ABSTRACT

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This study attempted to investigate the relationship between infant speech perception in noise and vocabulary outcomes. Newman (2005) conducted a series of studies to determine if infants were able to perceive their own name in the context of background noise. It was found that at five months, infants could perceive their own name when the signal-to-noise ratio was at least 10 dB and at thirteen months, infants were able to perceive their own name with a signal-to-noise ratio of at least 5 dB. Children who had participated in this study as infants returned to be assessed in terms of vocabulary and non-verbal intelligence at approximately five years of age. Children were divided into two groups depending on their success as infants and compared on these measures. No significant relationship was found between any of the measures of vocabulary or non-verbal intelligence and initial performance on the speech perception task.

INFANT SPEECH PERCEPTION AND VOCABULARY OUTCOMES

By

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Introduction

      Many months before human infants are able to utter their first word, they have learned an incredible amount of information about their native language. Many of the prerequisites to becoming a fluent speaker of a language, such as knowledge of what sounds belong to the language, of how sentences are organized and of words and word meanings, are obtained through the infant's early experiences with language in his or her environment. For the past thirty years, researchers have explored the speech perception capabilities of infants. Study in this field provides insight into how typically-developing (TD) infants begin to acquire language and eventually become children who are fluent speakers of their native language.

    Many studies in the infant speech perception field focus on the age when most infants are able to perceive linguistic information or perform a specific task. Despite substantial variability among infants, research has demonstrated a standard progression of abilities, such that most infants can be expected to be able to perform specific tasks at specific ages (Werker & Tees, 1999). Research in this field traditionally uses speech perception tasks to determine what typically-developing infants are able to do (Werker & Tees, 1999). Recently, researchers have explored whether they can be used to identify infants at risk for language delays. The inability to perform a given task by the age that most infants are expected to be able to could signal later difficulties in language development.

There have been relatively few studies that have investigated the correlation between early speech perception tasks and later language abilities (Choudhury, Leppanen, Leevers & Benasich, 2007; Newman, Bernstein Ratner, Jusczyk, Jusczyk & Dow, 2006; Tsao, Liu & Kuhl, 2004). Determining which speech perception tasks are indicators of later language performance could serve to provide measures of early identification of children who may be at-risk for language disorders.

This study investigates whether a particular infant speech perception skill, the ability to perceive speech in noise, may be predictive of later lexical development. The sections that follow discuss word learning, characteristics of input presented to children, individual patterns of vocabulary development, infant speech perception in noise, and studies that relate language outcomes to early speech perception. Finally, it contains a description of the current study including an explanation of the methods and results and a discussion of the findings.

Word Learning

Commonly observed patterns

In the later part of the first year of life, infants begin to understand the meaning of words that are commonly used in their environment. The development of vocabulary during the first year of life is gradual. TD eight–month-olds have a receptive vocabulary of around 15 words. At ten months, this number has only increased to 35 words on average, or an increase of about 0.3 words per day (Bloom, 2000). In order to learn a word, infants often must be exposed to the word multiple times before it becomes part of their lexicon. Children will acquire those words used more frequently by their parents before words used less frequently (Huttenlocher, Haight, Bryk,

Seltzer & Lyons, 1991). As children get older and learn more words, the rate of acquisition seems to increase. At 17 months of age, children learn about five words per week (Bloom, 2000). By the age of 2.5 years, children learn an average of 3.6 words per day (Bloom, 2000).

During their second year of life, children experience an increase in rate of word learning. This period of word learning is commonly referred to as the "vocabulary explosion." Recent research suggests that this vocabulary explosion is a result of parallel learning of words. That is, children do not learn words one at a time but develop representations for multiple words at the same time (McMurray, 2007).

All TD children demonstrate a similar overall pattern of vocabulary development in terms of the types of words they initially learn. During these early stages of vocabulary development, children learn names for things that are functionally relevant to them. These are likely to be words for items or people with which they interact or that are salient items in their environment (e.g., *car*, *ball,*) (Anglin, 1995). In addition, children tend to learn more general names for objects that have less significance to them (e.g., flower instead of rose, carnation, lily, etc.). However, they learn specific names for people and things in their lives that are especially important (e.g., *Mom*, *Dad*, *Fido* instead of dog) (Anglin, 1995). Additionally, although English-speaking children's first words do contain a variety of grammatical classes, they tend to use more nouns than verbs (Tardif, Gelman & Xu, 1999).

Although the majority of research about word learning in TD children focuses on the first several years of life, children's vocabularies continue to grow throughout

childhood and there have been a number of studies that have investigated lexical

skills of children at or about four to five years of age. For example, children at four

years of age are still in the process of learning the concept of proper nouns. A study

by Hall (1996) indicated that children at this age are more likely to interpret a given

word as a proper noun instead of an adjective if the word is only applied to one

individual. In addition, children continue to learn how to assign labels to novel

objects. This was investigated in a series of studies by Au and Glusman (1990). The

first study indicated that when children between the ages of 3.5 to 6 years of age are

shown a novel object and given a novel word to name the object, they will avoid

applying a second novel word to the same novel object. However, in subsequent

studies, it was determined that when children are given names that they believe are

from different levels of the naming hierarchy, they will assign more than one label to

a particular object.

Individual differences in vocabulary growth

Although first words may be similar, there tend to be significant differences in

the rate of vocabulary growth between individuals (Huttenlocher et al., 1991). Some

may have a working productive vocabulary of 500 or more words and be forming

sentences at 18 months, while others produce very few words at the same age

(Rollins, 2003). These differences in word learning can be attributed to a variety of

factors, including such infant-specific properties as intelligence, gender, and general

linguistic and cognitive abilities (Huttenlocher et al., 1991). These infant-specific

factors can affect the child's capacity to gain meaningful information from the

language signal and to learn from the input that he or she is receiving (Huttenlocher et

al., 1991). However, variance also occurs in factors that are extrinsic to the child such as the quality and quantity of parental linguistic input a child receives and the amount of noise present in the language-learning environment (Pan, Rowe, Singer, & Snow, 2005).

Just as younger children may vary in their rate of acquisition, there is reason to think that older preschool children might also have varying rates of lexical development. For example, standardized clinical assessments tend to have a range of normative data that would classify a child as TD. The range of standard scores considered to be average falls within plus or minus one standard deviation of the group mean. A child may demonstrate weaker or stronger abilities than his or her peers based on an assessment but still be considered to have TD linguistic skills. There has been less research on factors that might influence this variability in children in the age range of four to five years. Variability in terms of the input a child receives continues to be an important factor (Rice, Huston, Truglio, & Wright, 1990; Rice and Woodsmall, 1988).

Characteristics of input presented to children

Research has indicated that the speech input that children receive from their parents and other individuals in their environment is a major contributor to early word learning. In fact, "lexical learning is the aspect of language acquisition most uncontroversially related to input characteristics" (Weizman & Snow, 2001, p.277). Variations in the extent and the manner in which adults present language make a significant contribution to language-learning differences. In addition, research has

indicated that other forms of input, such as television, are also related to word learning (Rice, Huston, Truglio, & Wright, 1990; Rice & Woodsmall, 1988).

During the early stages of language development, parental input, in the forms of commenting and labeling, impacts child language outcomes (Namy & Nolan, 2004; Rollins, 2003). Rollins (2003) investigated the relationship between maternal commenting and the child's language abilities. This study videotaped 11 mothers and their typically-developing infants across three ages. Receptive vocabulary at 12 months was measured by the *MacArthur Communicative Development Inventory* (*MCDI*; Fenson et al., 1993) while expressive language at 30 months was measured by the *Index of Productive Syntax* (Scarborough, 1990). The number of contingent comments made by the mothers at nine months was positively related to receptive vocabulary at 12 months of age and expressive language at 30 months of age. These findings suggest that commenting on objects that infants are focused on helps them to establish a connection between the word name and the referent, which in turn facilitates word learning (Rollins, 2003).

While parental labeling of objects can be helpful for young infants, it can also have detrimental effects on older children. Namy and Nolan (2004) observed parent-child interaction in 17 families making note of all verbal and gestural labeling made by the parents when joint attention had been established. Child vocabulary was measured by the *MCDI* checklist, short version at 1, 1.5 and 2 years of age. A relationship between parents who used increasing amounts of verbal labeling past the age of 1.5 years and children with slower-growing vocabulary was found. Two possibilities were raised for why this occurred. First, while early labeling may benefit

vocabulary development, later labeling may lead to fewer chances for the child to produce labels on his or her own. Another possibility is that parents tend to continue labeling beyond 1.5 years only when their children are not producing labels themselves; that is, when their children are late talkers. The continued labeling would, in that case, be a parent's attempt to compensate for his or her child's vocabulary skills.

