produce complex sentences. However, normal language acquisition in childhood appears to be contingent upon exposure to language in infancy and early childhood; although the documented cases are thankfully few in number, infants and young children who are deprived of linguistic input for prolonged periods may never develop language normally (e.g., Curtiss, 1977). Research on deaf infants who receive cochlear implants also suggests that the earlier infants are able to listen to language, the more normal their subsequent oral language development will be (Tomblin, Barker, Spencer, Zhang, & Gantz, 2005). Yet, in a normal infant, this progression from listening to producing occurs very quickly; as such, it is no surprise to find that even very young infants possess highly specialized perceptual skills that assist them in learning about their native language (see Eimas, 1985, for an overview; specific highlights will be discussed later in this introduction). Although there has been a great deal of research on infant perception of language, much remains to be known about exactly how this perception aids later language development.

Identifying infant perceptual abilities that are particularly helpful in acquiring language could be important not only for better understanding the process of language acquisition, but also for earlier identification of language delays or disorders.

Several researchers have commented on the individual differences in abilities among infant participants during perceptual tasks, and have speculated that these differences may be related to later language development (Newman, 2005; Newman & Jusczyk, 1996; Trehub & Henderson, 1996; Tsao, Liu, & Kuhl, 2004). This speculation has sparked a growing number of longitudinal studies linking infant perception and language development by examining how individual differences in specific infant perceptual abilities relate to childhood language outcomes. Infant abilities that have been linked to childhood language abilities in the current research literature include temporal resolution, or the ability to detect brief pauses between sound stimuli (Trehub & Henderson, 1996), speech-sound discrimination (Molfese, Molfese, & colleagues; Tsao, Liu, & Kuhl, 2004), and speech segmentation, or the ability to extract whole words from the fluent speech stream (Newman, Bernstein Ratner, Jusczyk, Jusczyk, & Dow, 2006); these studies will be discussed in more detail in the literature review.

Although the body of literature linking infant perception with later language ability is growing, there are many infant abilities that have not been longitudinally investigated, indicating a need for further exploration in this area. One perceptual ability that may be of particular importance to learning language is the perception of speech in the presence of background noise, since infants frequently hear language in less than ideal listening conditions (Barker & Newman, 2004). To that end, this research was conducted as part of a broad longitudinal study exploring the potential link between individual differences in infant performance on laboratory tests of speech perception in noise performed by Newman (2005), and linguistic and cognitive outcomes in early childhood. The focus of this paper is the relationship between infants' ability to perceive speech in noise and their performance on measures of syntax and attention abilities in early childhood.

The following literature review will begin with a brief discussion of findings in the study of infant perception, followed by a summary of the current literature linking infant perception and language development. The current research on the perception of speech in noise will then be reviewed. Finally, the present study/research questions will be described, with a focus on the potential impact of infant speech perception in noise on childhood syntactic abilities and attention skills.

Infant Perceptual Abilities

Before discussing the present literature on the longitudinal link between infant perception and language development in childhood, it is worth briefly highlighting some of the specialized abilities in language perception that have been identified in infants. From early infancy, babies show a preference for listening to speech sounds over non-speech sounds (Colombo & Bundy, 1981; Vouloumanos, 2004; Vouloumanos & Werker, 2007), and are able to discriminate between their native language and a foreign language (Mehler et al., 1988; Moon, Cooper, & Fifer, 1993). During the first few months of life, they demonstrate the ability to discriminate subtle, non-native phonetic contrasts that many adults cannot perceive, such as voice-onset time contrasts that adults perceive categorically (Aslin, Pisoni, Hennessy, &

Perey, 1981; Eimas, Siqueland, Jusczyk, & Vigorito, 1971; Lasky, Syrdal-Lasky, & Klein, 1975). However, this sensitivity is gradually lost as native phonemic categories become more salient, and by approximately 1 year of age, infants perceive only the speech sound contrasts that are relevant to their native language (Werker & Tees, 1984).

Infants also become increasingly more responsive to their own native language's prosodic structure and patterns of speech-sound combinations within the first year of life. Sensitivity to prosodic characteristics of the native language appears to develop very early, as documented by data on orientation latencies for different language stimuli in 2-month old infants (Lambertz & Houston, 1997) and ERP data from 3-month-old infants (Shafer, Shucard, & Jaeger, 1999). Preference for native-language phonotactic patterns seems to develop slightly later; Jusczyk, Friederici, Wessels, Svenkerud, and Jusczyk, (1993) found that English-speaking 6-month-olds listened longer to English words than to Norwegian words, which have similar speech sound combinations despite differences in prosodic structure, but did not show a preference for English words over Dutch words, which have similar prosody but different phonotactic structure. By 9 months of age, however, infants demonstrated a preference for the English words over the Dutch words. The sensitivity to native-language phonotactic patterns in 9-month old infants has also been documented in a study of infant listening preferences for monosyllabic stimuli (Jusczyk, Luce, & Charles-Luce, 1994) and in a study of infant detection of word boundaries (Friederici & Wessels, 1993).

Another infant perceptual ability that has been studied extensively is segmentation, or the ability to break the speech stream into smaller units. Since infants generally do not hear isolated words, but a fluent stream of speech (see Aslin, Woodward, LaMendola, & Bever, 1996, for a discussion of this point), the ability to break down the speech stream could be very important for subsequent language development. Early segmentation abilities have been investigated in several studies by Jusczyk and colleagues, and have been found to emerge relatively late in infancy. Jusczyk and Aslin (1995) did a series of experiments where they familiarized infants with monosyllabic target words (e.g., "cup", "dog"); results showed that immediately after familiarization, 7.5-month-old infants, but not 6-month-olds, listened longer to passages containing the target words than to passages that did not contain the target words. In a further investigation of how these abilities continue to develop, Jusczyk, Houston, and Newsome (1999) found that 7.5-month-old infants demonstrate the ability to segment multisyllabic words provided the words had a strong-weak stress pattern (e.g., "doctor", "candle"), but were unable to segment words with a less salient weak-strong stress pattern (e.g., "guitar", "surprise"). By 10.5 months, however, infants were able to segment the weak-strong stimuli. These studies suggest that segmentation abilities continue to develop throughout late infancy, and are dependent on infants' growing sensitivity to the information in the speech signal.

The longitudinal connection

Since infants appear to rely heavily on auditory perceptual abilities to learn about the language they hear, it is possible that individual differences in these abilities might affect how well infants are able to acquire linguistic skills. Indeed, a growing body of research appears to confirm that this is the case. Several studies have linked infants' visual processing abilities with cognitive and linguistic outcomes in early and middle childhood. For example, researchers have found that measures of visual recognition memory at 7 months and measures of tactile-visual cross-modal transfer (recognizing an object visually after manipulating it tactually) at 1 year were related to outcomes in IQ and verbal ability at 6 years (Rose, Feldman, & Wallace, 1992) and IQ at 11 years (Rose & Feldman, 1995). McCall and Carriger (1993), in a meta-analysis of literature on infant visual recognition memory and speed of visual habituation, found that both predicted IQ outcomes between 1 and 8 years of age with a median correlation of 0.45.

Studies on the link between infant auditory perceptual abilities and later linguistic outcomes have been fewer in number, but the existing research is promising and warrants further investigation. Trehub and Henderson (1996) found that infants who performed above the median at detecting brief pauses in pure-tone stimuli were reported by parents as having more mature semantic and syntactic skills as preschoolers than those infants who had performed below the median at the task, suggesting a potential relationship between temporal resolution skills in infancy and language development in childhood. In a number of studies, Molfese and colleagues used event-related potentials (ERPs) with neonates to record physiological reactions to contrasting sounds, in an effort to link infant sound discrimination ability with performance on language measures in early childhood (for a useful review of the methodology and early research findings, see Molfese, Molfese, & Espy, 1999). By obtaining ERP data from newborn infants in response to both speech and nonspeech stimuli, these researchers showed links between infant sound discrimination ability and expressive language outcomes at age 3 (Molfese & Molfese, 1985), verbal intelligence at age 5 (Molfese & Molfese, 1997), and reading abilities at age 8 (Molfese, 2000; Molfese, Molfese, & Modgline, 2001).

In another longitudinal investigation of speech-sound discrimination abilities, Tsao, Liu and Kuhl (2004) tested 2-year-old children who had participated in a speech sound discrimination study using a conditioned head-turn paradigm at 6 months, and found a link between infant performance and later semantic comprehension and production. Specifically, those infants who had required fewer trials to reach criterion during the conditioning phase of the task were reported by parents on the *Macarthur Communicative Development Inventory* (*MCDI*; Fenson et al., 2000) as producing and understanding more words and phrases at 13, 16, and 24 months of age.

Infant speech segmentation ability is another area that has recently been linked to linguistic outcomes in childhood. Newman et al. (2006) found that performance on speech segmentation tasks as infants accurately discriminated between groups of high-scoring and low-scoring children on measures of expressive vocabulary at 24 months. They also found that children 4 to 6 years of age who had failed at segmentation tasks as infants scored significantly lower on standardized tests of semantic and syntactic ability than children who had succeeded. Furthermore, they found that nonverbal intelligence was not predicted by infant performance, suggesting that the outcomes were independent of general cognitive ability.

In all the previously discussed studies, the researchers identified the need for more longitudinal research to identify other perceptual skills that may be prerequisite to language acquisition, as well as highlighting the clinical relevance of such research in terms of early identification and intervention for possible language delay.

