

ABSTRACT

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STUDY

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While differences have been found in the ability of infants on a variety of speech perception skills including speech perception in the presence of background noise, the implications of these differences on later language skills are currently unknown. This study examines the relationship between a specific measure of infant speech perception in noise and later phonological awareness outcomes. In order to test this relationship, individuals who participated in Newman's (2005) study on infant speech perception in the presence of background noise were administered a battery of language, phonological awareness, and intelligence tests. Scores from these tests were analyzed to see if performance differences existed between those who had performed well as infants in the original study and those who had not. No significant differences between these two groups were found on the phonological awareness measures. Potential reasons for these findings and suggestions for future research are discussed.

INFANT SPEECH-IN-NOISE PERCEPTION AND LATER PHONOLOGICAL
AWARENESS SKILLS: A LONGITUDINAL STUDY

by

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Chapter 1: Introduction

Scholars, parents, and teachers have been attempting to understand the process of language acquisition for years. For infants, this process follows a very systematic and predictable progression (Hulit & Howard, 2002; McLean & Snyder-McLean, 1999; Reed, 2005; Santrock, 2005). However, for some children, the language development process does not go according to the standard schedule. In the United States, an estimated 2% to 8% of the preschool and Kindergarten-age population have specific language impairment (Law, Boyle, Harris, Harkness, & Nye, 2000; Tomblin, Records, Buckwalter, Zhang, Smith, O'Brien, 1997). Researchers and professionals are faced with the seemingly insurmountable task of predicting, understanding, and treating language disorders for which there are no definitive predictors, no single cause, and no single treatment approach that works for all individuals. Researchers are attempting to discover links between early measurable linguistic performance and the development of later language ability so they can better identify which children are most at risk of experiencing developmental language and reading disorders. Early identification and early intervention can then be provided, not only benefiting the children themselves, but also benefiting society. Early intervention has been found to save society money by decreasing long-term special education spending, grade repetition, welfare and juvenile justice costs (Diefendorf & Goode, 2005). The current study examines the relationship between infant speech-in-noise perception and the acquisition of various aspects of language to determine if infant speech-in-noise perception abilities impact later language learning. Specifically, this study examines the relationship between infant speech-in-noise perception and subsequent

development of phonological awareness skills. Below I discuss what is known about each of these domains.

Infant speech-perception and language development

Infant speech perception refers to the overall process by which an infant learns to obtain meaningful information from streams of speech. In order to obtain meaningful information from speech, the infant must be able to hear the phonemes in the speech stream (i.e., recognize the sounds /b/, /t/, and /g/ in a stream of speech), distinguish one phoneme from another (i.e., realize that the sound is /b/ not /d/), remember the order in which the speech sounds are presented (i.e., the word is “big,” not “gib” or “bgi”), compare the incoming speech sounds to speech sound combinations that the infant has heard before (i.e., “big” like I heard before in “big dog”), and determine if the intonation with which the groups of speech sounds is presented holds any meaning (i.e., “The dog is big.” vs. “The dog is big?”) (Hulit & Howard, 2002). Research has suggested that a variety of early infant speech perception skills are indeed related to later language ability. A sampling of these studies will be discussed.

Tsao, Liu, & Kuhl (2004) tested 28 full-term infants on phonetic discrimination (i.e., the ability to detect differences between individual phonemes). They examined how this skill might relate to later language development. To test their hypothesis that infant speech perception at 6 months of age predicts language development between the ages of one and two years, the researchers analyzed each infant’s ability to perceive a change between the Finnish vowels /y/ (a high-front vowel similar to the American English vowel /i/) and /ü/ (a high-back vowel similar

to the American English version of /u/). Finnish vowels were used instead of English vowels in an attempt to increase the difficulty level of the task and, as a result, to increase variability in performance between infants. Each infant's speech perception ability was assessed using a conditioned head-turn procedure (HT) which the authors describe in detail in their paper. In order to analyze the child's speech perception abilities, the authors not only examined the accuracy of infants' HT responses, but also the number of practice trials it took for the infant to meet the criterion to move on to test trials (i.e., how quickly was the infant able to learn the task). In order to track the infant's language development, the *MacArthur Communicative Development Inventory (MCDI)* (Fenson et al., 1993) was administered. At 13 months and at 16 months, the Infant Form of the inventory was administered. This inventory requires parents to complete a survey about their child's understanding and production of a variety of words. At 24 months, the Toddler form of the inventory was administered again. Regression analyses revealed a significant correlation between both measures of infant phoneme discrimination (i.e., accuracy of HT responses and number of practice trials to meet criterion) and parent-reported language abilities at 13, 16, and 24 months with children who scored better as infants on the measure of speech perception demonstrating higher scores on the *MCDI*. The authors acknowledge that this relationship is not necessarily a causal one. The authors note that on a trained HT task such as theirs, memory, attention, learning ability, and cognition could all come into play (Tsao, Liu, & Kuhl, 2004).