In addition to commenting and labeling, parental language characteristics such as vocabulary diversity, use of sophisticated lexical input, and mean length of utterance (MLU) relate to vocabulary abilities in children (Hoff, 2003; Hoff & Naigles, 2002; Pan, Rowe, Singer & Snow 2005; Weizman & Snow, 2001).

Pan and others (2005) identified a relationship between the number of different words a mother consistently produced and the child's rate of vocabulary growth between the ages of 14 and 36 months. Each child's vocabulary production was assessed by analyzing a language sample transcribed using the CHAT conventions of the Child Language Data Exchange System (CHILDES; MacWhinney, 2000) for number of word types and word tokens. Maternal input was examined in terms of word tokens produced, word types produced, and total number of pointing gestures. The greatest difference in expressive vocabulary between children whose mothers used more diverse vocabulary compared to those who had less diverse vocabulary existed at 24 months, during an early stage of language development (Pan et al., 2005). The number of pointing gestures produced by mothers and their children's vocabulary growth also were related.

Additionally, a relationship between the mothers' literacy as measured on a test of letter-word identification and vocabulary scores on the *Wechsler Adult Intelligence Scale-Revised* (*WAIS-R*; Wechsler, 1981) and number of word types her child produced was found. More specifically, mothers who had a higher vocabulary score on the *WAIS-R* had children who produced more words, and mothers who scored higher on the test of letter-word identification had children who produced more words. These findings suggest that even maternal factors that do not concern a mother's direct interactions with her child appear to impact child vocabulary scores. The authors suggest that the relationship between a mother's standardized vocabulary score and her child's vocabulary diversity score could possibly be attributed to genetics. Mothers with stronger language abilities could potentially pass this strength on to their children. Another possibility is that mothers with stronger linguistic abilities will interact with their children differently than mothers with linguistic abilities that are not as strong (Pan et al., 2005). There was also a relationship between maternal depression, as measured by the *Center for Epidemiologic Studies-Depression scale* (*CES-D*; Radloff, 1977) and children's vocabulary diversity, such that mothers who were more depressed had children with lower vocabulary diversity scores. The authors suggest that depressed mothers produced fewer word types which led to a less diverse vocabulary. There are a number of factors that can potentially contribute positively or negatively to language development. Although all of these factors help explain individual differences among language learning in

typically-developing children, it is difficult to determine if there is one factor that makes more of an impact.

Findings from Hoff and Naigles (2002) provide further support for the influence of maternal vocabulary diversity on child vocabulary development (see also Hoff, 2003). Sixty-three children between the ages of 18 and 29 months were observed interacting with their mothers. Each mother's input was analyzed in terms of total number of utterances, number of word tokens, number of word types, and MLU. Mothers were also rated in terms of the contingency of their comments in response to the child's utterance. Each child's vocabulary was assessed by counting the number of word types used in a 90-utterance language sample on two different occasions. No relationship was found between the number of contingent maternal comments and lexical growth in children. A positive relationship was found between maternal number of word tokens, number of word types, and MLU and lexical growth in children measured as the difference in the number of word types used across two visits that were 10 weeks apart. It seems a greater amount of maternal input can facilitate word learning by exposing children multiple times to the same word in a variety of lexical and syntactic contexts. Longer maternal MLUs can also contribute to development of word knowledge by allowing the child to experience how the new word relates syntactically to words he or she may already know, which can provide information about the meaning of the new word (Hoff & Naigles, 2002). In addition, longer utterances could provide specific information about the meaning of a new word, leading to further facilitation of word learning (Hoff & Naigles, 2002).

Thus, the quality of speech input that parents provide has a strong influence on their children's linguistic development. The quality of this input can be influenced by parental education or socioeconomic status (SES). Although SES and parental education do not directly influence vocabulary development, they are potential factors that influence parental linguistic input which in turn could impact word learning. For example, parents with higher educational backgrounds more frequently use more complex sentences, a larger quantity of words, and a greater variety of word types (Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2007). This kind of input could provide children with multiple exposures to a variety of words and better word-learning opportunities.

Relationships among levels of parental language input, SES, and child vocabulary outcomes were investigated in a longitudinal study conducted by Hart and Risley (1995). This study sought to determine which aspects of a child's early language experience act as contributors to vocabulary growth. Forty-two families from a range of demographic backgrounds in terms of size, racial background, and SES were included. Families were observed in their homes for one hour a month from the time their children were seven to nine months old to three years of age. During this time, observers recorded what the child said, what the parents said, and whether or not parental speech was addressed to the child. Differences existed among SES groups in the amount of input provided by the parent when the child was 11 to 18 months old. The higher the family's SES, the greater the average number of utterances that were addressed to the child in a one hour session. Vocabulary abilities were measured at three years of age in terms of vocabulary use, which was an average of

the number of different words a child used per hour from 34 to 36 months of age, and vocabulary growth, measured as "the trajectory of expressive vocabulary change at age three" (Hart & Risley, 2005, p. 142). Vocabulary use and growth were found to be strongly correlated with SES. However, parental diversity of vocabulary, in terms of words directed to the child per hour, was more strongly related to child vocabulary performance. Parental language was also measured in terms of five variables: Language Diversity (different nouns plus different modifiers used per hour), Feedback Tone (number of affirmative utterances divided by affirmative utterances plus prohibitive utterances per hour), Symbolic Emphasis (sum of nouns, modifiers, and past-tense verbs used per hour divided by utterances per hour), Guidance Style (auxiliary fronted yes/no questions divided by auxiliary fronted yes/no questions plus imperatives per hour), and Responsiveness (parental responses divided by parental initiations divided by parental responses per hour). The variables of Language Diversity and Symbolic Emphasis were found to be related to child vocabulary use at age three. The variables of Feedback Tone and Guidance Style were found to be related to rate of vocabulary growth. The variable of Responsiveness was found to be related to both measurements of child vocabulary. Thus, when parents used a greater variety of words, used more language to describe relations between events and nouns, and used more utterances that were in response to their child's utterances, their children had larger vocabularies in general. But their vocabularies grew at a faster rate when the parents were more encouraging and when they used language to give their children more choices. These parenting variables accounted for more of the

variance in rates of vocabulary growth and child vocabulary use than SES accounted for.

Twenty-nine of the children followed in this study were assessed in 3rd grade to determine if language performance at a later age was related to the variables measured at age three. Vocabulary use and vocabulary growth were found to be related to performance on the *Peabody Picture Vocabulary Test-Revised* (*PPVT-R*; Dunn & Dunn, 1981). and the *Test of Language Development-2: Intermediate* (*TOLD-I:2*; Hammill & Newcomer, 1988). In addition, the parent variables of Language Diversity, FeedBack Tone, Symbolic Emphasis, and Guidance Style were strongly related to performance on the *TOLD-I:2*. FeedBack Tone, Symbolic Emphasis and Guidance Style were also related to scores on the *PPVT-R*. These parent variables continued to account for more of the variance in children's scores on both tests than SES did. This study indicated that differences in parental language input exist between families of different SES. In addition, SES does relate to measures of child vocabulary. However, parental language input seems to account for more differences in vocabulary achievement among children than SES does.

Research has suggested that amount and frequency of parental language input is a large factor in the child's development of a lexicon. This relationship indicates that differences in rate of acquisition between children could be the result of the amount of language exposure they receive. Children who are exposed to more word-learning experiences will be better equipped to form correspondences between sounds and meaning (Huttenlocher et al., 1991). In addition, the research discussed above indicates that the content of that input has been shown to make a difference in

vocabulary development as well. Parents who consistently use a larger variety of words and have longer MLUs provide their children with more opportunities to learn new words in a variety of contexts.

Although findings suggest that parents' language input can impact their children's vocabulary development, it is important to consider that despite a vast range in terms of the quality and quantity of parental language input children may receive, most are able to learn to talk and have a TD vocabulary. For example, Hart and Risley (2005) observed large differences in the amount that parents talked to their children, a range of 56 to 793 utterances per hour addressed to children at 11 to 18 months old. Despite these differences, all of the children in their study learned to talk. Even the parents representing the lower numbers of that range provided enough input to their children in order to learn language. The point at which the amount of input provided becomes enough for a child to learn language is still unknown.