Speech in Noise

Another perceptual ability that could be related to childhood language outcomes is the perception of speech in the presence of background noise. Given that infants appear to rely heavily on subtle patterns in the acoustic signal to learn about their language, what happens when that signal is degraded? The answer to this question is very relevant to real-world language learning, since not only do many infants spend large amounts of time in noisy environments (Barker & Newman, 2004), but their hearing ability in noise has been found to be less sensitive than that of most adults. For example, Trehub, Bull, and Schneider (1981) found that infant thresholds for responding to a speech phrase masked in white noise were 10-12 dB higher than those of adult listeners. Similarly, Nozza, Rossman, Bond, and Miller (1990) found that infants required a greater signal-to-noise ratio than adults to discriminate between synthesized speech sounds in noise; further investigation found that infants have a 6-7 dB greater threshold for discriminating sounds in noise than do adults (Nozza, Miller, Rossman, & Bond, 1991). Although this difference seems small, the researchers acknowledged that their findings were limited to “only a single pair of speech sounds in a single noise environment" and that "infant-adult differences may vary as a function of the acoustic-phonetic composition of the speech stimuli as well as the intensity level and spectrum of the masking noise" (p. 349). It is possible that these threshold differences would have been even greater if infants were attempting to perceive differences in fluent speech. Nonetheless, the results do show that perception of speech in noise creates an added challenge to infants who are trying to analyze the speech signal to obtain important linguistic information.

Before discussing further what is known about infant speech perception in noise, it is important to review some basic definitions and findings in this field. At the basis of speech in noise perception in humans is a phenomenon called *streaming*, which has been studied quite extensively in adults. The most basic definition of streaming is as follows: when the human ear hears a single, rapidly presented sequence containing two types of sounds, if the sounds are perceptually dissimilar enough, the brain will perceive them as two separate sources of sound (see Bregman, 1990; for a review of this specific phenomenon, see Carlyon, 2004). Streaming seems to be a process by which the human ear organizes auditory stimuli, and can separate two sound sources, such as a vocal soloist from accompanying piano music.

Streaming appears to be another perceptual ability with its roots in early infancy, and may help infants come to the language learning task somewhat prepared for the challenge of imperfect listening conditions. Using a non-nutritive sucking paradigm, McAdams and Bertoncini (1997) demonstrated that at 3-4 days, infants showed some signs of stream segregation when presented with melodic sequences of tones consisting of two contrasting timbres (trumpet and vibraphone); however, the results of this task were inconclusive since the findings did not reach statistical significance. More recently, Winkler et al. (2003) used event-related potentials to demonstrate that infants as young as 2-5 days old are able to stream tone sequences if the tones represent two contrasting frequency ranges. They did so by combining a repeating tone sequence containing occasional deviant, or “oddball” tones, with an intervening tone sequence. In the “single-stream” condition, both tone sequences came from the same frequency range, so that the intervening tones masked the oddball tones. In the “two-stream” condition, the frequency range of the oddball sequence was lower than that of the intervening sequence, meaning that the oddball sequence should have been perceived as a separate sound source. The infants in the study demonstrated mismatch negativity (MMN) responses to the oddball sequences in the two-stream condition only, indicating that they had indeed perceived two separate sequences of tones. These findings suggest that infants use multiple sources of information, including pitch and sound quality, to organize the auditory information they perceive.

The type of streaming discussed so far is the most basic type because it creates the illusion of two concurrent streams of sound even though the sounds all derive sequentially from one source. However, the experience of hearing speech in background noise is quite different, since not only are speech sounds more complex than simple tones, but at least two concurrent sound sources are involved, rather than one sequential source. This more complex phenomenon, nicknamed the “cocktail party effect”, will hereafter be referred to as speech stream segregation, rather than simple streaming. Speech stream segregation abilities in newborn infants have not been investigated to date; however, several studies by Newman and colleagues have investigated speech stream segregation skills in older infants. Newman and Jusczyk (1996) conducted a series of four experiments with 7.5-month-old infants to determine the conditions under which they were able to segregate speech stimuli from noise. The first three experiments exposed infants to a series of isolated target words read by a female while a male distractor voice spoke fluently in the background. Immediately afterwards, the infants listened to passages containing the target words and passages containing novel words. The three experiments were identical except for the signal-to-noise ratio (i.e., the ratio of intensity of the target voice to the distractor voice), which was set at 10 dB, 5 dB, and 0 dB, respectively. With a 10 dB signal-to-noise ratio, 21 of 24 infants listened longer to the passages containing the target words than to the passages containing the novel words, suggesting that they had successfully segregated the target words from the distractor noise. The same was true for 18 of 24 of the infants when the signal-to-noise ratio was lowered to 5 dB. However, only 10 of 24 infants were successful at the task when the two voices were equally intense. A fourth group of infants was exposed to the target and distractor passages simultaneously with a 10 dB signal-to-noise ratio, and were then tested on the isolated words; 13 of 24 of the infants were successful at this task as well. In addition to the signal-to-noise ratio, the difference in timbre between the male and female voices also may have facilitated their success at this task. However, in a similar study, Barker and Newman (2004) found that 18 of 28 7.5-month-old infants were able to perform the same task (familiarization with target words with a distractor voice, followed by listening to passages with either target or novel words) with a 10 dB signal-to-noise ratio with two female voices provided that the target voice was familiar to the infant.

To further investigate the capacities of infant speech stream segregation and to investigate how this ability develops over the first year of life, Newman (2005) performed a series of experiments on infants of varying ages. The methodology for these studies was slightly different than those previously mentioned; rather than familiarizing infants with target words in the laboratory setting, the targets were the participants' names, with which they presumably were already familiar (see Newman, 2005, p. 354 for a discussion of this point). Also, rather than a single distractor voice, the distractor noise was composed of multiple voices talking in the background, which one could argue would be more representative of the auditory environments in which infants or young children might find themselves (e.g., a noisy restaurant, a daycare setting, at home with the TV on in the background). Infants were presented with trials of their own names, a stress-matched foil name, and two non-stress-matched foils with multitalker babble in the background. The results revealed that with a 10 dB signal-to-noise ratio, 18 of 25 5-month-old infants listened longer to their own names than to the stress-matched foil names. When the experiment was replicated with a 5 dB signal-to-noise ratio, only 10 of 25 5-month-old infants and 14 of 25 9-month-old infants were successful at the task. However, 17 of 25 13-month-olds listened longer to their names than to stress-matched foils with the lower signal-to-noise ratio. Newman concluded that speech stream segregation abilities are present in a limited capacity as early as 5 months of age, but that they continue to improve over the first year of life.

As is evident from the success rates described in the above studies of infant speech stream segregation, even in the experiments in which most of the infants were successful at the task, there were many infants who were not. In both the Newman (2005) and Newman and Jusczyk (1996) studies, the variable success rate of the participants was noted and discussed as worthy of further investigation, since it is similar to the variability found in laboratory tasks that have been longitudinally linked to later linguistic and cognitive outcomes in childhood (see the previous discussion on longitudinal research). Newman (2005) suggested that if some of her infant participants were less skilled than others at extracting speech information from a noisy background, these infants may be at a disadvantage for learning language. Specifically, she states that "poorer ability to segregate streams of speech could potentially lead to slowed language acquisition" (p. 361); presumably because an infant with more impoverished skills in this area would be less able to extract the information from the signal that facilitates the development of linguistic skills. To date, there have been no longitudinal investigations of infant speech stream segregation ability and its connection to later language or cognitive outcomes.

Current Study

As a longitudinal follow-up to Newman 2005's "cocktail party effect revisited", the present study is designed to investigate whether children who were unsuccessful at attending to their name in noise have different linguistic and cognitive outcomes in early childhood. The participants of interest to the study were those who had failed at the task at 5 months of age with a 10 dB signal-to-noise ratio or at 13 months with a 5 dB signal-to-noise ratio; since these were the conditions in which most infants succeeded, the infants who failed should represent the most atypical exemplars of speech stream segregation ability. Multiple linguistic and cognitive domains were investigated; however, this paper focuses on the domains of syntax and attention. Childhood semantic abilities, phonological awareness skills, and nonverbal intelligence were also explored, but these domains will be described and discussed in two separate papers. The following sections will explore the potential relevance of infant speech stream segregation abilities to childhood outcomes in syntax and attention, in order to introduce the research questions of this portion of the longitudinal study.

Syntax

The emergence of English syntactic production typically occurs between 2 and 3 years of age, and is characterized by two-word combinations with fixed word order (Brown, 1973). These early 'sentences', described as "telegraphic speech" by Brown and Fraser (1963), consist primarily of open-class words (nouns, verbs, and modifiers), with a notable lack of functors, or closed-class words (e.g., inflections, prepositions, articles, conjunctions, pronouns, and auxiliary verbs) (Tager-Flusberg & Zukowski, 2008). As the child's age and linguistic abilities increase, more complex syntactic structures begin to appear in the child's productions; Brown and Fraser's (1963) pioneering case studies on child language acquisition demonstrate that these syntactic structures, or grammatical morphemes, typically appear in a predictable order as the child develops. By the age of 3 or 4 years, the child has usually mastered the essential morphological and syntactic elements of the language, although refinement of these skills continues into the school-age years.

It is possible that the progression from production of open-class words to closed-class words and morphemes is related to the perceptual salience of what infants are hearing from birth (Wanner & Gleitman, 1982). Obviously, telegraphic speech is not representative of the way that caregivers and other adults speak to infants or young children. Instead, infants hear a fluent speech stream which they must segment, or break down, into smaller units. Research on early segmentation abilities shows that infants begin segmenting the speech stream by extracting items with high semantic content, such as nouns, verbs, and adjectives; these items are much more likely to be stressed in fluent speech, making them easier for infants to extract from the speech stream (Jusczyk & Aslin, 1995). This perceptual salience may be why open-class words are typically the first items to appear when a child begins to talk (see Barrett, 1995, for a discussion of lexical development).

In English, many closed-class items such as prepositions, conjunctions, articles and pronouns, are unstressed and are frequently reduced or even omitted in fluent speech (Wanner & Gleitman, 1982). The fact that these closed-class items are harder to hear makes them harder for the infant to segment, and may account for the fact that closed-class items appear later in typical language development than content, or open-class, words. Peters (1995), in her discussion of how children acquire syntax, supports this idea by noting that the earliest appearing grammatical morphemes in English as well as other languages tend to be those that can carry stress or that are located in prominent places in the fluent speech stream, such as at the end of a word (p. 464).