Newman, Bernstein Ratner, Jusczyk, Jusczyk and Dow (2006) examined the relationship between infant speech segmentation ability and later language ability. In

this study, performance on the *MCDI* at 2 years was compared to performance on speech segmentation tasks administered to infants. The researchers found that an infant's ability to recognize familiar words in connected speech (i.e. speech segmentation) was related to vocabulary at 2 years, as measured by the *MCDI* (Fenson et al., 1993). It was also related to later language scores at 4 to 6 years as measured by the *Test of Language Development – Primary 3rd Edition (TOLD-P:3;* Newcomer & Hammill, 1997) and the *Speech and Language Assessment Scale (SLAS;* Hadley & Rice, 1993). Further examination of *TOLD-P:3* scores indicated specific discrepancies in the areas of syntax and semantics between those who were better at segmenting speech as infants (i.e., “segmenters”) and those who were comparatively weaker at segmenting speech (i.e., “nonsegmenters”).

Finally, Molfese, Molfese, and Modglin (2001) tested the IQ and reading abilities of 96 children who had had their speech perception tested within 36 hours of birth as measured by Event-Related Potentials (ERPs), measures of brain activity collected through the use of electrodes placed on the head. Infants were presented with repeated /bi/ syllables with intermittent substitutions of /gi/ while their brain activity was monitored. Infants who performed well on the task, recognizing the switch between the /bi/ and /gi/ syllables, were found to have increased reading ability at age eight as measured on the Wide Range Assessment Test – Revised (WRAT-R; Jastak & Wilkinson, 1984).

Given these studies, it appears that there may be some relationship between early speech perception and later language acquisition. Logically this makes sense, because in order for the language learning process to take place efficiently, an infant

must be able to accurately perceive sound in his or her environment. It follows that an infant's ability to perceive speech sounds serves an important role in the development of speech and language by allowing the child to access the wealth of speech and language that surrounds him or her. Any deterrents to that speech perception would be expected to negatively impact this learning process and would be expected to result in decreased abilities in speech and language.

Impact of noise on speech perception

Background noise makes listening, reading, and learning new information difficult for school-aged children and adults. For example, Clark et al. (2006) examined the relationship between airport noise and children's performance on a variety of tasks. The reading comprehension of a total of 2,010 nine- and ten-year-old children from Spain, the United Kingdom, and the Netherlands was tested, and data on the amount of airport noise in their classrooms were also collected. The researchers found that airport noise was linearly correlated in a negative direction with reading comprehension. This relationship was consistent across the countries and across various socioeconomic and environmental factors.

Evans and Maxwell (1997) examined the impact of chronic noise exposure by comparing children regularly exposed to airport noise to children from a comparatively quiet school. The children were tested in a quiet room to differentiate between the effects of acute noise exposure (which would be obtained if the child was tested in the noisy classroom) and chronic noise exposure (which the child was

regularly exposed to that was presumed to impact performance even when the noise is no longer present). Not only did Evans and Maxwell find that children who are chronically exposed to noisy environments performed worse on reading comprehension tasks administered in quiet settings than those from quiet schools, they also found that the children at the noisy schools were not as able to understand speech in white noise whereas those in quiet skills were able to.

Infants have been found to require significantly louder presentation of stimuli in order to discriminate between relatively similar syllables (e.g., /ba/ – /ga/ and /ba/ – /da/) than do adults (Nozza, Rossman, and Bond, 1991). Judging by this study, speech perception is already more difficult for infants than adults in quiet environments. Moreover, infants are at an additional disadvantage compared to adults when listening to speech in the presence of noise. Nozza, Rossman, Bond, & Miller (1990) compared the ability of infants and adults to discriminate between speech sounds in the presence of noise by presenting repetitions of the syllable /ba/. The syllable /ga/ was inserted in experimental trials to see if the individual being tested was able to identify a change in the speech signal. Sixteen infants were conditioned to perform a head turn response when they detected the change from /ba/ to /ga/. Sixteen adults were asked to perform a similar task, but their response to the change was to press a response button rather than perform a conditioned head turn. The stimuli were presented at signal-to-noise ratios (SNRs) of -8, 0, 8 and 16 dB for infants, and adults were tested at signal-to-noise ratios of -12, -8, -4 and 0 dB. The performance of each group was plotted, revealing a similar slope of improvement as SNR increased, with infants clearly performing worse in each of the overlapping

levels of stimuli presentation (-8 dB SNR and 0 dB SNR). The authors interpret this as a disadvantage that infants face in perceiving details of speech in noise (Nozza, Rossman, Bond & Miller, 1990). Nozza, Miller, Rossman, and Bond (1991) confirm this disadvantage and add that infant's performance on tasks measuring speech discrimination in noise are reliable for both infants and adults. Thus, noise seems to pose more of a problem for infants than for adults, suggesting they may be particularly disadvantaged in noisy environments.

In Newman's (2005) study, infants were tested on their ability to recognize their own name in the presence of multi-talker speech background noise at a variety of ages and levels of background noise. The Newman (2005) study followed the procedures of Mandel, Jusczyk, and Pisoni's (1995) study in which infants were found to be able to demonstrate recognition of their own name in a quiet environment through a head-turn procedure. In both studies, researchers presented infants with four different names, their own name (e.g., "Jack"), a stress-matched foil name (e.g., "Ben"), and two names with different stress patterns (e.g., "Ethan" or "Cassie"). The specific head-turn preference procedure used for obtaining looking-time data is described in the original Newman (2005) study and in Nelson, Jusczyk, Mandel, Myers, Turk, and Gerke (1995). The duration of time spent looking at the perceived source of the sound (i.e., in the case of this study, one of two flashing red lights) was recorded for each name by the researchers.