Input from television

In addition to establishing relationships between parent input and vocabulary, research has found relationships between input from the television and child vocabulary. Rice and others (1990) investigated the relationship between watching the television show *Sesame Street* and vocabulary scores on the *PPVT-R*. Parents were asked to record their children's television viewing habits in a diary. This was done for five one-week time frames over a two-year period. Researchers classified television shows reported in the diary according to the intended audience: child or adult. In addition, television shows were classified according to whether they were intended to be educational or entertaining (e.g., a news-program versus a game-

show). A separate count of frequency of viewing *Sesame Street* was made. The *PPVT-R* was administered at the beginning of the two years and again at the end. The amount of time parents spent watching television with their child was also taken in account. Results indicated that the parents in the study watched informative child-directed television shows with their children less than 25% of their total television-watching time. Viewing of *Sesame Street* at 3 to 3.5 years of age was found to contribute to vocabulary scores at age five. While television viewing with no adult present was related to later vocabulary scores, television viewing with a parent present was found to be unrelated to later vocabulary. This study's findings indicate that children continue to use their environment to aid their word learning at three to five years of age.

Similarly, Rice and Woodsmall (1988) presented a short video to groups of three-year-old and five-year-old participants over two sessions. The video contained target words in four different categories: objects, actions, attributes, and affective state. Results indicated that the five-year-old group was able to learn more target words that were objects and attributes than the three-year-old group. This finding suggests that input continues to benefit children's word learning through at least five years of age.

Other individual factors in vocabulary development

Although parental language input plays a significant role in influencing child vocabulary development, it is important to note that genetics is a major factor in language outcomes and could be a contributing factor to some of the results reported above. Parents with stronger language capabilities can pass these capabilities on to

their children genetically, not only via language input. However, Huttenlocher (1998) argues that her previous findings (Huttenlocher et al., 1991) cannot be the result of genetics alone. The mothers who participated in this particular study did not vary significantly in terms of their verbal intelligence quotient, which was not controlled for in the study (Huttenlocher, 1998). In addition, the words that the mothers in the study used with their children were all very similar (e.g., baby, bottle) and words that all mothers would know regardless of their vocabulary size (Huttenlocher, 1998). Huttenlocher (1998) notes that it was only the frequency with which the words were used that varied.

Still, very few studies have investigated the strength of language input as an influencing factor when compared to the role of genetics. One way to investigate language input versus the role of genetics would be to look at the role of input from parents to adopted children. Although this has yet to be done, research on the role of caregivers' input to children suggests that input continues to influence language development when the role of genetics is less of a factor. One such study compared kindergarten and first-grade children's language skills at four time points during the school year (Huttenlocher, Levine, & Vevea, 1998). Two of these time points spanned periods where children would be receiving greater amounts of input from school (October to April), and the other two points spanned periods during which children receive lesser amounts of input from school (April to October). It was found that during periods with more school input, children showed more language growth which was measured by performance on a multiple-choice assessment that tested vocabulary and syntactic knowledge. This study only examined input very generally

but its results provide some evidence that language development is not solely a product of genetics.

Stronger evidence for the role of input (rather than only genetics) on language development comes from a study by Klibanoff, Levine, Huttenlocher, Vasilyeva, and Hedges (2006). This study examined whether the amount of math-related vocabulary used by teachers during "circle time" affected their students' knowledge of math vocabulary. Preschool children and children in day-care centers were assessed twice during the school year on their knowledge of math vocabulary (e.g., the meaning of "half," shape names). Researchers examined teachers' input to their students for usage of math-related language. The amount of math-related language used by teachers was found to be related to their students' growth in knowledge of math vocabulary as determined by difference in performance on the math assessment that was administered in October and April. These studies indicate that although it is important to take the role of genetics into account, input continues to be a factor in language development when the effects of genetics have been decreased.

Infant Speech Perception in Noise

Although the research described above has established that the speech input that is provided to children is very important to vocabulary development, such analyses often presume the infant is in an ideal listening environment. Very often, parents may be talking to their child in the presence of background noise such as that caused by noisy siblings or a television. Additionally, many children spend most of the week at a daycare setting where speech is less often directed solely at them, and

time spent with adults is split among many children. In these situations, it can be potentially more difficult to learn vocabulary. Newman (2006) investigated toddlers' ability to recognize a single word that was partially obscured either by noise or by a moment of silence. Participants were assessed using the preferential-looking paradigm. Names of two kinds of animals were presented auditorily accompanied by two videotapes of the animals. The two words were presented in three conditions, with the medial consonant obscured by noise, with the medial consonant obscured by silence and unobscured. Participants who were able to understand the word being said despite it being obscured would be expected to look at the corresponding video longer than the video that did not match the word. It was found that when children miss a part of a word because of background noise, this makes them less likely to recognize it (Newman, 2006). This complication would conceivably make it harder for them to learn it.

Research indicates that is it more difficult for infants to process speech in the presence of background noise than it is for adults (Nozza, Rossman, Bond, & Miller, 1990; Trehub, Bull, & Schneider, 1981). Infants require a larger speech-to-noise ratio than adults in order to process speech sounds (Nozza et al., 1990). In fact, at times, in order to be able to detect the presence of a speech signal in noise, the signal may need to be as much as ten times more intense for children than adults. This means that in environments with moderate levels of noise (i.e., daycare settings, households with multiple children or animals, households that frequently have the television or radio on), speech signals that adults may think are easily perceived could be confusable or even imperceptible to infants (Trehub et al., 1981).

Infants' ability to discriminate between similar speech sounds is not as strong as adults' and the impact that noise has during the language acquisition period for infants is much greater than on older children and adults (Nozza et al., 1990). Continually exposing infants to noise in the home and other environments could potentially affect language acquisition (Mills, 1975). Infants who can successfully detect speech when background noise is present may be better prepared to learn vocabulary. Following this argument, it might be expected that the ability to hear speech in the presence of noise would give these infants more word-learning experiences which in turn would give them more opportunity to learn new words.

Predicting language outcomes from early speech perception

There is great variability within the infant population in terms of speech perception abilities. Most infant speech perception research examines infants as a group in order to determine the abilities that most infants possess. However, within each group of infants, there may be variability. At a given age, some infants may be able to perform a specific task that other infants may not be able to. Research has begun to explore relationships between the ability to perform a particular task as an infant and later language outcomes. It is thought that perhaps certain speech perception tasks could indicate that a child is more or less prepared to learn later language skills (Benasich, Thomas, Choudhury, & Leppanen, 2002; Choudhury et al., 2007; Friedrich & Friederici, 2006; Molfese, Molfese, & Modgline, 2001; Newman et al., 2006; Tsao, Liu & Kuhl, 2004)

Researchers have begun to establish relationships between early speech perception skills and later language outcomes. One method to measure early speech

perception skills is event-related potentials (ERPs). "ERPs are voltage deflections of scalp-recorded EEG, which are time locked to a particular stimulus event" (Benasich et al., 2002, p 285). They are frequently used to evaluate auditory processing abilities and are advantageous in that they do not require active participation from the infant (Benasich et al., 2002). ERPs appear to be a powerful predictor of some language outcomes. ERPs in response to consonant-vowel speech sounds obtained within 36 hours of birth were found to be related to reading scores at eight years of age (Molfese et al., 2001). In addition, ERP readings taken at 19 months concerning phonological-lexical priming abilities were related to expressive language skills at 30 months (Friedrich & Friederici, 2006). Children with poor lexical development at 19 months seem to continue to have poor expressive language skills one year later (Friedrich & Friederici, 2006). Research using ERPs has suggested that infants' early speech-processing abilities seem to relate to language outcomes in childhood.

Recently, researchers have started to investigate the relationship between performance on speech perception tasks measured through common behavioral paradigms and later language outcomes. Discrimination of contrasting vowels at six months of age was found to be related to language development at follow-up tests up to 18 months later (Tsao, Liu, & Kuhl, 2004). Those infants with stronger performance on the discrimination task were found to have stronger lexical skills at 13 months of age. Later, at 16 months, discrimination performance was associated with both expressive and receptive vocabulary skills. The ability to discriminate between contrasting vowels was also associated with vocabulary production and

production of irregular words and grammatical complexity at 24 months of age (Tsao, Liu, & Kuhl, 2004).

Children's comprehension scores on the *MCDI*, and their number of gestures produced at 12 months were related to rapid auditory processing (RAP) ability at six months (Choudhury et al., 2007). RAP ability was measured by two different paradigms, the head-turn procedure and the auditory-visual habituation/recognition memory procedure. Additionally, higher vocabulary scores at 24 months were found to be related to successful performance on segmentation tasks as infants (Newman et al., 2006). In segmentation tasks, children are exposed and familiarized to a specific word. They are then presented with fluent speech passages, some that include the word and some that do not. Infants able to recognize the familiarized word by segmenting the fluent speech passage would be expected to pay longer attention to the passages that contained the word than those passages that did not. Children who later had higher vocabulary scores performed better on these tasks than those with lower scores. Furthermore, at 4 to 6 years of age, the children who had been more successful as infants had stronger semantic and syntactic abilities as measured by the *Test of Language Development-Primary Third Edition* (*TOLD-P:3*, Newcomer & Hammil, 1997) (Newman et al., 2006).