Peters (1995) also used perceptual salience to account for the fact that in English, children acquire inflectional morphemes before derivational morphemes. Cross-linguistic evidence from studies of the acquisition of Mohawk (Mithun, 1989) and Eskimo languages (Fortescue & Lennert Olsen, 1992) supports this idea by showing that grammatical morphemes and inflections which are stressed, and thus more perceptually salient, are learned earlier than those that are not.

It appears that infants do not demonstrate sensitivity to closed function morphemes when listening to speech stimuli until late in their first year of life. Using ERP data with infants, Shafer, Shucard, Shucard, and Gerken (1998) found that 11-month-old infants, but not 10-month olds, successfully distinguished between passages that contained normal function morphemes and passages that had the function morphemes "is, the, a, of, with, and that" replaced with nonsense syllables. However, they acknowledged that these findings may not have reflected the true emergence of sensitivity to functors, because the substituted nonsense syllables they used (which were composed of a stop consonant and a vowel) were dissimilar in phonological composition and duration to the English function words they replaced. Nonetheless, behavioral data from a head-turn preference paradigm found that 10.5-month-olds preferred listening to passages containing unmodified function morphemes than passages with "nonsense morphemes" even when the nonsense syllables were phonologically similar to the morphemes they replaced (Shady, 1996). The above research does indeed suggest that initial sensitivity to the phonological characteristics of function morphemes emerges between 10 and 11 months of age. However, further data from the Shady (1996) studies suggest that infants are not sensitive to the specific roles that function morphemes play within sentences (i.e., recognizing that certain function morphemes begin verb phrases while others begin noun phrases) until later in infancy. Infants 10.5 months and 13.5 months of age did not demonstrate a preference between passages containing grammatical functors and those that had the function morphemes associated with verbs (e.g., “was”, “is”, “have”, and “had”) replaced with those that usually accompany nouns (e.g., “the”, “of”, “a”, “with”, and “that”). It was not until 16 months of age that the majority of infants showed a preference for the grammatically correct passages. These data suggest that infants acquire phonological information about function words before they learn about their grammatical relations within sentences.

The relevance of the previous discussion to the present study of speech stream segregation in noise becomes obvious when one considers that background noise affects the speech stream by making information even less perceptually salient and thus more difficult to segment. This decreased perceptual salience would suggest that an infant with relatively poor speech stream segregation abilities may have particular difficulty extracting morphosyntactic information from the signal when listening to speech in the presence of background noise. As such, it would not be surprising to find that these infants exhibit less sophisticated morphosyntactic production in early childhood than those infants who were more skilled at listening to speech in imperfect conditions.

Attention

When considering the possibility that individual differences in infants’ speech stream segregation abilities could affect their later language development, it is also important to consider why those differences might occur. Perceptual development is inextricably linked to cognitive development, so perceptual skill level is likely linked to related cognitive abilities. One such ability that seems particularly relevant to speech stream segregation is attention; for an infant to learn from speech heard in noisy conditions, they not only have to separate two concurrent streams of sound, but must also attend to the speech signal rather than the background noise (Newman, 2005). The following discussion will begin with some general background on attention, and will then define the specific areas of interest to this study.

Attention is a term for which there is no single definition: it is a construct which pervades multiple realms of perception and cognition and has been defined in myriad ways. A very basic definition of attention is that it is a concentration of mental activity (Matlin, 1998). At any given time we are presented with multiple stimuli in different sensory modalities (e.g., visual, auditory, tactile), and attention refers to the process of concentrating our awareness on particular stimuli. Matlin discusses two types of attention that can be used when confronted with multiple stimuli or tasks: divided attention and selective attention. Divided attention refers to the ability to equally allocate attention to multiple tasks, whereas selective attention refers to the ability to focus attention on one stimulus or task while disregarding the others. Many laboratory tasks have focused on using selective attention to filter competing auditory and visual stimuli; speech stream segregation tasks are one such example.

Just as there are many different types of attention, there are also many theories of attention. While a comprehensive review of all of them is beyond the scope of this paper, a common feature among many is that they define attention tasks as falling on a continuum of consciousness, ranging from tasks which can be done virtually automatically to tasks which require more conscious awareness (Ashcraft, 1998). There is some debate about where on this continuum auditory speech stream segregation tasks fall. The fact that newborn infants show evidence of stream segregation (e.g., Winkler et al., 2003) suggests that the task may involve attention at a very basic, automatic level; it could simply be involved in the perception of two sound sources as different units or "objects" (see Alain & Arnott, 2000, for a discussion of this point). Bregman's (1990) theory of auditory scene analysis, however, suggests that rather than being necessary to perceive two distinct sound sources, attention may be necessary at a more conscious level to select which source is relevant and needs to be analyzed further. Regardless of the level of conscious awareness involved, attention seems to play an important role in streaming tasks; for example, Carlyon, Cusack, Foxton, and Robertson (2001) found that streaming of tone sequences containing tones from two differing frequency ranges was less likely to occur in adult participants when their attention was distracted by a competing task.

Unfortunately, it is not possible to retroactively test the participants from the 2005 Newman experiments to directly examine their selective attention abilities as infants; however, it seems likely from the above discussion that individual differences in these abilities may have determined whether infants succeeded or failed at identifying their names in background noise. Could these differences in attention ability still be present in childhood? Some studies have indeed found evidence of long-term stability in individual differences in attention abilities beginning in infancy.

For example, Ruff, Lawson, Parrinello, and Weissberg (1990) found evidence that qualitative ratings of attentiveness during free play at 1 year of age predicted quantitative measures of attentiveness during an auditory reaction time task at 3 1/2 years. Kannass, Oakes, and Shaddy (2006) measured distraction latencies in infants by calculating how quickly an infant looked at distracting visual stimuli while playing with a toy; infants with shorter latencies were considered to be more distractible (i.e., less attentive) than those with longer latencies. Longitudinal follow-up of the participants revealed a significant correlation between the infants' distraction latencies at 9 months of age and those at 31 months of age ($r = 0.4$). It is therefore possible that individual differences on the infant speech stream segregation task could result in differences in childhood attention abilities.

How might individual differences in selective attention abilities manifest themselves later in childhood? When contemplating this question, it is important to consider how attention relates to other types of behaviors. The basic definition of attention as a filter for competing stimuli is usually defined in response to external factors, such as novel sounds or objects. However, attention can also be defined in terms of its role in internally driven, higher-order thinking processes. Just as people use selective attention every day to filter multiple sources of sight and sound, they must also filter competing internally-driven cognitive and emotional demands (Berger, Kofman, Livneh, & Henik, 2007). This skill requires more conscious planning and metacognitive awareness. It is therefore possible that an infant who has difficulty with selective attention to external stimuli could demonstrate difficulty with higher-order selective attention tasks in childhood.

Although most researchers do acknowledge that attention has an important role in higher-order thinking processes (Matlin, 1998), there has not been much literature on the theories of higher-order organization of attention in typical individuals, and much of the discussion of these processes comes from models of attention impairments in clinically disordered populations, (Mateer, Kerns, & Eso, 1996). One such model of attention was developed by Sohlberg and Mateer (1989) by combining their clinical observations of patients who had suffered traumatic brain injuries with their knowledge of cognitive theories of attention. By examining the behaviors which were most impaired in their patients, they hierarchically defined five different types of attention: focused, sustained, selective, alternating, and divided. Focused attention, the simplest type defined on the hierarchy, refers to the basic ability to respond to external sensory stimuli. Sustained attention refers to persistence at a continuous activity over time. Selective attention is described as the ability to maintain attention to an activity in the presence of competing stimuli. Alternating attention is the ability to switch focus between multiple activities. The most complex type of attention according to this model is divided attention, which refers to the ability to respond to or perform multiple tasks simultaneously. Each domain of attention defined by this model incorporates the domains below it on the hierarchy. Selective attention, for example, would require the ability to respond to a sensory stimulus (focused attention) and to maintain attention to that stimulus (sustained attention), even in the presence of competing information.

Based on the above definitions, selective attention seems to be the type most closely related to the infant speech stream segregation task. Mateer, Kerns, & Eso (1996), in a further discussion of Sohlberg and Mateer's model, describe selective attention as "the ability to maintain a cognitive or behavioral set" in the presence of distracting stimuli (p. 622). These distracting stimuli include both external factors (e.g., visual and auditory information) and internal distractions (e.g., worries, irrelevant thoughts). Selective attention of internal thought processes is important for cognitive tasks such as problem solving and decision-making, since they both require a person to disregard irrelevant information and focus on the important details (Matlin, 1998). This type of selective attention falls under the umbrella of executive functions, or the central decision-making and planning processes that organize and direct thinking (Singer & Bashir, 1999).

In exploring the link between infant speech stream segregation ability and later development, it would be interesting to see if children who differed as infants in this ability also performed differently on measures of attention in early childhood, particularly those involving selective attention. Establishing a link between stream segregation ability and later attention ability could provide insight into an aspect of the cognitive abilities related to perceptual development.

Summary and Research Questions

To reiterate, this study was designed as a longitudinal follow-up to Newman 2005's "cocktail party effect revisited", to investigate whether children who were unsuccessful as infants at identifying their name in noise have different outcomes in syntactic abilities and attention skills than children who were successful at the task as infants. The present study will be a useful addition to the growing literature on the link between infant perceptual abilities and later language outcomes. The link between speech perception in noise and later syntactic and attention abilities could provide insight into the way that infants may use the speech signal as a starting point in their acquisition of language, and the way that attention may affect their ability to do so. The specific research questions to be answered are as follows:

1) *In early childhood, are the syntactic abilities of the participants who failed at the infant speech perception task worse than those of the participants who were successful?* When given standardized measures of syntactic ability, the predicted outcome is that although most of the scores will fall within the normal range of syntactic abilities, the children who failed at the infant speech stream segregation task will perform significantly more poorly than those who succeeded.