As was observed in the Mandel, Jusczyk, and Pisoni (2005) study, infants should attend longer to familiar items, such as their own name than to less familiar speech. The Newman (2005) study increased the difficulty of the task by presenting

the names in the presence of multi-talker background noise. Under these circumstances, an infant would only be expected to attend longer to their own name if they are able to recognize what they are hearing.

Newman tested four different groups of twenty-five infants to see if they could identify their own name in different levels of noise. First, a group of 5-month-olds were tested at a 10 dB SNR. In order to assess each infant's abilities to attend to interesting speech in noise, the amount of time infants spent looking at a light in response to their hearing each name was averaged for each name presented to each child. These mean looking-times were then compared to see if the group was generally able to recognize their own name in noise (i.e., they attended longer to their own name than to the other names that were presented).

When the group of 5-month-olds were found to be able to perform the task at this level of background noise, the decision was made to conduct a second experiment examining how 5-month-olds would perform at a more difficult level, a 5 dB SNR. At this level, the infants attended to their own name and the stress-matched foil approximately equally, indicating that they were not recognizing their own names in this level of background noise. To follow up this study, the same experiment was conducted but with 9-month-olds instead of 5-month-olds to see if older children would be able to detect their own name at 5 dB. This group, like the second group of 5-month-olds, was also unable to detect their own name.

Finally, a group of infants even older than the 9-month-olds (the 13-month-olds) was tested at a 5 dB SNR. Unlike the previous two younger groups who had not been successful at 5 dB SNR, the 13-month-olds did demonstrate an ability to

recognize their own name when presented at 5dB SNR. This suggested that by 13 months, the speech perception in noise abilities of most infants had improved to the point that they could recognize their names in greater levels of background noise.

The Newman (2005) study showed that, as infants develop, their ability to perceive speech in the presence of background noise improves. At 9 months or younger, most infants required a 10 dB SNR in order to recognize their name, but by 13 months they were able to perform the same skill with only a 5 dB SNR. However, in each of the groups, there were some infants who performed better than others. In the studies where the majority of infants tested were able to recognize their own name in noise (i.e., the 5-month, 10 dB SNR study and the 13-month, 5 dB SNR study), some infants failed to recognize their own names and instead attended to the stress-matched foil names for longer. One possibility is that these infants who were unsuccessful may have had poorer speech perception in noise abilities compared to others tested at their age. In contrast, it is possible that, in the studies where the majority of infants tested were unable to recognize their own name in noise (i.e., the 5-month, 5 dB SNR study and the 9-month 5 dB SNR study), the infants who were able to recognize their own name in noise possibly had superior speech perception in noise abilities compared to others tested at their age. Although the results of this study suggest that some variation does exist between the ability levels of different infants, the impact that these differences in speech perception in noise have on later language outcomes is currently unknown. As this current study serves as a follow-up to the Newman (2005) study, the details of how Newman's study relates to this thesis will be discussed in greater depth in the discussion section later in this paper.

The differences that exist in children's abilities to perceive speech in noise may be an important factor for researchers to consider because much of a child's early speech and language exposure takes place in noisy environments. Approximately two-thirds of parents reported that when they speak with their infants, other members of the household are "frequently" also speaking (Barker & Newman, 2004) and thus are creating "noise" that potentially interferes with the child's perception of the signal. In day care settings, perception can be even harder than at home because within the typical daycare setting, background noise levels often exceeding the Environmental Protection Agency's recommended maximum levels of 70 dB (Evans & Maxwell, 1997). While the vast majority of infants are able to acquire speech and language adequately in spite of these less-than-optimal listening and learning environments, the possibility that infants who are less able to deal with background noise may be missing out on key aspects of the incoming speech and language signal could have far-reaching developmental implications across the domains of language. One aspect of language that it may influence is phonological awareness.

Relationship between speech perception in noise and phonological awareness

The term phonological awareness refers to the knowledge of how speech sounds and syllables can be broken apart into smaller units. Manipulating speech sounds (i.e., deleting sounds from the beginning, middle, or ends of words, adding sounds to the beginning, middle, or end of words, or substituting one sound in a word

for another sound), segmenting (i.e. breaking words into smaller components such as syllable, onset and rhyme, or individual phonemes), rhyming (i.e., detecting or producing rhyming words), blending individual speech sounds, onset/rhyme parts of words, or syllables to create words, and counting the number of syllables or speech sounds in a word are all ways of demonstrating phonological awareness (Stahl & Murray, 1994). Phonological awareness skills such as grouping words based on rime and onset of the words and blending syllables and phonemes to form words are used by children as they begin to learn how to read and spell (Bourassa & Treiman, 2007; Treiman & Zukowski, 1996), and these skills have also been found to relate to later reading ability (Leather & Henry, 1994; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997; Vellutino & Scanlon, 1987). As such, the area of phonological awareness is an important one for researchers to study.