The above studies have begun to establish how infant speech perception task performance may relate to later language abilities. They also provide impetus for further investigation into other speech perception tasks that could possibly predict language outcomes. One possibility that has not yet been investigated is that performance on speech perception tasks in noise could relate to future language skills.

Infants who are better able to detect speech in the context of noise would have more opportunities to hear and learn novel words and benefit from parental language input. This ability would give them an advantage as they would have larger vocabularies than children who were not as strong listeners in noise. Thus, it might be expected that infants who perform better on speech-in-noise tasks would have stronger vocabulary outcomes in later years.

Hypotheses

The current study's primary research question was: Does a relationship exist between speech perception in noise abilities as infants and later vocabulary abilities at approximately five years of age? I attempted to answer this question by assessing vocabulary outcomes of children who participated in a perceptual study as infants. The earlier infant study evaluated the infants' ability to recognize their own name in the context of multi-talker babble (Newman, 2005). The vocabulary scores of those children who were more successful in the original speech perception task were compared to those who were less successful in order to determine if there was a difference in vocabulary ability at approximately five years of age. It was hypothesized that children who have more difficulty hearing speech in noise have poorer vocabulary outcomes. If the test of hearing in noise used by Newman (2005) is an accurate measure of the ability to perceive speech in noise, it would follow that infants who were not successful on the speech perception tasks in noise are likely to have weaker expressive and receptive lexical language abilities as children. Children who had difficulty identifying their own name in multi-talker babble may not be as able to learn novel words. Children who are not able to recognize words in the

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presence of background noise may be at a disadvantage for language learning because they would have fewer opportunities to hear and learn new words. A relationship between infant speech perception in noise and vocabulary development at a later age could provide support to using infant speech perception tasks as a means of early detection of potential language deficits. If a relationship is not found to exist between these two measures, one possibility is that those infants who had difficulty in speech perception in noise tasks at some point are able to compensate for this weakness and are still able to develop lexical skills as strong as their peers

Other research questions of this study were: (a) Does the amount of noise in the household impact vocabulary ability? (b) Does amount of time in a day that a parent spends in one-on-one conversation with their child impact vocabulary ability? (c) Does a relationship exist between nonverbal intelligence scores at five years of age and performance on a speech perception in noise task as an infant?

As the frequency of parental input has been established as an important factor in language development, it was hypothesized that children who have less one-on-one conversation time with their parents have poorer vocabulary skills. In addition, it was hypothesized that individuals who live in reportedly noisier homes have poorer vocabulary skills, as noise in the household is likely to interfere with the ability to benefit from parental input

It was hypothesized that nonverbal intelligence scores would not relate to vocabulary abilities at five years of age as there has been no previous research indicating that speech perception may be related to nonverbal intelligence. Additionally, while it logically follows that having poor speech perception skills as an

infant would result in learning fewer words, a theoretical relationship for speech perception skills and nonverbal intelligence is not as strong.

Method

Infant study

Participants

Newman (2005) conducted a series of four experiments investigating infant speech perception in noise. Each of the experiments had twenty-five infants. Across the four studies, the participants consisted of 55 boys and 45 girls. All experiments used the same exclusionary criteria. Participants were not excluded based on language spoken at home provided that the infant's name was one easily pronounced by an English speaker. However, infants were excluded when the name used in testing was not the one most commonly spoken to him or her or when one of the foil names was a name with which the infant was familiar (e.g., names of family members or pets). In addition, infants were excluded if they were not in the age range being tested.

Procedure

These speech perception experiments used the head-turn preference paradigm (Kemler Nelson et al., 1995) to determine the ability of infants to perceive their own name at a 10 dB and a 5 dB signal-to-noise ratio (SNR). All experiments took place in a three-sided booth where the infant sat on his or her guardian's lap. An attention-getting light was located on the front wall of the booth, and a red light and loudspeaker were mounted on each of the two side walls. At the start of a trial, the

light on the front wall of the booth would flash until the infant began looking at it. Next, a red light on one of the side panels would flash. When the infant oriented toward that side, the stimulus would begin playing. Initially, the stimulus was a musical passage intended to familiarize the participant with the task. Adequate familiarization was determined to occur when the infant had acquired at least 25 seconds of time listening to each of two musical passages. This was measured by how long the infant looked at the flashing red light.

During 12 test trials, infants listened to a female talker present the infants' own name, a stress-matched foil, and two non-matched foils. At the same time, multi-talker babble, a stream of nine women reading passages from books, was played to the infant. Those infants who were able to perceive their name despite the distracting background babble should have, in theory, attended for a longer length of time to the flashing light while their names were being spoken compared to the length of time they attended to the flashing light while the foils names were being spoken.

Results

The first experiment included 25 infants that were, on average, approximately five months old. During this experiment, the SNR was 10 dB. In general, infants listened significantly longer to their own name than to the stress-matched foil. Despite this overall finding, only 18 of the 25 participants listened to their own name longer than to the stress-matched foil.

In order to determine if five-month old infants are able to separate streams of speech at a lower SNR, the ratio was lowered to 5 dB in Experiment 2. Twenty-five infants who were approximately five months of age participated. Unlike Experiment

1, the majority of the infants attended for equal amounts of time to the foils matched for stress and their own name, although they attended longer to their own names than the foils not matched for stress. Only 10 of 25 of the participants listened longer to their own name than to the stress-matched foil.

Experiments 3 and 4 examined when the ability to listen in noise developed further. In both experiments, the SNR remained at 5 dB. Experiment 3's results were similar to Experiment 2's in that infants listened to their own names and stress-matched foils for the same amount of time and longer to their own names than the unmatched foils. Only 14 of 25 of those participants listened to their own name longer than to the stress-matched foil.

Results of Experiment 4 indicated that as a group, the infants listened significantly longer to their own name than to the stress-matched foil. Of the 25 infants in the group, 17 listened longer to their name than to the stress-matched foil. By the age of thirteen months, infants demonstrated some improvement in their ability to separate streams of speech in that infants listened significantly longer to their name than to the stress-matched foil at a lower SNR.

The results of these experiments indicate that although infants show some early ability to recognize familiar words in a multi-talker environment, their ability to separate speech is somewhat limited (Newman, 2005). Generally, the infants were unable to recognize their own name at a 5 dB SNR until approximately 13 months. This study revealed that in noisy situations, infants may have difficulty recognizing and understanding language.

Even in those cases where infants, as a group, were successful, some infants were not. That is, seven of the infants in Experiment 1 and eight of the infants in Experiment 4 did not listen significantly longer to their own name than to the stress-matched foil. One possibility is that these infants may have had poorer abilities at listening in noise than their peers. If so, this might indicate a relationship between initial speech perception performance as an infant and later vocabulary scores. The current study tests this explicitly.

Current study

Participants

In two of the original studies, children in general listened longer to their name than to the foil name. But in the other two studies (the ones testing 5-month-olds and 9-month-olds at a 5 dB SNR), this was not the case. In these studies, the SNR was apparently too difficult for infants to recognize their name. Although some infants did listen longer to their own name than the foil name in these studies, such performance is likely due to chance. Because of this, only data from children participating in the two studies that had significant results (the ones testing 5-month-olds at a 10 dB SNR and 13-month-olds at a 5 dB SNR) were included in the present study.

Sixty-four families were sent a personalized letter or email to the address on file in the Language Perception and Development lab, inviting them to participate in a full language assessment. The mailing was followed by a phone call in order to confirm receipt of the letter, to determine if the parent was interested in having their child participate and to provide further information if requested. During this time the

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parent either indicated that they were not interested in participating or indicated

interest and were then asked three screening questions to determine eligibility. These

questions were: "Has your child been diagnosed with a hearing loss?", "Has your

child been diagnosed with a developmental delay?" and "What is the primary

language spoken at home?" Any child who had been diagnosed with a hearing loss or

developmental delay was excluded from participation. Additionally, if English was

not spoken in the home, the child was not eligible for participation, as the

standardized tests used were normed on English speakers. Of the 46 families to which

either phone or email contact was established, 28 families were interested and

available to participate. Two of the families had twins, so a total of thirty children

were tested. Every effort was made during recruitment for the current study to ensure

that there was equal participation from both original age groups.