2) *Are the attention abilities of child participants who failed at the infant speech stream segregation task worse than those of the participants who succeeded?* When the children's attention abilities are evaluated using a standardized measure, the predicted outcome, like that of the first research question, is that the scores of the children who failed at the speech stream segregation task will be significantly lower than those who succeeded. This is particularly likely to be the case on measures of abilities and behaviors related to selective attention.

Chapter 2: Methods

Participants

The participants were 9 male and 14 female children (mean age = 5:3, range = 4:6 to 6:1) from the Newman (2005) studies of infant speech stream segregation. The participants had either performed the infant task at 5 months of age with a 10 dB signal-to-noise ratio, or at 13 months with a 5 dB signal-to-noise ratio. The specific distributions and age ranges for the participants from each study are summarized below.

Table 1. Participant Information

Original Study	N	Mean Age	Age Range
5 month 10 dB	14	5:4	4:6 - 6:1
13 month 5 dB	9	5:0	4:10 – 5:3

Contact information for the infants' families was obtained from the database of participants in the Language Development Laboratory at the University of Maryland. Letters and/or emails were sent to 64 families who were still active in the database, and follow-up phone calls and/or emails were attempted to all families to whom letters were sent out (unless the letter was returned with no forwarding information). Phone and/or email contact was established with 46 families, and those who were interested in participating were administered screening questions to rule out hearing loss, developmental delay, or a primary language other than English. Of the

46 families contacted, 28 families (61%) participated in the study; two of the families had twins, so a total of 30 children were tested.

The parents of nine of the participants reported that their children had a history of otitis media; two children were reported to have had more than three significant ear infections. Tympanometry was performed on all participants on the day of the evaluation to rule out the presence of otitis media. The criteria for passing were adapted from the 1996 guidelines of the American Speech-Language Hearing Association for audiologic screening in children 6 years of age and over (ASHA Audiological Assessment Panel, 1997), and included an ear canal volume of no more than 1.0 cm^3, a tympanometric width of no more than +/- 400 daPa, and a peak admittance of no less than 0.4 mmhos. Although ASHA recommends that these conditions be met in both ears, for the purposes of this study it was decided that meeting all three criteria in at least one ear was sufficient for the participant's data to be included in the analysis. Since testing occurred in a quiet setting with one-on-one instruction, and since none of the language assessment measures were auditory tasks, it was felt that these criteria adequately ruled out any children whose middle ear status could have affected their assessment results. Four children's data were excluded from the analysis for failing the tympanometric screening.

The data for three additional children were discarded because of previously undisclosed conditions (two children had developmental delays, and one child had been diagnosed with epilepsy shortly after his initial participation in the infant study, raising the possibility that his performance on the infant task had been affected). Of the 23 remaining children, 18 were Caucasian, three were African American, and two were of mixed ethnicity. All were native English speakers, and English was the primary language spoken in the home. Of the participants' mothers or primary caregivers, eight had a doctoral degree or equivalent, 12 had a master's degree or equivalent, one had a bachelor's degree or equivalent, one had a professional degree, and one had a high school diploma.

As compensation for participation, each family received a brief written summary of the results of their child's assessment. Each child was also given a small gift (a toy from a prize box) at the end of the testing session.

Materials

The assessment procedure consisted of both standardized and non-standardized tests of multiple linguistic and cognitive domains. The measures of particular interest to this study are discussed in detail below, and a brief summary of the other tests is provided in Table 2.

Syntax

Childhood syntactic and morphological abilities were assessed using the Syntax Composite portion of the *Test of Language Development- Primary, 3rd Edition* (*TOLD-P:3*; Newcomer & Hammill, 1997). The *TOLD-P:3* is a test battery used with English-speaking children ages 4:0 to 8:11 to determine a specific profile of language strengths and weaknesses. Separate standard scores can be obtained for receptive and expressive language skills, and for lexical and syntactic abilities. The Syntax Composite consists of three subtests: Grammatic Understanding, Sentence Repetition, and Grammatic Completion. The 25-item Grammatic Understanding subtest assesses comprehension of different syntactic structures by asking a child to listen to sentences and choose the matching picture from a field of three choices. The 30-item Sentence Imitation subtest examines the ability to produce English sentences using correct word order and morphological markers, by asking the child to imitate sentences of increasing length and grammatical complexity. The Grammatic Completion subtest is a 28-item sentence cloze task used to measure both comprehension and production of commonly used English grammatical forms, particularly word endings. In addition to separate standard scores for each subtest (mean = 10, SD = 3), performance on all three measures can be combined into a Syntax Composite quotient, which yields a standard score (mean = 100, SD = 15) reflecting the child's overall morphosyntactic ability. The *TOLD P:3* was chosen because of its appropriateness for the age of the participants and its ability to yield both a standard score for general syntactic ability and for separate subtest scores. It also demonstrates excellent psychometric properties, such as high test-retest and interrater reliability coefficients, as well as a thorough analysis of content, criterion, and construct validity (Madle, 2004; Newcomer & Hammill, 1997).

In addition to the *TOLD P:3,* the wordless picture book, *Frog Where Are You?* by Mercer Mayer, was used with each participant to elicit a short narrative sample. The samples were elicited by showing each child the book, stating the title, and directing the child to "tell the story from the pictures". Language samples were felt to be a useful addition to the *TOLD P:3* since they allowed for analysis of morphosyntactic abilities during more spontaneous language production. Measuring mean length of utterance (MLU) in morphemes provided an opportunity to see if the participants who were unsuccessful as infants used less grammatically complex sentences than the participants who had been successful. The mean number of syntactic errors per utterance was also calculated from the samples to see whether unsuccessful participants made more morphological and syntactic errors during spontaneous language production than successful participants.

Table 2: Additional assessment measures

Assessment	**Domain examined**
• *Expressive Vocabulary Test- 2nd Edition* (EVT-2; Williams, 2007) • *Peabody Picture Vocabulary Test- 4th Edition* (PPVT-4; Dunn & Dunn, 2007)	Semantic Abilities
• Subtests of the *Phonological Awareness Test* (PAT; Robertson & Salter, 1997) • *Yopp-Singer Test of Phoneme Segmentation* (Yopp, 1995) • Upper-case Alphabet Recognition subtest of the *Phonological Awareness Literacy Screening PreK* (PALS-PreK; Invernizzi, Sullivan, Meier, & Swank, 2004) • *Family Literacy Scale* (Morrison, McMahon-Griffith, Williamson, & Hardway, 1993)	Phonological Awareness Skills
• Matrices subtest of *Kaufman Brief Intelligence Test- Second Edition* (K-BIT:2; Kaufman & Kaufman, 2004)	Nonverbal Intelligence
• *Speech and Language Assessment Scale* (*SLAS*; Hadley & Rice, 1993)	Functional communication skills

Attention

Since there is a dearth of standardized tests which directly measure attention abilities in children under the age of 8, behaviors relating to attention skills were assessed using the Parent Ready Score Form (for ages 3-7) of the *Brown Attention Deficit Disorder Scales for Children and Adolescents* (*Brown ADD Scales*, Brown, 2001). In the previous discussion of attention, the possibility was raised that poor skills in selectively attending to one's name in the presence of distracting background noise could be a precursor to higher levels of difficulty attending to tasks in the presence of both external (e.g., sensory) and internal (e.g., cognitive) distractions. Such abilities in childhood are likely related to the domain of executive functions, or the higher-order processes involving organization and planning of thoughts. The *Brown ADD Scales* are a set of instruments designed to elicit parent, teacher, and for older children, self-report of symptoms that may indicate impairment in higher-order attention processes, including related executive functions, that commonly occur in children with Attention Deficit/Hyperactivity Disorder (ADHD). The Parent Ready Score form elicits this information by asking parents to rate the frequency of targeted behaviors on a scale of 0 (never a problem) to 3 (occurs almost every day). The 40 items on the scale are grouped into six clusters, each representing a domain of attention or executive function that is frequently affected by ADHD. The domains of attention defined in the Brown ADD Scales do not correspond directly with the domains previously discussed according to Sohlberg and Mateer's model, but do incorporate behaviors that could reveal differences between the successful and unsuccessful infants in abilities related to attention. The clusters are listed below:

1: *Activation* involves behaviors that require the child to organize, prioritize, and activate to work tasks; in particular, items refer to difficulty following directions and completing daily routines. Difficulty in this area could reflect higher-order difficulties in responsiveness to stimuli (i.e., focused attention).

2. *Focus* relates to behaviors which require the child to concentrate, maintain, and shift attention to tasks. Examples of specific behaviors include requiring

adults to ask a child to stop and listen, problems in listening to stories when being read to, and getting easily sidetracked. This seems to be the domain most directly related to selective attention ability, since it refers to the ability to concentrate one's attention on a relevant task without being sidetracked. As such, the largest differences between children who failed at the infant task and those who succeeded were expected to be found in this domain.

3. *Effort* involves the regulation of alertness, sustaining of effort, and speed of processing, particularly during work-related tasks; items focus on behaviors such as slow information processing, inadequate task completion, and giving up too quickly when learning a new task. Impairment in this area is related to difficulty maintaining attention to tasks (i.e., sustained attention).

4. *Emotion* refers to regulating emotional reactions such as frustration or worry; items refer to excessive irritability, worry, or hurt feelings. While this skill could be related to the ability to ignore internal distractions, this domain seems less directly related to attention skills.

5. *Memory* involves behaviors which require the child to utilize working memory and access recall. Items focus on forgetfulness in daily routines and following directions, as well as problems recalling learned material. While certain types of attention (e.g., focused, sustained) could affect the ability to learn material or routines, this domain does not appear to directly relate to attention abilities.

6. *Action* refers to the ability to evaluate situations and recognize what should be done, and self-regulating behavior to do what is appropriate; in

particular, items refer to frequent interruption, inappropriate conversational turn-taking, and difficulty waiting. This domain could incorporate higher-order skills in selective attention, since disregarding irrelevant information and attending to situationally relevant details is involved in problem solving and decision making (Matlin, 1998).