Currently, hypotheses have asserted that speech perception is a precursory skill to the development of more advanced phonological knowledge and abilities. Such hypotheses argue that if an individual is unable to adequately perceive a word, he or she will not have a sufficient phonological representation of that word in order to perform phonological or phonemic awareness tasks on it. This basic premise serves as a portion of McBride-Chang's (1995) proposed theory of reading acquisition, derived after a review of nineteen speech perception studies conducted between 1978 and 1993, which suggests that innate speech perception skills (level 1) are used to develop phonological abilities (level 2) which in turn support the development of word reading ability (level 3).

If an individual's phonological representations of words are impaired by poor speech perception, as McBride-Chang proposes, and if noise makes listening more difficult for individuals in general, it would follow that poor speech perception could result in less fully-formed phonological representations of words if exposure to those words occurs in noisy environments. Additionally, it is possible that individuals who do not experience speech perception difficulties under acoustically ideal circumstances (but who have diminished ability to process speech in noise) may demonstrate decreased speech perception in the presence of background noise. In theory, this could result in weaker phonological representations of words during the language acquisition process that, in turn, may result in poorer overall phonological awareness skills.

While this makes sense in theory, the actual relationship between phonological awareness and speech perception in noise is currently up for debate. Boets, Wouters, van Wieringen, and Ghesquière (2007), while investigating the relationship among auditory processing ability, speech perception ability, and phonological awareness to literacy success among children with an increased familial risk for dyslexia, observed a relationship between phonological awareness and speech perception in noise. In their study, a battery of tests was administered to a total of sixty-two kindergartners. To assess phonological awareness, the children were administered a rhyming task and three "sound identity tasks" in which the child was asked to select a word from a field of four that had the same beginning sound, ending sound, or rhyme as a given word (Boets, Wouters, van Wieringen, Ghesquière, 2006). To assess speech perception in noise, the children listened to a list of frequently-used,

monosyllabic words at -1, -4, and -7 dB SNRs and were required to repeat the word they heard. Literacy skills were assessed at the end of the first grade through a spelling test, standardized reading tests, a one-minute word reading test, a non-word reading test, and four additional tests to assess reading speed and accuracy. As a group, the children who were determined to have “literacy impairments” at the end of the first grade scored lower as kindergartners than individuals judged to have normal literacy on both the phonological awareness measures and the speech-perception in noise measures. However, not all of the literacy-impaired individuals demonstrated deficits in speech perception in noise and not all individuals with speech-perception-in-noise deficits demonstrated decreased phonological awareness skills. Moreover, not all individuals with poorer phonological awareness demonstrated concurrent deficits in speech perception in noise. To summarize this study, although both speech perception in noise and phonological awareness appear to be linked in some way to later literacy success, it is not clear that they are linked to each other.

Research Questions/Hypothesis

The purpose of the current study was to determine whether individuals who, as infants, demonstrated poorer ability to perceive speech in noise (as measured in the Newman 2005 study) have more difficulty with phonological awareness tasks than children who had demonstrated good ability to perceive speech-in-noise. To test the hypothesis, this study tracked children who had already been tested on their speech-in-noise perception abilities as infants and compared the phonological awareness ability of those who had been successful as infants to those who had been unsuccessful. If these measures of speech perception in noise are predictive of the

development of later phonological awareness skills, one would hypothesize that children who performed more poorly in Newman's (2005) speech-in-noise perception study would perform more poorly on measures of phonological awareness than children who demonstrated better speech-in-noise perception abilities in the original study.

Chapter 2: Methods

Participants

The experimental sample consisted of 41 children (15 males and 26 females) with no history of language or developmental disorders. The participants ranged in age between 4 years 6 months and 6 years 1 month old (mean age = 5 years 3 months). Participants were assigned to their groups based the experiments in which they participated in in the original Newman (2005) study. Because the original experiments conducted by Newman (2005) yielded different patterns of results for different testing ages and noise levels, the current 41 participants were also grouped according to whether or not the study they participated in as infants was generally "successful" (as described in the current research study as original experiments in which most of the infants were able to recognize their own name in the level of background noise it was presented) or generally "unsuccessful" (experiments in which the majority of the infants were unable to recognize their own name in the level of background noise it was presented). The "successful" studies were the 5-month 10 dB study and the 13-month 5 dB study, while the "unsuccessful" studies

were the 5-month 5 dB study and the 9-month 5 dB study. Table 1 summarizes the participation in each study by group.