Of the 30 participants, three children were excluded as a result of

developmental delay or epilepsy, which was indicated through a parent questionnaire

that was provided on the day of the study. Tympanometric screenings were done on

the day of testing, and data were excluded from any child who did not pass the

screening (n=4), as noted in the procedures below. This left 23 participants.

Participant grouping criteria

The participants were divided into two groups depending on their performance

on the initial speech perception task. Participants were considered to be in the

"successful group" if they had listened to their own name for at least 2 seconds longer

than to the stress-matched foils. It was possible that some of the infants were

attending to their own names longer than to the stress-matched foils by chance. In

order to decrease the chances of this affecting the way that participants were grouped in the current study, the amount of time infants spent attending to their own names was examined to determine if there was an evident point in the data at which infants were differentiated as "successful" or "unsuccessful" in the original study. Infants who had not recognized their own name were likely to listen to all of the presented names equally. The natural cut-off for being labeled "successful" or "unsuccessful" seemed to be at approximately 2 seconds, so this criterion was selected in order to divide the participants in the current study.

Those participants who failed to meet this 2 second cut-off were considered to be in the "unsuccessful" group. There were 13 participants placed in the "successful" group and 10 participants were in the "unsuccessful" group. Examiners were blind to group status during the testing session.

Of the 23 participants, 14 were female and 9 were male. 14 children participated in the initial study at five months using a SNR of 10 dB and 9 were tested at 13 months using a SNR of 5 dB. The average age of the participants at the time of follow-up testing was 5.25 years with a range of 4.5 years to 6.08 years. Groups did not vary significantly in terms of age. The mean age of the successful group was 5.37 years, and the mean age of the unsuccessful group was 5.1 years. Of the participants, 9% were African American, 13% were of mixed race and the remaining 78% were Caucasian.

In terms of maternal education, the highest level of education of 9% of the mothers was high school or professional school and 4% of mothers had a college degree as their highest level of education. Of the remaining mothers, 52% also had a

graduate degree and 35% also had a doctoral degree. Mean number of years of maternal education for the successful group was 18.4 years and for the unsuccessful group was 18 years. The two groups did not differ significantly in terms of age or maternal education level.

Materials

The participants were assessed using a battery of linguistic and cognitive tests. The *Expressive Vocabulary Test-Second Edition* (*EVT-2;* Williams, 2007), *Peabody Picture Vocabulary Test-Fourth Edition-4* (*PPVT-4*; Dunn & Dunn, 2007), the *Matrices* subtest of the *Kaufman Brief Intelligence Test-Second Edition* (*K-BIT 2*; Kaufman & Kaufman, 2004) and vocabulary measures from language sampling are the assessment measures that are specific to this thesis. The remaining tests mentioned were administered as part of master's theses of two other graduate students. They were: the *Upper-case Alphabet Recognition* subtest of the *Phonological Awareness Literacy Screening PreK* (*PALS-PreK*; Invernizzi, Sullivan, Meier, & Swank, 2004), select subtests of the *Phonological Awareness Test* (*PAT*; Robertson & Salter, 1997), the *Yopp-Singer* (Yopp, 1995), and the *TOLD-P: 3*. In addition, screening tympanometry was used to assess middle ear function on the day of testing.

During testing, the parent was given a number of questionnaires in order to gain more information about the child and home environment. These included: a questionnaire created by the researchers that focused on factors at home that contribute to a noisy environment, and the child's language, literacy, and schooling

history (see Appendix), the *Speech Language Assessment Scale* (*SLAS*; Hadley & Rice, 1993), the *Family Literacy Scale* (Morrison, McMahon-Griffith, Williamson, & Hardway, 1993), and the parent questionnaire from *Brown Attention-Deficit Disorder Scales for Children and Adolescents* (Brown, 2001). The *SLAS* asks the parent to rate their child's communication abilities on a 7-point scale as compared to typically-developing peers. The *Family Literacy Scale* asks the parent a variety of questions regarding how often reading occurs in the house and the types of materials read in the house on a regular basis. The parent questionnaire from the *Brown Attention-Deficit Disorder Scales* has the parent rate their child on a number of behaviors associated with attention-deficit disorder

The current thesis is focused on vocabulary, and thus is based on the testing described in more detail below. In order to determine the child's expressive vocabulary abilities, the *EVT-2*, a test that assesses vocabulary production and word retrieval in children and adults, was used. It measures these skills by having the participant label picture items and identify synonyms for given words. Receptive vocabulary abilities were assessed using the *PPVT-4*, which measures the vocabulary comprehension of children and adults by having them choose the appropriate picture out of four choices given a spoken word. The *Matrices* subtest of the *K-BIT 2* measures non-verbal intelligence in children and adults by testing the participant's ability to determine relationships and complete analogies through selection of the appropriate picture, given a field of five

The *EVT-2* and *PPVT-4* were chosen because they are age-appropriate, standardized tests, with high reliability and validity that provide information about

each child's expressive and receptive vocabulary abilities. During development of the *EVT-2* and *PPVT-4*, the tests were administered to 3,540 individuals using a sample that closely matches the U.S. population (Dunn & Dunn, 2007; Williams, 2007). The *EVT-2* and the *PPVT-4* had high internal consistency both in split-half reliability and in the coefficient alpha reliability demonstrating that the items within each test had a high degree of uniformity (Dunn & Dunn, 2007; Williams, 2007). In addition, the *EVT-2* and *PPVT-4* had high test-retest reliability indicating that the test scores were not highly subject to variability in participant or examiner characteristics.

The *EVT-2* has content validity in that it assesses what it purports to be assessing: expressive vocabulary and word retrieval. Items for this test were selected based on their frequency in standard American English (Williams, 2007). The *EVT-2* also has high convergent validity with the *PPVT-4* and other common tests of child language ability.

The *PPVT-4* also has content validity. The words in the assessment represent 20 different content areas, and are all words that could be illustrated (Dunn & Dunn, 2007). The *PPVT-4* has convergent validity with other common measures of vocabulary knowledge such as subtests of the *Comprehensive Assessment of Spoken Language* (Carrow-Woolfolk, 1999) and the *Clinical Evaluation of Language Fundamentals Fourth Edition* (Semel, Wiig, & Secord, 2003).

Procedure

All sessions were recorded using a digital voice recorder and a *Panasonic VDR-D100* video camera. Approximately 30% of the participant data were reviewed by a second graduate clinician in order to assess accuracy in converting raw scores to standard scores and percentiles. Each graduate clinician recalculated raw score totals and confirmed that standard scores were accurate. In cases of disagreement, both graduate clinicians recalculated the scores until a consensus was reached. In addition, two graduate clinicians compared participant scores to the information in the table containing all participant data in order to ensure that all numbers were transferred correctly. This procedure to confirm accuracy of data conversion and transfer was performed in lieu of obtaining traditional measures of reliability.

Testing was conducted in a therapy room equipped with a one-way mirror. The participant and his or her parent were escorted into the room upon arrival. The examiner described the procedure to the parent and obtained consent. During this time, the child was provided with toys to allow him or her to gain familiarity and comfort with the therapy room before the parent left. After consent was obtained, the parent was given the choice of staying in the therapy room or observing the testing session behind the one-way mirror. Parents who opted to remain in the therapy room were instructed to not prompt their child or interfere during the testing session. Most of the parents chose to observe the testing session from behind the mirror or remain in the waiting room with other siblings. The parent was asked to complete the four surveys during this time.

The examiner provided the participant with task instructions and explained that upon completion of the activities, he or she would be able to take home a token incentive. Testing took approximately 1.5 to 2 hours and took place over one session. Vocabulary assessments were administered first, followed by assessments of other linguistic skills. The *EVT-2* was administered first in order to ensure that words used during other portions of testing would not influence the child's ability to name pictures in the test. This was followed by the *PPVT-4*. Next, as a break from formal testing, a language sample was obtained, followed by administration of the *Upper-case Alphabet Recognition* subtest of the *PALS-PreK*. Next, select subtests of the *PAT* and the *Yopp-Singer* were administered. Both of these tests assess children on a number of phonological awareness skills (e.g. blending of words, segmentation of words, rhyming of words). As the *PAT* and the *Yopp-Singer* can be difficult for children of this testing age, they were administered in the middle of testing in order to prevent fatigue from being an issue. This was followed by the *TOLD-P: 3*. The *Matrices* subtest of the *K-BIT 2* was administered as the last of the standardized testing as the response format required was less complex than that of other tests (e.g., pointing to the correct answer instead of verbally responding). Finally, screening tympanometry was conducted last to prevent any distress it caused from influencing the other testing. The scores of the children who demonstrated atypical middle ear function based on tympanogram results were excluded from data analysis. Criteria for passing were taken from the normative data detailed by the American Speech-Language Hearing Association in *Guidelines for Audiologic Screening* (American Speech-Language-Hearing Association Audiologic Assessment Panel 1996, 1997).