Once the parent form is completed, the total scores and scores for each cluster can be tallied and converted into standard scores known as t-scores (mean = 50, SD = 10) based on the child's age and gender. Higher t-scores indicate increased difficulty in an area; a t-score above 60 indicates possible clinical impairment. It is important to note that the intent of the current study was not to identify or diagnose ADHD in the participants, and participants were not expected to score beyond the normal range in any of the clusters. However, the Parent Ready Score Form was felt to be a useful, quantifiable measure of attention-related behaviors that could be compared across participants. The *Brown ADD Scales* demonstrates strong internal consistency and test-retest reliability, as well as strengths in intercorrelations between cluster and total scores and convergent validity with other comparable attention scales (Brown, 2001; Jennings, 2004).

Demographic information

A parent questionnaire which contained items on each participant's linguistic and cultural background was created (see Appendix 1). For the purposes of this study, it was used to obtain demographic information such as ethnicity, maternal education level, and relevant medical history.

Procedure

All participants were tested by one of three graduate student clinicians in Speech-Language Pathology who were blind to the participants' performance in the infancy studies. Assessments took place in therapy rooms at the University of Maryland Speech and Hearing Clinic and were typically completed in 1.5-2 hours. All participants were accompanied to the lab by one or both parents. Each session was videotaped using a Panasonic VDR-D100 Camcorder; the camera was positioned so that the child and the stimulus materials were visible. Audio recordings of each session were also made using an Olympus VN-960PC digital voice recorder. Upon arrival at the lab and after completion of consent forms, parents were given a packet containing the Parent Ready Score Form of the *Brown ADD Scales*, the *SLAS*, the *FLS*, and the general questionnaire to complete during the testing session, and were instructed to fill out each form as completely as possible. During breaks in the testing session, the clinician checked with the parent or parents to answer any questions they had about individual questionnaire items. Parents were invited to sit in an observation area and observe the testing session through a one-way mirror. In three cases, a parent remained in the room during testing to minimize separation anxiety, but was instructed not to interact with or prompt his or her child during testing; these participants were also seated with their backs to their parent in order to minimize distractions.

Tasks were administered in a fixed order, which is listed in Table 3. Although task order randomization would have minimized potential order effects, it was felt that certain tasks should appear at the beginning and end of each testing session to avoid frustration, overlap between items, and anxiety. Tests that required minimal verbal responses were administered at the beginning of the session to reduce test anxiety while the participants became accustomed to the testing environment and the examiners. Tests which required longer or more complex responses were administered in the middle of the session to try to ensure that participants were more used to the testing procedures, but were not yet too fatigued to complete the tasks. Tympanometric testing was always performed last, to ensure that any anxiety about the procedure did not affect performance on the other measures.

Since the assessment procedure was quite lengthy, breaks were provided between tasks as needed. To maintain motivation, each child was also given a picture schedule of tasks and a paint stamper to mark when a task had been completed. At the end of the testing session, the child was allowed to exchange his or her completed task list for a small toy from a prize box.

Table 3. Task order

1. *EVT-2*	5. *PAT* subtests and Yopp-Singer
2. *PPVT-4*	6. *TOLD P:3* Grammatic Understanding, Sentence Imitation, and Grammatic Completion subtests
3. Narrative Sample using Frog Story	7. *K-BIT* Matrices
4. Upper-Case Alphabetic Recognition	8. Tympanometry

Scoring and Design

Each participant's test forms, including the parental report scales, were scored by the test administrator. Although traditional reliability measures were not obtained for the *TOLD P:3* or *Brown ADD Scales*, 30% of the participants' test forms were rechecked by a second graduate student clinician to ensure that raw scores and standard scores had been computed accurately. The data for each child were entered into a Microsoft Excel spreadsheet for exporting to SPSS. Before any data were analyzed, the spreadsheet was double-checked for accuracy by two of the three graduate student clinicians.

The language sample recordings were converted to digital files and stored on a Dell Inspiron 6000 computer. Each sample was transcribed by one of the three test examiners using the CHAT coding format described in the Child Language Data Exchange System (CHILDES; MacWhinney, 2000). Each transcript was double-checked for coding errors by a second graduate clinician. To check for reliability in transcription, approximately 30% of the samples were double-coded; any utterances whose transcriptions were discrepant were listened to by a third examiner until an agreement was reached. Agreement for the transcribed child utterances was 98.8%.

The two measures of interest, MLU and mean syntactic errors per utterance, were derived from the language sample data by running analyses using Computerized Language Analysis (CLAN; MacWhinney, 2000) Version 14 software. MLU measurements were obtained by running a CLAN morphological analysis which computed the total number of utterances per sample, as well as the average number of morphemes per utterance. Syntactic errors were defined as either word order errors or as substitutions, omissions, or unnecessary insertions of articles, conjunctions, tense markers, possessive markers, or prepositions. Each error found in the sample was flagged and coded so that CLAN frequency analyses could be run to calculate the number of errors per sample. The number of overall errors was then divided by the number of child utterances in each sample.

To examine the relationship of the test measures with the participants' ability to perceive speech in noise as infants, participants were classified according to their outcomes during the Newman 2005 infant perception studies. Newman determined participant success by comparing the total time that an infant spent attending to his or her own name in noise to the total time spent listening to a stress-matched foil name. If the listening time for the infant's own name was greater than that for the stress-matched foil, the infant was considered to have succeeded at the task. However, there were several cases when the two listening times differed by only a few milliseconds, raising the possibility that the infant listened longer to his or her own name by chance. Therefore, a more stringent criterion for task success was created for the current study: in order to be considered successful, an infant had to have listened at least 2 seconds longer to his or her own name than to the stress-matched foil name. This criterion was created by examining the original data and looking for a point which marked a clearer division between the two groups; with the original criterion, there was only a 0.8 second difference between the lowest successful participant and the highest unsuccessful participant, as compared to a 1.46 second difference with the new criterion. Those infants who had still succeeded with the 2-second criterion were therefore classified for this study as the "successful" group, and those who had not were classified as the "unsuccessful" group. Of the 23 participants, the successful group contained 13 (5 male and 8 female) children and the unsuccessful group contained 10 (4 male and 6 female) children. A two-tailed t-test revealed no significant differences between the two groups in age ($t(21) = 1.31$, $p = 0.203$). A Mann-Whitney test revealed no significant differences in mean ranking of maternal education level between the two groups ($z = -0.55$, $p = 0.58$). The two groups also did not differ significantly in distributions of gender (χ^2 (1, N = 13) = 0.013, $p = 0.91$) or ethnicity (χ^2 (1, N = 13) = 0.077, $p = 0.78$).

Chapter 3: Results

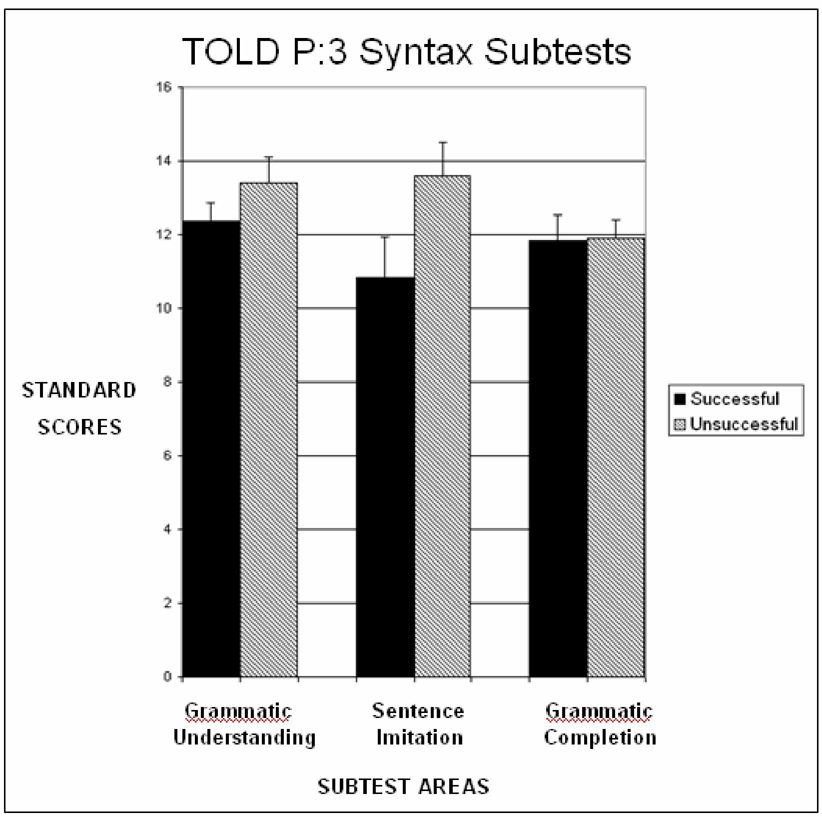
Following each participant evaluation, raw scores or standard scores for each assessment measure were entered for storage in a Microsoft Excel database. Once testing was complete, the data set was exported to an SPSS 16.0 data set for statistical analysis. Since the purpose of the research questions was to determine whether the unsuccessful group performed significantly worse than the successful group, one-tailed t-test analyses were used to examine the relevant end of the distribution when comparing means on standardized composite scores and language sample measures. Repeated-measures analyses of variance (ANOVAs) were used to compare differences within and between groups for comparable sets of subtest scores.

The descriptive statistics for the participants on the *TOLD P:3* measures are reported in Table 4. A one-tailed t-test revealed no significant group differences between the successful and unsuccessful groups on the *TOLD P:3* Syntax Composite Score ($t(21) = 1.45$, $p = .081$). To examine potential interactions between group and task type, a one-way repeated measures ANOVA of a 2 (groups) by 3 (subtests, or task types) design was performed, but revealed no significant main effects of group ($F(1,21) = 2.142$, $p = .158$) or task type ($F(2,42) = 1.398$, $p = .258$). There was also no interaction effect found ($F(2,42) = 2.440$, $p = .099$). These results are summarized in Figure 1.