Table 1: Participant Information

Original Study	Number of Participants	Age Range	Mean Age	Were participants generally successful?
5-month 5 dB	12	4:7 – 5:7	5:3	No
5-month 10 dB	18	4:6 – 6:1	5:3	Yes
9-month 5 dB	8	5:1 – 5:7	5:4	No
13-month 5 dB	9	4:10 – 5:3	5:0	Yes

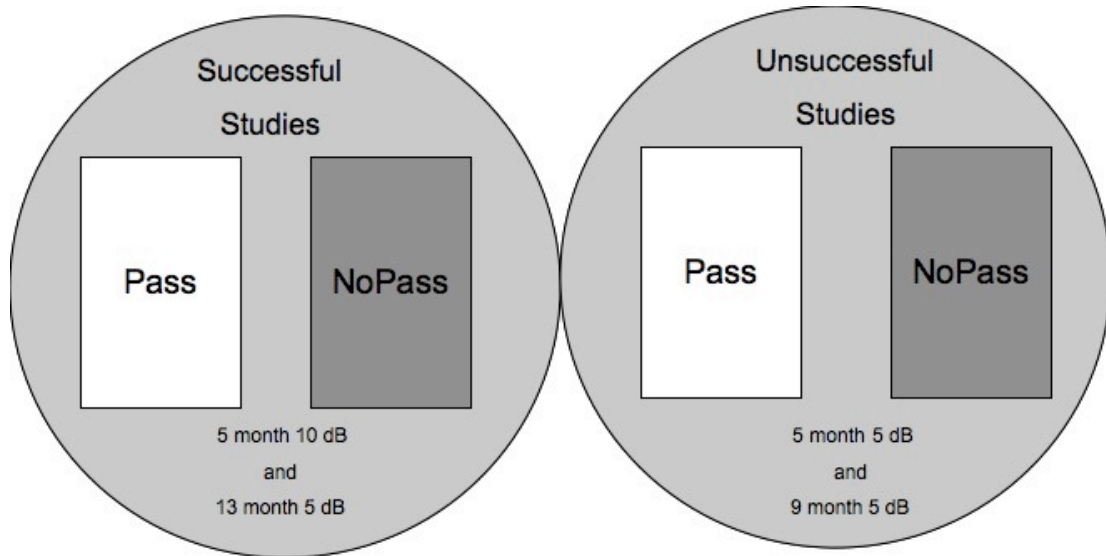
Overall mean age = 5:3

Overall range = 4:6 – 6:1

Note: This table includes participants who were excluded due to abnormal tympanometric findings

In addition to the general successfulness of the study the child had participated in as an infant, participants were coded as having originally “passed” or “not passed” Newman’s (2005) study. An infant was deemed to have “passed” the earlier speech-in-noise perception task if they demonstrated listening to their own name for a minimum of 2 seconds longer than they listened to a stress-matched name, and were labeled as “NoPass” if they did not. Since an infant who did not recognize his or her own name in noise would be expected to attend approximately equally to both names (i.e., to not show a preference for either stimulus item), it would be equally likely for an infant who did not recognize his or her own name to attend to it for a few milliseconds longer than the stress-matched name by chance as for them to attend to the stress-matched name for longer than their own name. To account for this, we examined the differences in looking-time duration to see if there appeared to be a natural cut-off in the data where individuals who appeared to be performing at chance would be classified as “NoPass.” The two-second cut-off was implemented by researchers after this examination of looking-times recorded in the original study. Figure 1 illustrates the categories into which participants were placed.

Figure 1: Categories based on original study performance



Participants were recruited using the following procedure: Letters were sent to the parents of the original participants in Newman's (2005) speech perception in noise study. This letter was followed up by a phone call. If phone contact could not be established, attempts to include the participant in the current study were discontinued. When the parents were contacted, the study was explained to them and then their children were invited to participate in the study. Prior to scheduling a testing time, the parents of those children who agreed to participate in the study were asked a series of three pre-screening questions. They were asked what the primary language spoken in their home was, if the child had a diagnosis of hearing loss, and if the child had a diagnosis of a developmental delay. Participants who did not speak English as their primary language or who had diagnoses of hearing loss or developmental delays were not included in the current study as these factors could

invalidate the scores of standardized tests and could impact understanding of directions on both standardized and non-standardized assessments. Of the 80 families who were initially contacted, 48 families agreed to participate in the study (an acceptance rate of 60%). Two of the families included twins who were both tested, so the number of initial participants was 50. Of the 50 children who were available to participate in this study, three participants were excluded from the study before testing was started due to previously undisclosed language-related diagnoses (epilepsy and developmental delays) that were revealed by the pre-screening questions. Six participants' data sets were excluded after testing was completed based on the results of tympanometric testing which indicated possible middle-ear disturbances that might interfere with their ability to perform the experimental tasks and interfere with the validity of this study. This left 41 participants with usable data (15 boys and 26 girls). Approximately 51% (N=21) of these had recognized their name during initial speech-in-noise perception testing as infants, and approximately 49% (N=20) had not. This suggested there was not a bias in parents' decisions to re-enroll their child in the follow-up testing based on factors directly related to performance on the initial speech-in-noise perception assessment as infants.

All of the participants were native speakers of English, although two of the children were being exposed to a foreign language for more than 10% of their waking time. The languages they were exposed to were Hebrew and sign language (reportedly used because of extended family members with hearing loss). The group consisted of European Americans (89%), African or African Americans (6%), and children of mixed ethnicity (6%). Ninety-eight percent of the primary caregivers

reported having some amount of higher education: 3 earned professional school degrees, 8 earned bachelor's degree, 19 earned master's degrees, and 10 earned a Ph.D., M.D., or equivalent. One parent reported a high school diploma as his or her level of highest education.