According to this document, ear canal volume measures must be between 0.3-0.9 cm3 and peak admittance must be less than 0.3 mmho.

The order of test administration remained constant through each session. Standardized scores for each test were calculated in order to facilitate comparisons across assessments. All testing was conducted by one of three graduate student clinicians and took place at the University of Maryland Speech and Hearing Clinic. A supervisor with accreditation from the American Speech-Language and Hearing Association was accessible during all testing sessions.

The participants were also asked to narrate a short picture book, *Frog, where are you?* (Mayer, 1969). A language sample was taken in order to obtain information about each participant's vocabulary usage in connected speech. This was important as it provided a more accurate depiction of the words the participant actively used rather than words they were able to recognize or name when asked to.

In order to introduce the task, the children were told that they were about to look at a book that had no words. They were instructed to tell the clinician the story in the book based on the pictures they saw. The children were given the title of the book and the book was then opened to the first page. If a participant had difficulty initiating this task, they were asked to tell the clinician what they saw. Clinician prompting and commenting was kept to a minimum in order to avoid influencing the participant's performance. At the start of each new page, the clinician would say "and" in order to signal to the participant to continue the story. Language samples were analyzed according to the guidelines detailed in the *CHILDES* project (MacWhinney, 2000) in order to determine measures of vocabulary diversity and in order to calculate the

number of lexical errors each participant made. A second graduate clinician reviewed 40% of the language samples for transcription errors. In cases of disagreement, the second graduate clinician shared her findings with the initial clinician and together a coding was agreed upon. An average of 10.5 differences per sample was found between clinicians. If they were unable to come to a consensus, a third clinician was consulted to listen to the language sample and give her opinion. A means of coding was accepted when two out of three of the clinicians were able to agree. A third clinician was needed to make a decision on transcription in 4 out of 9 samples that were checked.

Analysis technique

The two groups of participants, the successful group and the unsuccessful group, were compared in terms of expressive and receptive vocabulary abilities and non-verbal intelligence using a multivariate analysis of variance (MANOVA). A MANOVA was selected because the *EVT-2*, *PPVT-4*, and *K-BIT-2* all use standard scores which enables use for the same analysis procedure. In addition, using a MANOVA reduces the probability of a Type 1 error. The two groups' results from the *SLAS* and the *Family Literacy Scale* were also compared using an independent samples two-tailed *t* test. Additionally, each participant's measure of vocabulary diversity, VoCD, was obtained from the CLAN software (CHILDES; MacWhinney, 2000). VoCD takes into account the relationship between type-token ratio and sample size. Each participant's mean number of lexical errors was also obtained from the language samples. An independent samples two-tailed *t* test was used for each language sample measure in order to compare results between the two groups.

Separate *t* tests were used because the above measures are not being compared to each other and use scores that cannot be directly compared. Data from the questionnaire created for this study that pertained to levels of parent input (see question 10 in the Appendix) and noise in the household (see questions 4,5, and 8 in the Appendix) were used to determine whether differences in input such as amount of time a parent spent talking one-on-one with their child, reported level of noise in the house, and reported amount of time the television or radio is on each day were related to vocabulary outcomes. The Spearman's rank correlation was used to compare the questionnaire data and vocabulary scores.

Results

Standardized Test Results

The *EVT-2*, *PPVT-4*, and *K-BIT 2* were analyzed using a MANOVA. No significant relationship between participants' expressive vocabulary scores (*EVT-2*) and initial performance on the speech perception in noise task was found (F $(1,20)$ = 1.43, *p* =0.25). Results indicated no significant relationship between receptive vocabulary scores (*PPVT-4*) and performance on the initial speech perception task (F (F $(1,20)$ =0.001, *p* = 0.97). In addition, there was no significant relationship between non-verbal intelligence (*K-BIT 2)* and performance on the speech perception task (F $(1, 20)$ = 0.14, *p* = 0.72). Figures 1, 2, and 3 show the mean standard score and error range for each group for the *EVT-2*, *PPVT-4*, and *K-BIT 2*, respectively.
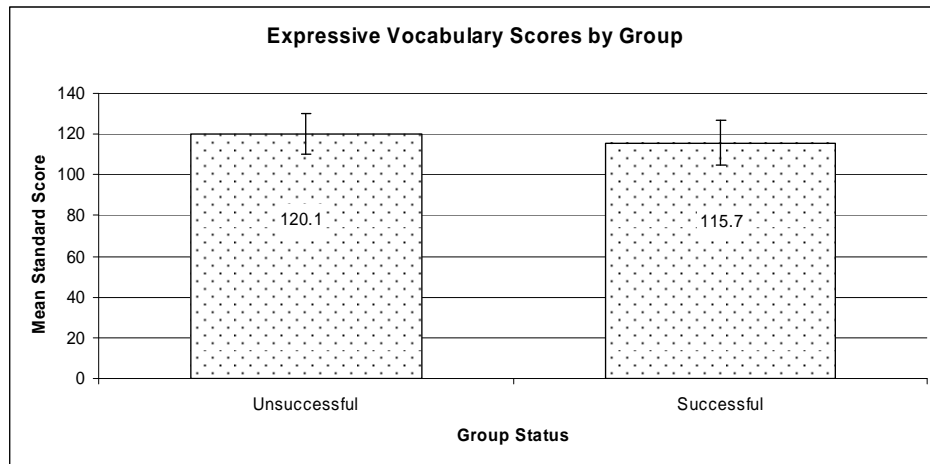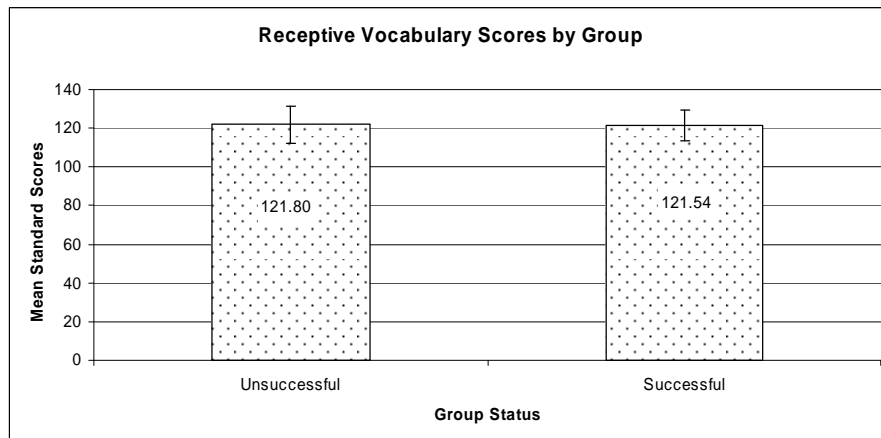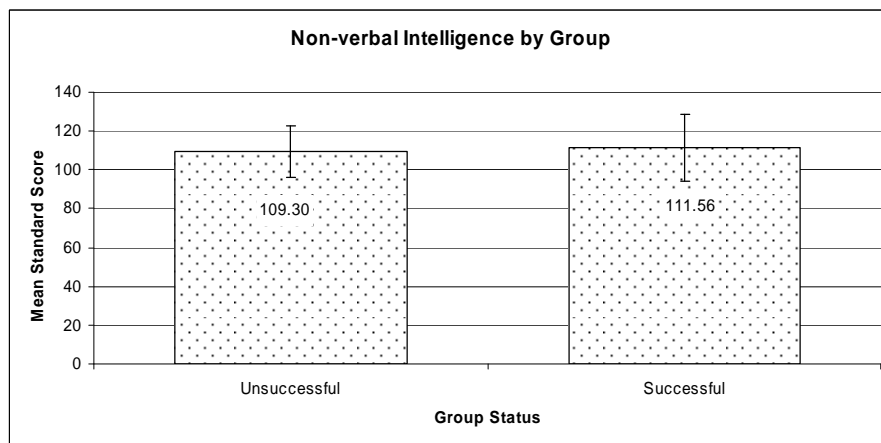
Figure 1

Figure 2

Figure 3

Group vocabulary diversity scores were compared using an independent samples two-tailed *t* test. No significant differences were found between groups on measures of vocabulary diversity (t (21) =-0.07, p= 0.95). Figure 4 indicates the mean vocabulary diversity score for each group.