Table 4. Descriptive statistics for *TOLD P:3* measures by group

Assessment Measure	Group	N	Mean	SD	Std. Error
TOLD-Syntax Quotient	Unsuccessful	10	119.00	12.570	3.975
	Successful	13	110.92	13.720	3.805
TOLD-Grammatic Understanding	Unsuccessful	10	13.40	2.319	.733
	Successful	13	12.38	1.981	.549
TOLD-Sentence Imitation	Unsuccessful	10	13.60	2.875	.909
	Successful	13	10.85	3.955	1.097
TOLD-Grammatic Completion	Unsuccessful	10	11.90	1.449	.458
	Successful	13	11.85	2.512	.697

Figure 1. Comparison of successful and unsuccessful groups on *TOLD P:3* syntactic subtests



Descriptive statistics for the language samples are provided in Table 5. Before comparing the groups on the two measures of interest, a two-tailed t-test was run to ensure that the two groups had samples of similar length. No significant difference was found ($t(21) = -0.118$, $p = 0.907$), suggesting that the groups provided comparable samples for analysis. One-tailed t-tests did not reveal significant differences between groups for the mean number of syntactic errors per utterance ($t(21) = .805$, $p = 0.215$). However, a significant difference emerged between the two groups for MLU ($t(21) = -1.817$, $p = .042$); the children in the successful group demonstrated significantly higher MLUs than those in the unsuccessful group. These results are summarized in Figures 2 and 3.

Table 5. Descriptive statistics for language sample measures by group

Measure	Group	N	Mean	SD	Std. Error
Errors per utterance	Unsuccessful	10	.1103	.03839	.01214
	Successful	13	.1965	.33481	.09286
MLU	Unsuccessful	10	5.2709	1.44731	.45768
	Successful	13	6.1835	.96090	.26651

Figure 2. Comparison of successful and unsuccessful groups on morphosyntactic errors per utterance

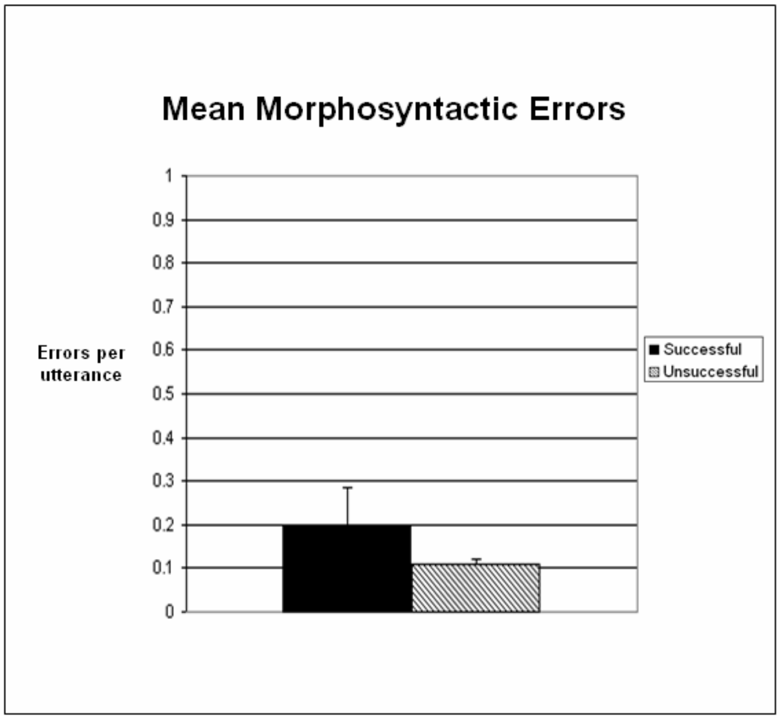
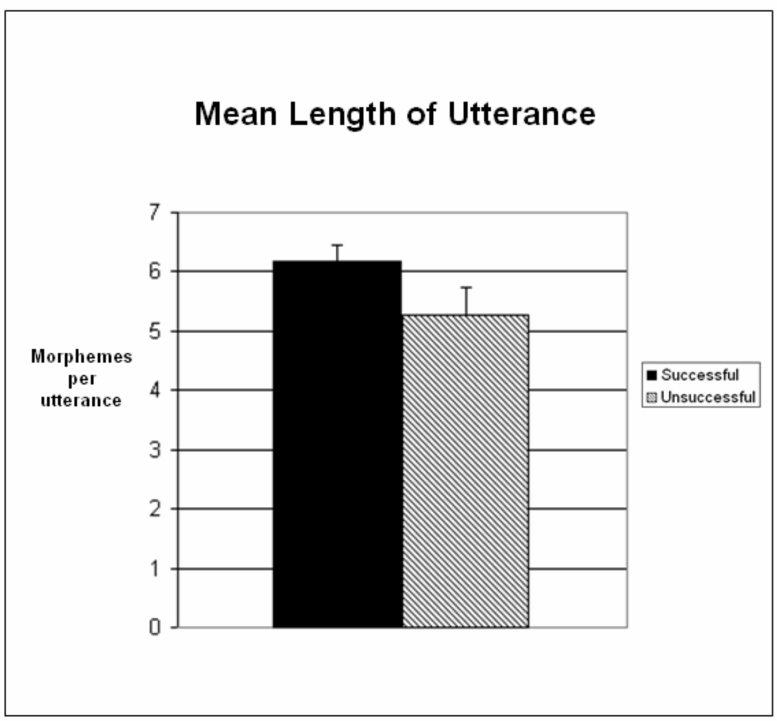


Figure 3. Comparison of successful and unsuccessful groups on MLU



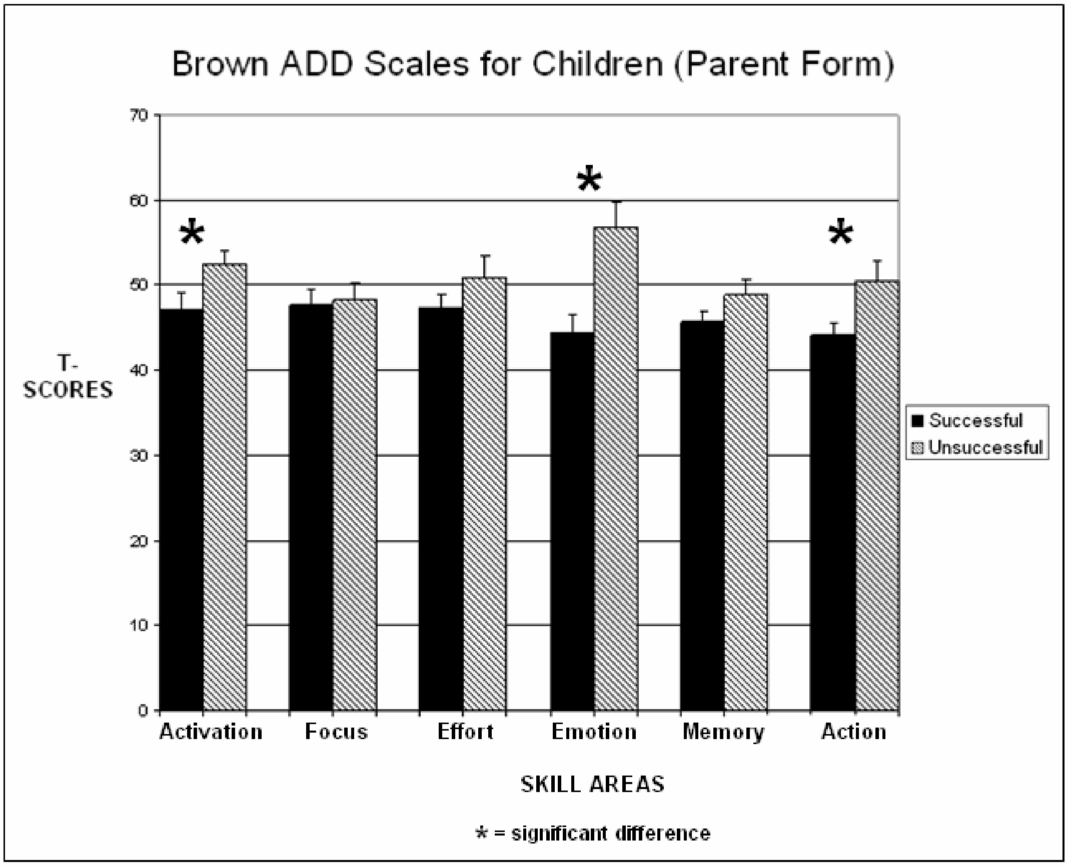
The descriptive statistics for the participants on the parent form of the *Brown ADD Scales* are summarized in Table 6. A one-tailed t-test on the *Brown ADD Scales* Combined Total score revealed that the participants in the unsuccessful group were rated significantly higher on a composite score of attention difficulty than the children in the successful group ($t(18) = 1.85$, $p = .041$). A one-way repeated measures ANOVA of 2 (groups) by 6 (domains of attention) was performed to examine the separate areas more closely. As expected, a main effect of group was found ($F(1,18) = 7.913$, $p = .012$), with the unsuccessful group being rated significantly higher overall than the successful group. A group by skill area interaction was also found ($F(5, 90) = 3.035$, $p = .014$), indicating that this difference was significant for some skill areas, but not others. Follow-up one-tailed t-tests revealed that the unsuccessful group scored significantly higher than the successful group in the areas of activation ($t(20) = 2.009$, $p = .029$), emotion ($t(19) = 3.627$, $p = .001$), and action ($t(20) = 2.426$, $p = .013$). Although the trends were in the same direction, no significant differences were found in the domains of effort ($t(19) = .280$, $p = .391$), focus ($t(20) = 1.376$, $p = .100$), or memory ($t(20) = 1.437$, $p = .085$). These results are summarized in Figure 4.