Materials

For the current study that focused on phonological awareness, the tests of interest were the *Yopp-Singer Test of Phoneme Segmentation* (Yopp-Singer; Yopp, 1995), and seven subtests of the *Phonological Awareness Test* (PAT; Robertson & Salter, 1997). The subtests were arranged in order of increasing complexity beginning with a receptive task at the word level and increasing to the most complex expressive phoneme deletion task (Troia, Roth, & Graham, 1998; Troia, 2004; Roth, 2004). The *Yopp-Singer* was administered following the syllable segmentation subtest of the *PAT* because it was substituted for the Segmentation- Phonemes section of the *PAT*. The decision was made to assess earlier developing skills before later developing skills in order to provide the children with early success and to cover a wider spectrum of age and ability levels. Further description of these subtests follows:

PAT

The specific subtests of the *PAT* that were used for this study were the Rhyming- Discrimination, Rhyming- Production, Blending- Syllables, Blending- Phonemes, Segmentation- Syllables, Deletion- Compounds and Syllables, and Deletion- Phonemes subtests. Similar to other tests of

phonological awareness that were considered for use in this study, the *PAT* is designed to be administered to children age 5 and above. Because of the age range of the group who participated in this study and a lack of standardized measures of phonological awareness that provide norms for children below the age of 5, raw performance scores from the seven subtests of the *PAT* were unable to be transformed into standard scores. The *Yopp-Singer* is not a norm-based assessment and, as such, yields no standard scores. As a result, raw scores from all eight assessments were used for comparisons.

The test-retest reliability of the *PAT* subtests for individuals between the ages of 5 years of age and 5-years, 5-months of age ranged between $r = .64$ (Blending- Syllables) and $r = .92$ (Deletion- Compounds and Syllables). Internal consistency for this age group ranged between $KR20 = .77$ and $KR20 = .91$. For individuals between the ages of 5-years, 5-months of age and 6 years of age, test-retest reliability ranged between $r = .53$ (Deletion- Compounds and Syllables) and $r = .95$ (Blending – Syllables). Internal consistency for this age group was also high, ranging between $KR20 = .78$ and $KR20 = .94$. These reliability values support the decision to use the *PAT* to measure phonological awareness.

Rhyming- Discrimination

The *PAT*'s Rhyming- Discrimination subtest is designed to test a child's ability to determine if two words demonstrate a correspondence in their terminal sounds to a degree that would be

recognized by adults as rhyming with each other. The Rhyming-Discrimination subtest of the *PAT* starts by providing one practice item during which the child is asked whether a pair of words presented by the examiner rhyme or do not rhyme. Reinforcement or correction is given to the child's response on this practice item as needed.

Following the practice item, a series of ten pairs of words are read aloud to the child. Six of the items are pairs of rhyming words and four are pairs of nonrhyming words. The child's responses are marked as accurate if they correctly identify a pair of two rhyming words (e.g., fan/man) as rhyming or if they correctly identify a pair of two nonrhyming words (e.g., ring/rat) as "different." The child's score on this subtest is determined by counting the number of correct responses. The maximum score a child could earn on this subtest is ten.

Rhyming- Production

The *PAT*'s Rhyming- Production subtest is designed to assess a child's ability to generate a word that rhymes with a stimulus word presented by the examiner. In order to assess this ability, the child is asked to tell a word that rhymes with a word given by the examiner (e.g., "Tell me a word that rhymes with "cat"). The child is told that he or she is permitted to "make up" a word in necessary. One practice item is administered following these instructions, and reinforcement or correction is provided on this item based on the accuracy of the child's

response. Then, ten words are read aloud one at a time by the examiner, and the child is asked to provide a rhyming word for each word. Some of the stimulus words are monosyllabic and some are disyllabic. The child's response is marked as correct and assigned a point if they respond with a real word or a made-up word that rhymes with the stimulus word provided. The score for this subtest is determined by totaling the points that the child earns for producing acceptable rhymes. The maximum score possible on this subtest is ten.

Blending- Syllables

The *PAT*'s Blending-Syllables subtest is designed to assess a child's ability to combine parts of words presented at the syllable level to create familiar words. To assess this skill, the examiner presents a disyllabic or multisyllabic word that has been segmented into its syllables, asking the child "What word is this?" immediately before presenting each segmented word. For example, when presented with the syllable string "/te/ - /bəl/," the child is to respond "table." Approximately one-second of silence is left between each syllable in order to avoid making the answer too obvious to the child, and the intonation and stress on each syllable is presented as uniformly as possible to avoid providing prosodic cues that may impact the child's performance. As with other *PAT* subtests, one practice item is

administered and followed by reinforcement or correction, as appropriate, to let the child know if he or she is performing the task correctly or not. Following the practice item, ten segmented stimulus strings are read orally one string at a time to the child by the examiner. These stimulus items range in length from two to four syllables. A response is considered correct if the child provides the complete, blended version of the word that was presented by the examiner in segmented form (e.g., when presented with the stimulus item “/te/ - /bəl/” the correct response would be “table.”). A child’s score is equivalent to the number of correct answers on the subtest, and the maximum possible score on this subtest is ten.