The vocabulary diversity score was also calculated while omitting instances of retracing (when a participant started to say something but then stopped and either repeated the same material or changed what they were going to say) in each child's language sample as these occurrences could add to the length of the passage and to the amount of word types being used if the child corrected his or her original statement. There were again no significant differences between group means when vocabulary diversity was calculated in this manner (t (21) =-0.11, p= 0.91) (See Figure 4).

Figure 4

38
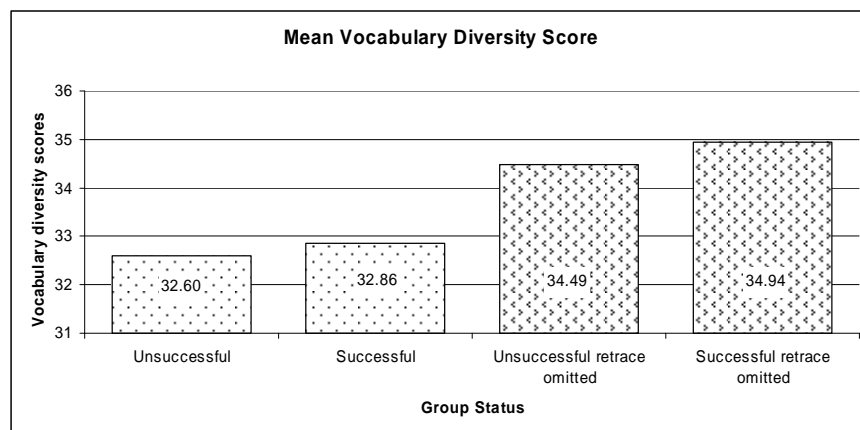
The mean number of lexical errors each group made during the language sample was also compared. A word was counted as an error if the incorrect word was used (e.g., the picture was of a jar but the participant called it a bowl). Incorrect words as errors were only counted the first time they were used. The successful and unsuccessful groups did not differ significantly in terms of lexical errors made (t (21) = -1.73, p = 0.098). The successful group had an average of 2.08 errors and the unsuccessful group had an average of 1.1 errors. Although the successful group made more errors overall than the unsuccessful group, the successful group had longer passages (measured by word count) which could result in more opportunities to make errors. However, neither of these differences was significant. The percentage of errors the successful group made was 0.56% while the percentage of errors the unsuccessful group made was 0.35%.

Parent Questionnaires

SLAS

Individual scores for the *SLAS* were calculated by averaging each parent's ratings of their child's language abilities on all 19 items. Mean parental ratings of participant's speech and language abilities on the *SLAS* from each group were compared using an independent samples two-tailed *t* test. No significant difference in parent ratings of speech and language abilities (t (21) = 0.20, p = 0.84) between the successful and unsuccessful group was found. Figure 5 depicts the average SLAS scores for each group.

Figure 5

SLAS scores and group status
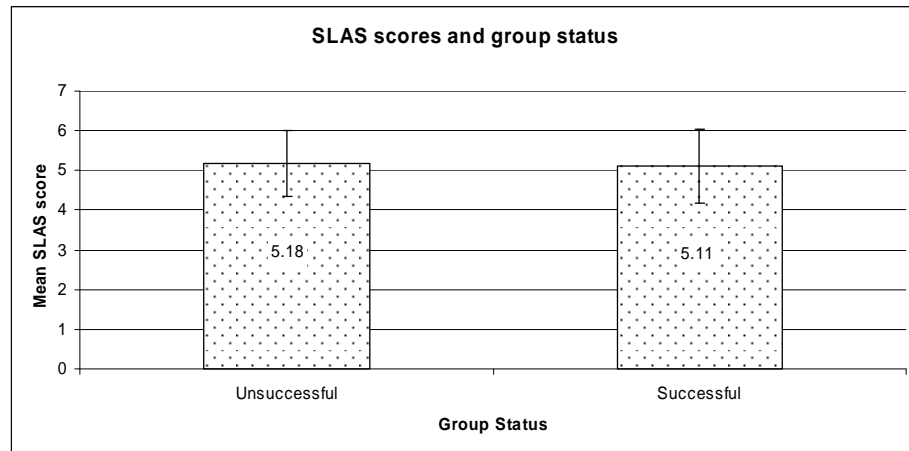
Family Literacy Scale

Scores on the *Family Literacy Scale* were determined by calculating the total

based on point-values assigned to each question. The maximum possible score was 36

points. Mean scores were compared using an independent samples two-tailed *t* test.

Group means are depicted in Figure 6. No significant differences were found

between parent ratings in successful and unsuccessful groups (t (20) = -0.398, *p*=

0.69)

Figure 6

Family Literacy Scale
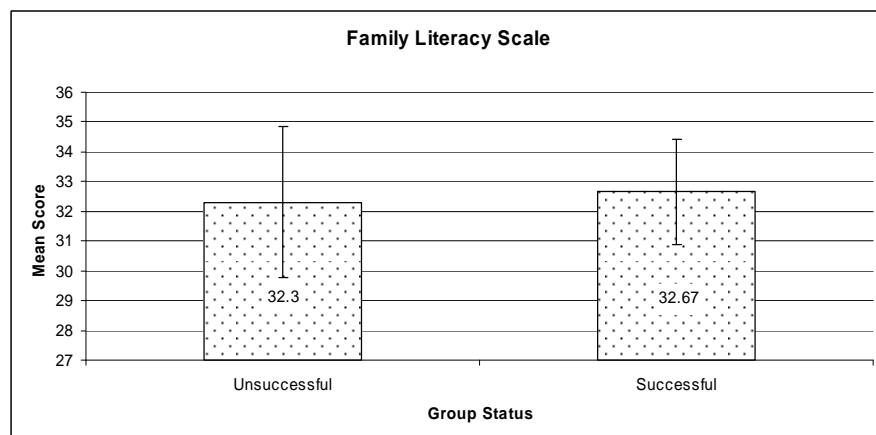
Study Questionnaire

One-on-one interaction

Each parent was asked to rate the time spent each day in one-on-one conversation with their child (see item #10 in the Appendix). One parent reported that they "constantly" were in one-on-one conversation with their child. As this leaves much to interpretation of what is actually meant by constantly (e.g., all waking hours of the day, all of the hours mother and child spends together), this participant was excluded from this particular analysis. To determine if there was a relationship between amount of reported time spent in one-on-one conversation and vocabulary performance, a Spearman rank correlation was performed. Reported time spent in one-on-one conversation did not correlate significantly with vocabulary performance. (*EVT-2*: (r (20) = 0.03, p =0.88), *PPVT-4*: (r (20) = 0.04, p = 0.86).

Household Noise

Parents were also asked to rate how noisy their house was on a scale of 0 to 100 (see #8 in the Appendix). One parent did not respond to this question. To determine if there was a relationship between how noisy a household reportedly was and vocabulary performance, a Spearman rank correlation was performed. Reported house noise did not correlate significantly with vocabulary skills. (*EVT-2*: (r (20) = 0.06, p = 0.79), *PPVT-4*: (r (20) = 0.23, p = 0.30)).

<u>Television/Radio Exposure</u>

Items 4 and 5 on the questionnaire were combined to determine how many hours per day each parent reported that their television or radio was on in order to determine how much background noise existed in the household each day. To determine if there was a relationship between how many hours per day the television or radio was on and vocabulary performance, a Spearman rank correlation was performed. Reported number of hours the television or radio was on per day did not correlate significantly with vocabulary skills. ((*EVT-2*: (r (21) = 0.13, *p* =0.56), *PPVT-4*: (r (21) = 0.06, *p* = 0.79)).

Discussion

This study sought to investigate whether there was a relationship between the ability to perceive speech in noise in infancy and vocabulary abilities at a later age. A variety of measures were used to assess vocabulary abilities. In addition, non-verbal intelligence was assessed to rule it out as a factor influencing the potential relationship between speech perception and vocabulary. As expected, there was no significant relationship between non-verbal intelligence and speech perception. No significant relationship was observed between vocabulary abilities and performance as infants on the speech perception task. This was found to be true on the standardized measures as well as the measures of vocabulary ability from the language sample.