Table 6. Descriptive statistics for the *Brown ADD Scales* by group

Assessment Measure	Group	N	Mean*	SD	Std. Error
COMBINED TOTAL SCORE	Unsuccessful	9	50.89	4.936	1.645
	Successful	11	46.45	5.628	1.697
Activation	Unsuccessful	10	52.40	5.461	1.727
	Successful	12	47.17	6.548	1.890
Focus	Unsuccessful	10	48.30	6.056	1.915
	Successful	11	47.55	6.283	1.894
Effort	Unsuccessful	10	51.00	7.364	2.329
	Successful	12	47.25	5.413	1.562
Emotion	Unsuccessful	9	56.89	8.652	2.884
	Successful	12	44.50	7.013	2.024
Memory	Unsuccessful	10	48.80	5.594	1.769
	Successful	12	45.67	4.418	1.275
Action	Unsuccessful	10	50.50	7.427	2.349
	Successful	12	44.08	4.926	1.422

*One parent did not complete the *Brown ADD Scales* form, and two other parents either chose not to fill out all items on the scale, or were not able to be reached for follow-up questioning. This accounts for the different Ns in each area.

Figure 4. Comparison of successful and unsuccessful groups on the *Brown ADD Scales* domains



Chapter 4: Discussion

Introduction

When children who were unsuccessful at the infant speech stream segregation task were compared with those who were successful, there were no significant differences found between the two groups on a standardized measure of syntactic ability (the *TOLD P:3*). However, the children in the unsuccessful group were found to have significantly lower MLUs than the children in the successful group on a narrative language sample. Significant differences between the two groups were also found on the composite score and three subdomains of the *Brown ADD Scales* Parent Report Form: specifically, in the areas of activation, emotion, and action, the children in the unsuccessful group were rated as having significantly more difficulty than the children in the successful group.

The results of this study will be discussed in more detail according to domain below. Since this research was part of a broader study which examined different linguistic and cognitive domains, it is also worth noting that the other two researchers found no significant differences between the successful and unsuccessful groups on measures of expressive and receptive vocabulary, phonological awareness skills, or nonverbal intelligence (Singer, 2008; Stimley, 2008).

Syntax

The first question put forth by this study was whether or not the syntactic abilities of the participants who failed at the infant speech stream segregation task were different from those of the participants who were successful. The predicted outcome was that the children who failed as infants at the task would perform significantly worse than children who had succeeded. The results were somewhat ambiguous: overall, the participants' performance on the *TOLD P:3* did not support this prediction, since the successful and unsuccessful groups did not perform significantly differently on either the Syntax Composite or the individual subtests. However, when the narrative samples were examined, the unsuccessful group was found to have significantly lower MLUs than the successful group.

There are several possible explanations for why performance on the *TOLD P:3* was not significantly different between the two groups. The first explanation is that the test may not have been a sensitive enough measure of the morphosyntactic skills that might be affected by impoverished speech stream segregation ability. It was expected that no participants would fall below the normal range of performance on the test, and the results supported this prediction. However, this means that in order to reflect slightly depressed skills in syntactic ability, the test would have to be very sensitive to subclinical differences in performance. There are two possible reasons why this may not have been the case.

First, a documented weakness of the *TOLD P:3* is that it is prone to ceiling effects; that is, if a child is within the normal range of ability, they are likely to perform at or close to 100% accuracy on the test items. The latest edition of the test battery, the *TOLD P:4* (Newcomer & Hammill, 2008), was created in part to address this very issue; unfortunately, however, it was not released in time for use in this study. Since the *TOLD P:3* is designed for a range of ages, it was difficult to directly assess from the data at what point a ceiling effect might have occurred, but 13 of the

23 participants (56%) received Syntax Composite scores in the above average range (115 or higher), suggesting an overall high level of performance on the test. It is therefore possible that the *TOLD P:3* may not have been sensitive enough to pick up slight differences in syntactic abilities which may have been present.

The second, and perhaps more likely, possibility is that the *TOLD P:3* may not have been a valid measure of the syntactic abilities most likely to be affected by poor speech stream segregation skills. The hypothesis regarding syntax in this study was based on the idea that poor speech stream segregation skills would prevent an infant from learning specific syntactic structures that are often less salient in fluent speech; thus, the syntactic abilities in question were primarily those that involved the correct production of functors and bound morphological endings, rather than correct word order. The Grammatic Understanding subtest of the *TOLD P:3* measures comprehension of word order as well as morphological structures, and the Sentence Imitation subtest primarily targets word order errors rather than omissions of bound morphemes; thus, these two subtests in particular may not have provided opportunities to observe differences in the abilities of interest. Finally, although the Grammatic Completion subtest does primarily target word endings, the fact that production was limited to a small number of single-word responses may limit its utility as a measure of productive morphosyntax. It may be that the *TOLD P:3* was simply not the best standardized measure for the purposes presented here.

Just as the *TOLD P:3* may not have been a valid measure of the abilities relevant to this study, the nature of the infant task raises questions about its validity as a measure of speech stream segregation. The hypothesis presented was that speech stream segregation skills facilitate segmentation of the speech signal in noisy conditions, and that impoverished skills in this area would make it particularly difficult to segment at the syntactic level. However, the infants in the Newman studies were not performing actual speech segmentation in noise; they were listening to an isolated word that was being repeated. The task was therefore not measuring their ability to extract information from a fluent speech signal with competing noise in the background, but instead was measuring their ability to attend to a familiar word (their name).

The fact that the target stimuli in the infant studies were the participants' own names may also make it difficult to ascertain the exact skills being measured by the task. Bregman's (1990) theory of auditory speech stream segregation suggests that it consists of two stages, and that the first stage involves only basic perception of the fact that two simultaneous sound sources are different. It is in the second stage, of actual auditory scene analysis, that the listener begins to analyze what he or she is hearing and separate the relevant from the irrelevant. Assuming this theory to be true, in the presence of competing noise, segmentation and subsequent extraction of meaning from the speech signal would occur at the second, and higher level, of analysis. It is possible, however, that the infant perception task examined here was only a measure of the first stage of auditory scene analysis. In dichotic listening experiments of adult subjects using participants' own names as distractor stimuli, many participants responded to their names even while actively listening to another speech signal (Moray, 1959; Wood & Cowan, 1995). Alain and Arnott (2000) took this evidence to suggest that particularly significant stimuli such as names could be perceived without the level of attention that would occur at higher levels of auditory scene analysis. Thus, the familiarity and significance of the target stimuli in the infant perception task examined here may not have required the same level of signal analysis as more complex tasks involving speech segmentation, and thus may not be as relevant to linguistic outcomes.

Although the overall results did not support the prediction that infant speech stream segregation in noise is related to childhood syntactic abilities, the finding that the unsuccessful group had significantly lower MLUs in their narrative samples than the successful group may indicate a connection between speech stream segregation and syntactic production. Although it is important not to attribute too much importance to one measure when others lacked significance, the narrative language samples may have been a better and more sensitive measure of the abilities of interest than the *TOLD P:3*. As previously discussed, the *TOLD P:3* provided limited and isolated opportunities for production of the functors and morphological markers predicted to be the most vulnerable to deficits in the ability to separate speech from noise. The narrative samples, however, looked at morphosyntactic production in a more naturalistic context, and required the children to independently produce multi-word utterances that were more representative of their own knowledge and command of the language. The children who failed as infants at distinguishing between their names and stress-matched foil names in the presence of background noise used, on average, utterances containing fewer morphemes than children who had been successful at the task, even though the two groups did not differ on average number of utterances per sample or on measures of vocabulary diversity (see Singer, 2008).

This suggests that those children who were better at speech stream segregation in noise as infants had a larger repertoire of syntactic structures and a better spontaneous command of morphology, which was manifested in longer, more complex utterances. It is, however, important to note that although the two groups did not differ significantly in mean age or in mean number of utterances, the successful group was on average 3 months older than the unsuccessful group. It is therefore possible that the difference in MLU was at least partly attributable to normal developmental differences. Nonetheless, it is an interesting finding that warrants further investigation.

Attention

The second question raised by this study was whether or not the children who were poorer at speech stream segregation as infants would differ from those who were better at the task on measures of behaviors related to attention. The predicted outcome was similar to that of syntactic ability: that the unsuccessful group would perform significantly worse on measures of attention than the successful group, particularly in areas involving selective attention. When the two groups were compared, the unsuccessful group was rated by parents as having more overall difficulty at attention-related behaviors than the successful group. Significant differences between groups were found in some domains, but not others; and although these results partially supported the predictions, the domains in which the differences appeared were somewhat unexpected. No significant difference was found between groups in the Focus subdomain, which was predicted to be the one most closely related to the selective attention abilities involved in the infant speech stream segregation task. However, the participants from the unsuccessful group were rated as having significantly more difficulty in the domains of Activation, Emotion, and Action.

Although significant differences were not found between groups in the domain most directly associated with selective attention, the trend in all domains was that the children from the unsuccessful group had more difficulty than the children in the successful group. The Parent Report Form of the *Brown ADD Scales* is a criterion-referenced measure of functional behaviors related to attention and executive function, and is therefore not a measure of specific attention skills. Also, as previously discussed, the attention-related domains defined in the Brown ADD Scales did not correspond directly with the types of attention described in this study. Furthermore, since there are only 40 items on the Parent Report form of the *Brown ADD Scales*, there are only a few questions devoted to each domain. It is therefore possible that differences in specific abilities were either not adequately measured by this assessment, or were not statistically powerful enough to show up in the results. The manual for the *Brown ADD Scales* also specifically states that the six domains are not discrete or mutually exclusive, and that difficulty in one area is often associated with difficulty in other areas (Brown, 2001, p. 35).