Blending- Phonemes

The *PAT*’s Blending- Phonemes subtest is designed to test a child’s ability to combine individual speech sounds to create familiar words. In order to assess this ability, the child is asked to identify a word after being given the “sounds” of the word. To elicit this response, the examiner prompts “What word is this?” before presenting the stimulus item (e.g., the examiner say “/k/ + /aɪ/ + /t/”, and the child is supposed to respond by saying “kite”). The examiner inserts a silent pause of approximately one second between each pair of phonemes in the word, to avoid making the answer too obvious to the child. One practice item is provided. Reinforcement or correction

is provided as needed on this practice item. Following the practice item, a series of ten stimulus items are given, ranging between two and five phonemes in length. Responses are judged to be correct if the child provides the complete, blended version of the word that was presented as a segmented string of speech sounds by the examiner. The total for this subtest is determined by adding up the number of correct answers. The maximum score possible on this subtest is ten.

Segmentation- Syllables

The *PAT*'s Segmentation- Syllables subtest is designed to test a child's ability to break words into their composite syllables. For this assessment, the examiner assists the child by "clapping-out" the syllables in a word in unison with the examiner's spoken model of the word. For example, if the stimulus word was "monkey," the examiner and the child would clap two times (one clap for each syllable). Once the child is able to clap along with the examiner, he or she is asked to "clap one time for each part or syllable" in an orally-presented word. During this practice trial, correction or reinforcement is provided based on the child's response. Following the practice item, the examiner presents ten more stimulus words ranging in length between one and four syllables. If the child claps the correct number of syllables in the word, he or she earns one point. The total number of

points accumulated by the end of this subtest serves as the child's score. The maximum score possible on this subtest is ten.

Deletion- Compounds and Syllables

The Deletion- Compounds and Syllables subtest of the *PAT* is designed to assess a child's ability to break apart words into smaller segments and to manipulate those segments by deleting specific parts of spoken stimulus words. For this subtest, the child is asked to say a word, and then to say the word again leaving out a specified syllable. After being given instructions, the child is given one practice item and his or her response is reinforced or corrected by the examiner accordingly. Next, ten stimulus items are presented one at a time orally by the examiner. Half of the words are compound words (e.g., "spaceship" or "baseball") and half were multisyllabic words that were not compound (e.g. "octopus"). The child's answer is judged to be correct if he or she responds with the part of the word left after following the examiner's directions (e.g., the correct response to "Say 'baseball' but don't say 'base'" would be for the child to say "ball"). The child's score is determined by counting the number of items on this subtest that the child answers correctly. The maximum possible score on this subtest is ten.

Deletion- Phonemes

The *PAT*'s Deletion- Phonemes subtest closely resembles the Deletion- Compounds and Syllables subtest with the exception that instead of being asked to delete a whole syllable from a given word, the child is asked to delete a single phoneme. As with the Deletion- Compounds and Syllables, children are given one practice item during which they could be reinforced or corrected based on their response accuracy (e.g., the correct response to “Say ‘cat’ but don’t say ‘/k/’” would be “at”). Next, ten stimulus items are presented orally by the examiner one at a time. The child’s responses are judged to be correct if he or she responds with the part of the word that would be left after excluding the phoneme specified by the examiner. The child’s score is determined by counting the number of items on this test that the child answers correctly. The maximum score possible on this subtest is ten.

Yopp-Singer Test for Phoneme Segmentation (Yopp-Singer)

The *Yopp-Singer* is an orally-presented test designed to assess a child’s ability to segment words into their individual phonemes. For this assessment, the child is seated facing the examiner and is told he or she is going to play a “word game” requiring the child to say each *sound* (i.e., not each letter) he or she hears in the word the examiner says (e.g., the word “race” would be segmented into the phonemes of /r/, /e/, and /s/ instead of the letters “r,” “a,”

“c,” and “e”). The examiner models the task, and then presents three practice items. Twenty-two stimulus items follow the practice items. All stimulus items are monosyllabic words (e.g. “three,” “lay,” “race”). In contrast to most standardized assessments, the child taking the *Yopp-Singer* is either reinforced or corrected based on the accuracy of his or her response to all of the individual practice and test stimuli. An item is scored as correct if the child successfully segments the stimulus word into its each of its separate constituent phonemes in the order in which they occur. The score for this test is the number of items correctly answered. The maximum score possible is twenty-two.

The *Yopp-Singer* was substituted for the phoneme segmentation subtests on the *PAT* for two reasons. First, the *Yopp-Singer* has research supporting its superior internal consistency (Cronbach’s $\alpha = .95$) as compared to the *PAT*’s phonological segmentation subtest ($KR-20 = .82$). While the *Yopp-Singer* does not report test-retest reliability, the *PAT* phonemic segmentation subtest’s test-retest reliability ($r = .61$) shows this subtest as a relatively weaker subtest than others included in the *PAT*. Second, the *Yopp-Singer*’s use of frequently-occurring stimulus words would make it easier for the younger children in the study to perform the task (Troia, 2004). The choice was made to use the *Yopp-Singer* instead of the *PAT*’s segmentation subtest in the hope that using the more familiar words of the *Yopp-Singer* (e.g., “she,” “wave,” “that,” and “red,” compared to the *PAT*’s stimuli such as “plop,” “liver,” and “eyebrow”) would allow the researchers to

better detect beginning understanding of this phoneme segmentation skill in the young children who served as our participants.