Despite previous findings that relate infant speech perception to later language abilities (Benasich, Thomas, Choudhury, & Leppanen, 2002; Choudhury et al., 2007; Friedrich & Friederici, 2006; Molfese, Molfese, & Modgline, 2001; Newman et al., 2006; Tsao, Liu & Kuhl, 2004), this study found no relationship between the particular skill of perceiving speech in noise as an infant and vocabulary scores at five years of age. One possibility to consider is that speech perception in noise as an infant and language abilities are only related until a certain age. Many of the longitudinal studies that were discussed in this paper found relationships but were only assessing their participants during toddlerhood (Choudhury et al., 2007; Friedrich & Friederici, 2006; Tsao, Liu & Kuhl, 2004). Perhaps children receive the most benefit from being able to discriminate words in noise during the age at which they are first learning language or the age at which their vocabulary is most rapidly increasing. It is possible that children who initially had difficulty discriminating words in noise might have trouble with word learning at first, but eventually catch up. In future studies, it may be important to test participant's vocabulary at earlier ages and at multiple ages in order to gain more information about the influence speech perception in noise may have.

It is also important to consider that perhaps background noise as a form of input does not make as big of an impact on language learning as parent input does. A measure of parental input was analyzed in this study; however, it was only a rough general estimate of how much time a parent spends talking to their child. This does not provide us with information about the frequency of input given to the child throughout the language development years or the quality of input being provided to

the child. Frequency of language input has been shown to be an important factor in language development (Hart & Risley, 2005; Hoff, 2003; Huttenlocher et al., 1991; Panscofar & Vernon-Feagans, 2006). Perhaps the children with stronger vocabulary skills based on the measures in this study simply had parents who were able to speak to them more frequently and used an overall greater quantity of speech than those children who did not do as well. The presence of background noise in the household which may have obscured parent input at times may have been negated by the amount that a parent spoke. In other words, parents in noisier homes might have talked more. A novel word that was presented in the presence of background noise at one point may have been presented in a more suitable listening condition at another point, giving the child multiple opportunities to learn new vocabulary. Unfortunately, the only measure of parental input taken in this study was the amount of time the parent reported to spend in one-on-one conversation with his or her child. A broad estimate of total time spent in one-on-one conversation does not provide any information about how much actual speech was being used and the quality of the speech.

In addition to frequency of input, quality of parental language input has been found to be a large factor in language development (Hart & Risley, 2005; Hoff, 2003; Hoff & Naigles, 2002; Pan et al., 2005; Panscofar & Vernon-Feagans, 2006; Weizman & Snow, 2001). It is possible that the children who performed more successfully on the measures of lexical ability in this study had parents who used more sophisticated vocabulary, more complex sentences, and a greater number of word types than the children who did not perform as well. It may be more important for the parent to provide their child with more sophisticated input than it is to present

the information in a noise-free environment. Additionally, it is possible that the parents who have greater vocabulary diversity and use longer sentences give their children more opportunities to learn new words.

In terms of the original study, the infant speech perception task was not designed in order to be compared to later language skills. It is possible that the original speech perception task was not the best way to assess speech perception in noise. Additionally, it is possible that testing speech perception in noise at a time closer to when children are more actively beginning to learn language may have yielded more significant results.

It is also important to consider the possibility that infant speech perception in noise and vocabulary outcomes are simply not related. Perhaps significant results would have occurred by picking speech perception skills that are more closely related to how children learn language. Newman et al. (2006) were able to find lexical and syntactic skill relationships to infant segmentation tasks. However, the ability to segment fluent speech has been established as a major part of word learning (Hoff & Naigles, 2002) while only logical connections have been made between speech perception in noise and language learning. It will be important to continue investigating potential relationships between particular speech perception tasks and language as this knowledge has the potential to be used to screen infants who may be at risk for language disorders or language-learning difficulties during the language development period.

Limitations in the study design may relate to the results of this study. One limitation was the number of returning participants. Approximately 47% of the original participants came back for this study. The original series of studies took place over four years prior to the current study. During this time, many families moved away or had lost interest in traveling to the University of Maryland to participate in research. Although it is difficult to predict, it is possible that inclusion of greater number of participants would change the results of the study. A better turn-out of participants from each of the original studies may have better represented the abilities of the pass and no-pass groups.

Limitations also exist in the characteristics of the families that agreed to participate in this study. Families that are able to bring their children in for research studies typically do not represent a variety of SES levels. The majority of children in this study came from households with parents who had at least a college education. As previously discussed, SES, parental intelligence, and education level influences the kind of input a parent is providing to his or her child (Hart & Risley, 1995; Huttenlocher, et al., 2007). Although there were no significant differences between groups in terms of parental education, this pool of participants can not be considered truly representative of the general United States population. In addition, many of the participants would be considered above average in terms of vocabulary skills based on their performance. Sixty-five percent of the participants scored in the above average range (scores that were greater than one standard deviation above a standard score of 100) on the *EVT-2* and the 78% of the participants scored in the above

average range on the *PPVT-4*. None of the participants scored in the below average range on either test. This indicates that results of the study might have been affected by the above average vocabulary abilities of the participants. It is possible that children with advanced linguistic skills might not be as affected by noise in their environment. The non-verbal intelligence of the majority of the participants (68%) was within the average range, with 27% scoring in the above average range and 5% scoring in the below average range. This indicates that the results using the *KBIT-2* more closely resembled those of the general population.

Another issue is that this study only tested the participants one time. The problem with testing a single time, a number of years after the initial speech perception study, is that is it impossible to control for all of the life events that occurred between infancy and five years of age. There are a multitude of factors that could have contributed to or detracted from a child's language development. Although we attempted to gain information about some of them in the parent questionnaire (e.g., major medical events, information about daily life at home), it was not possible to control for it or gain enough information to get a full picture of the home environment.

Issues also existed with the manner in which the relationship between home factors and lexical abilities were measured in this study. It is difficult to avoid the bias that occurs when parents are filling out information about their own children and home interactions. It is impossible to give any more than an estimate of how much time a parent talks to their child one-on-one unless a researcher shadows a family during a "typical" day. Some of the questions also caused some confusion. For

example, some parents wrote down that they watched "no television" on a day-to-day basis but later mentioned watching multiple DVDs in a day suggesting that they were interpreting "television" to refer only to broadcast television, rather than to all cases where the television itself was on. It would have been beneficial to review the parent questionnaires for content rather than just making sure there were no questions left unanswered. Another way to avoid confusion and to make analyses easier would have been to give the parents choices on the survey questions instead of leaving them open-ended. For example, when asked how often they spent in one-on-one conversation with their children, parents responded with a broad range of times including one parent who responded that she is "constantly" in one-on-one conversation with her child. A multiple-choice questionnaire would have left less up to interpretation by the researchers.

Future Research

Research indicates that some infant speech perception tasks do relate to later language development. Additionally, research suggests that the quality of linguistic input that a parent gives to their child is important in lexical development. It seems logical that a disruption in the quality of input, such as from background noise, could have a negative impact on lexical development. However, results of the current study were not able to confirm this relationship. Perhaps children who have a weaker ability to understand speech in the context of noise eventually perform just as well as those with stronger abilities because they have parents with more diverse vocabularies. A potential study could investigate the relationship between performance on speech perception tasks in noise and parents' linguistic tendencies. After an initial visit

during which the infant would participate in a task that assesses speech perception in noise, vocabulary of the parents and their children would need to be assessed regularly, perhaps every three months. During the first years of language development, word learning quickly increases and so it would be important to assess the child multiple times during this period. Earlier receptive and expressive vocabulary skills could be measured by a parental questionnaire such as the *CDI* in addition to language sampling. Once the children reached approximately 30 months of age, they would be able to be tested with standardized tests such as the *EVT-2* and *PPVT-4*. Testing the child's vocabulary at a number of different ages may help to determine if at some age children with poorer speech perception in noise skills do lag behind their peers, but perhaps later catch up.   Language samples would be taken from the mothers at each of these points as well. Maternal vocabulary diversity and MLU would be examined in order to determine if there is a relationship between maternal linguistic skills and performance as an infant on speech perception tasks in noise. A study such as this could help to provide more information about the role that maternal linguistic input may play in compensating for background noise in the environment during the early stages of language learning. In addition, it might indicate a relationship between speech perception in noise and vocabulary development at an earlier age than tested in the present study.

Conclusions

      Although this study did not find any significant relationships between infant speech perception in noise and vocabulary outcomes, these relationships between speech perception and language should continue to be investigated. Past research has

implicated that some relationships do exist. Research suggests that parental input of language is a major factor of child language development and should be taken into account when investigating how infant speech perception in noise may relate to later language performance. In addition, assessing children at a variety of ages may provide more information about the potential impact that the ability to perceive words in background noise could have on language development.

Appendix

Parent Questionnaire

Participant 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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