Nonetheless, it is interesting and somewhat surprising that the largest differences were found between groups in the domains of activation, emotion, and action. The first domain, activation, involves activating to work tasks, following directions, and following daily routines. This was predicted to be a measure of higher-order focused attention, or responsiveness to stimuli, which was previously defined as a component of selective attention. When one considers the original infant task, success was measured as an infant listening longer to his or her own name than to a stress-matched foil name. The assumption was made that infants who were unsuccessful at the task must not have been able to tell the difference between their name and the foil name. However, it is also possible that the infants could tell the difference, but were just not particularly responsive to the relevance of their name as opposed to that of the stress-matched foil. When one considers this possibility, it becomes easier to see how this could result in a child who is less responsive to directions or commands by an adult.

The other two domains, emotion and action, refer to reacting appropriately in everyday situations and exhibiting appropriate levels of emotions such as irritability, worry, or frustration. It could be argued that these skills would require a child to regulate or choose between competing emotional or cognitive demands, and to inhibit irrelevant responses in favor of more appropriate ones. Thus, these domains may be linked to higher-order, metacognitive selective attention abilities that have their roots in infancy.

Although the specifics of the relationship between infant speech stream segregation in noise and childhood attention abilities were not adequately revealed by the results of this study, it is possible that the infant task was more a measure of attention skills than linguistic skills.

Conclusions and Future Research Questions

It was predicted that infants who were less skilled at segregating concurrent speech streams would be at a disadvantage for learning language, since they would presumably be less adept at extracting information from the speech signal which would enable them to learn about their language. It was also predicted that these infants could be at a disadvantage in abilities related to attention, since some degree of selective attention was necessary for success at the speech stream segregation task. The results of this research, when taken in conjunction with the results of the other portions of the longitudinal study, suggest that performance on the infant speech stream segregation task was indeed related to childhood abilities in attention, but not to language skills or nonverbal intelligence. Since laboratory performance on other infant language perception tasks, particularly speech-sound discrimination and speech segmentation, have been linked with childhood language abilities, the present results suggest that the original infant perception task may have been more of an attention task than a language perception task.

Nonetheless, the results of this study suggest several potential directions for future research, in areas relating to both language and attention. Newman et al. (2006) commented on the shortcomings of retroactive studies linking infant perception to later language development, since the original laboratory tasks were not specifically designed for longitudinal investigation. The current study is no exception, and the fact that there were no data about the infant participants' attention abilities makes it particularly difficult to interpret the relationship between the task and childhood measures of attention. Future studies designed to specifically investigate the longitudinal connection between infant perception and childhood outcomes in language production or in cognitive ability would be a useful addition to the research literature.

The somewhat ambiguous results regarding the link between infant speech stream segregation and syntactic abilities warrant further investigation. The successful and unsuccessful groups in this study did not perform differently on standardized measures of syntax, but were significantly different in MLU, a more naturalistic measure of morphosyntactic production. However, the specifics of the task performed by the infant participants (particularly the stimuli used) may not have adequately measured the speech stream segregation skills that are most likely to be linked with later language development. It would be useful to see if differences in linguistic outcomes are present in children who performed differently as infants in actual speech segmentation tasks in noise.

The significant differences found for parental ratings of attention skills also raise some questions for future investigation in non-linguistic research such as cognitive psychology. For example, what is the exact nature of the relationship between infant attention abilities and attention abilities in childhood? Could performance on infant measures of selective attention predict childhood outcomes in other areas, such as temperament, personality, or overall executive function? And finally, could performance on early measures of attention be a useful indicator for early identification of attention impairment? Answering these questions would require the development of more standardized measures of attention abilities for infants as well as for young children.

In the meantime, however, it would also be interesting to see if the participants from this study perform differently once they are old enough to participate in the standardized tests of specific attention skills that are currently available. For example, the *Test of Everyday Attention for Children* (TEA-Ch; Manly, Robertson, Anderson, & Smith, 1999) is a standardized, norm-referenced assessment for children aged 6-16, and contains nine subtests designed to examine abilities in selective and focused attention, as well as attentional switching (McCurdy & Albertson, 2004). A measure such as this could provide a valuable source of additional data on the study participants once they reach the appropriate age, and could shed further light on the relationship between the speech stream segregation task and childhood attention.

Overall, although the results of this study were somewhat different than those predicted at its outset, it provided some interesting insights into the area of research linking infant perception and childhood abilities in linguistic and cognitive domains. Although the exact mechanisms driving the rapid development of skills in the first few years of life may always remain somewhat mysterious, identifying early perceptual skills that are particularly important to the process brings us that much closer to understanding it. Hopefully, this study has contributed at least in part to the research literature in this area by identifying speech perception in noise as an important potential link to linguistic and cognitive development, and by raising possible research questions for the future.

Appendix 1: Parent Questionnaire

Questionnaire form:

Subject ID#: ____________________

Person completing form (please circle one):

Parent Legal Guardian Caregiver Other: _____________________

The following questionnaire requests case history information which may be relevant to the research questions being examined in the study. This information will remain completely confidential and will only be available to the researchers conducting the study. If any of this information is used in the final research report, all identifying information will be removed.

Please fill out the following information as completely as possible.

Child's gender: M/F (circle)

Please indicate the race/ethnicity of each parent or legal guardian and the participant. Check all that apply. These data are for reporting purposes only.

Parent/legal guardian 1:

____ African American
____ Hispanic
____ Caucasian (white)
____ Asian
____ Native American
____ Pacific Islander
____ Other: ____________________________

Parent/legal guardian 2:

____ African American
____ Hispanic
____ Caucasian (white)
____ Asian
____ Native American
____ Pacific Islander
____ Other: ____________________________

Child:

____ African American
____ Hispanic
____ Caucasian (white)
____ Asian
____ Native American
____ Pacific Islander
____ Other: ____________________________

1. Number of caregivers in household: ______________________

2. Number of siblings: ______________________

    Ages: ______________________

    On average, how many hours per day does your child spend playing with his/her siblings? ______________________

3. Primary language spoken in the home: ______________________

    Is your child exposed to any other languages during the day? Y / N

    If so, which one(s)? ______________________

        For what percentage of the time? ______________________

    Has your child spent one month or longer outside of the U.S.? Y / N

        Where? ______________________

        For how long? ______________________

4. How many TVs are in the household? ______________________

    Please estimate how many hours per day the TV is on ______________________

    Please estimate how many hours of TV your child watches per day? ___________

    What is your child's favorite TV show (s)? ________________________________

5. How many radios/stereo systems are in the household? ______________________

    Please estimate how many hours per day the radio/stereo is on. _____________

6. Does your child play computer games? Y / N

    If so, how many hours per day?_______________

    What is your child's favorite computer game? ________________

7. Does your family own any pets? Y / N

    If so, what kind(s)? _________________

    How many? _______________________

    On scale of 1(silent) to 10(constant noise), how noisy is your pet? ________

8. Please give a general rating on a scale of 0 (absolutely silent) to 100 (rock concert) of how noisy you judge your house to be on a daily basis._____________

    Where is your house located (e.g. near highway, near train tracks, in a rural area)? _________

9. On average, how many books per week does your child read (or have read to him/her)? _____

Please estimate: how many books you own _________________

how many books your child owns _____________

10. On average, how much time per day do you (or another primary caregiver) spend in

one-to-one conversation with your child? _____________________

11. On average, how many hours per day do you (or another primary caregiver) spend in

one-to-one play with your child? _____________________

12. On average, how many hours per day does your child spend playing alone? ________________

13. On average, how many hours per day does your child spend playing with other children? _______

14. On average, how many hours per day does your child spend napping or sleeping?______________

15. Does your child have any history of ear infections? Y / N

How many? _____________________

Approximate dates: _____________________

16. Has your child had any major medical events since four months of age? Y / N

If so, please explain below ____________________________________

At what age(s)? _____________________

Number of hospitalizations: _____________________

Length of hospital stay(s): _____________________

17. Has your child ever been diagnosed with a language or learning disability? Y / N

If so, please describe: ____

18. Currently or previously, are any special education services provided to your child at home or at school/daycare? Y / N Does your child have an IEP/504 Plan? Y / N

For what concerns? ____

For how long? ____

19. Is there any history of language and/or learning disabilities in your immediate family, such as problems paying attention, learning, or other school problems? Y / N

If so, please describe: ____

20. Please describe what your typical dinnertime is like: ___________

Does your child eat with siblings, with you and his/her other caregiver, or alone? ___________

During most dinners, does your family
__________watch TV?
__________listen to the radio?
__________ engage in conversation?
__________ other activities?

21. Does your child take part in any activities that are specifically designed to enhance his/her language or reading abilities? ____

22. Who cares for your child during the day? Please check all that apply.

____ Parent/Legal Guardian

Other children present? Y / N How many? ______________________

____ Relative (please fill out information below)

Relationship to child ______________________

Primary language ______________________

Hours per week ______________________

Other children present? Y / N How many? ______________________

____ Babysitter/nanny (please fill out information below)

Primary language ______________________

Hours per week ______________________

Other children present? Y / N How many? ______________________

____ Daycare (please fill out information below)

Name: ______________________

Hours attended per week: ______________________

Years or months attended: ______________________

Language(s) of instruction: ______________________

Class size: ______________________

____ Preschool/Kindergarten (please fill out information below)

Name: ______________________

Hours attended per week: ______________________

Years or months attended: ______________________

Language(s) of instruction: ______________________

Class size: ______________________

____ Other (please describe) ____

23. Do you drive your child to his/her school/daycare/daily activities? Y / N

If so, how many hours per day are spent together in the car? _________________

Please select all of the following that best describe the time your child spends in the car:

While in the car, my child:

____ watches a video

____ listens to the radio, to a CD or tape

____ talks to siblings in the car

____ talks to me (or other primary caregiver)

____ looks at a book

____ other (please explain)____________________________________

24. Please check the highest level of education completed by the mother or primary caregiver. If providing information about a primary caregiver, please list relationship to the child: ___________________________

____ Elementary School

____ Middle School

____ High School

____ Professional School (Associate's degree or equivalent)

____ College (Bachelor's degree or equivalent)

____ Master's degree or equivalent

____ Doctoral degree or equivalent

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