Kauffman Brief Intelligence Test – Second Edition (K-BIT 2)

As an experimental control, the *Matrices* subtest of the *Kauffman Brief Intelligence Test-Second Edition (K-BIT 2; Kaufman & Kaufman, 2004)* was included as a control measure because non-verbal intelligence would not be expected to be impacted by infant speech-in-noise perception abilities.

Additional Tests

As this study was conducted as a part of a group of studies examining a wider variety of language outcomes (beyond phonological awareness) that might be affected by different levels of infant speech-in-noise perception ability, additional standardized language tests were given during the testing session. The larger test battery consisted of the *Expressive Vocabulary Test-Second Edition (EVT-2; Williams, 2007)*, the *Peabody Picture Vocabulary Test-Fourth Edition (PPVT-4; Dunn & Dunn, 2007)*, and the Grammatical Understanding, Sentence Imitation, and Grammatical Completion subtests of *The Test of Language Development-Primary Third Edition (TOLD-P:3; Newcomer & Hammill, 1997)*. The complete test battery was used to specifically assess syntax, phonological awareness, and semantics, as well as non-verbal intelligence. Responses required for the tests included both

pointing to pictures, clapping, and giving verbalized responses to stimulus items.

Parent Surveys

The *Speech-Language Assessment Scale (SLAS)* (Hadley & Rice, 1993), the *Family Literacy Scale* (Morrison, McMahon-Griffith, Williamson, & Hardway, 1993), the *Brown Attention-Deficit Disorder Scales for Children and Adolescents (Brown ADD Scale)* (Brown, 2001), and a researcher-created survey designed to assess the language and literacy environment in the home were given to parents to fill out. These parent surveys were used to collect information about the demographics of the participants, attention abilities, current language skills, home language and literacy environment in the home (e.g., how many books does the child own, how does the child's language ability compare to other children's, what is the typically level of noise in the house, has the child had a history of ear infections).

Procedure

When participants arrived for the study, they and their parent(s) were escorted into a therapy room equipped with a one-way mirror. A description of the study and the tasks that the child would be asked to do was provided to the participant's parent and informed consent was obtained. Once consent was obtained, the participant's parent was directed to an observation room.

After the participant's parent(s) left the testing room, instructions were given to the participant about what tasks he or she would be expected to perform.

Participants were told that they were going to play some thinking, listening, pointing, and word games with the clinician. They were told that once they finished completing all the games (tests), they would be able to choose a prize to take home with them.

During testing, participants were administered a battery of standardized language and cognitive tests which are described in the Materials section of this paper. Of this test battery, only the scores from the selected portions of the *PAT*, the *Yopp-Singer*, and the *K-BIT 2* were used to address the research question that is being addressed in this thesis paper about the relationship between infant speech-in-noise perception and various measures of phonological awareness. The results from the other tests in the larger test battery were utilized by other student researchers for their examination of the relationship between infant speech-in-noise perception and the other language outcomes mentioned above.

In addition, a number of surveys were given to the child's parent for them to complete while their child was being tested. Also, each participant was asked to name the letters of the alphabet given a printed list of upper-case letters arranged in a random order and to describe a short picture book in order to obtain a sample of spontaneous language.

Tympanometric screenings were performed on each participant at the end of the testing session to rule out current ear infections or other types of middle ear dysfunction that may interfere with test performance. Such problems were important to eliminate since the other tests in the battery were attempting to assess central language abilities and not the effects of peripheral hearing disorders. Any disturbances in hearing would be especially important on tasks such as the

phonological awareness measures that required clear perception of the stimulus words in order to respond correctly. An audiology clinician reviewed all tympanograms and interpreted the tympanograms in cases where the results were abnormal in order to determine whether the participant's middle ear status could affect the results of the study. As tympanometric screening was regularly done without an audiologist present during the testing sessions, results of the tympanometric screening were completed after all of the testing was completed. As previously mentioned, six participants' data were later excluded based on the audiologist's interpretation of the results of the tympanometric screening.

Table 2

<u>Test Administration Order</u>
1. <i>Expressive Vocabulary Test – Second Edition</i>
2. <i>Peabody Picture Vocabulary Test- Fourth Edition</i>
3. Language sample
4. Alphabet naming task
5. Phonological awareness tasks
6. <i>Test of Language Development- Primary Third Edition</i>
7. <i>Kaufman Brief Intelligence Test – Second Edition</i>
8. Tympanometric screening

The order in which tests were presented in the test battery is reported in Table 2 and was selected in an attempt to minimize overlapping stimulus items and fatigue. The *EVT-2* and *PPVT-4* served as “icebreakers,” requiring only minimal responses from the child. Following these two standardized tests, the language sample was

collected and the alphabet-naming task was administered, allowing the child a break from more rigidly-structured standardized testing. Following this “break,” the phonological awareness tasks were administered. These particular phonological awareness tasks require the child to pay close attention to orally presented stimulus items and to follow sets of instructions that changed between each of the eight phonological awareness measures included in this section of the battery. The *TOLD:P3* and the *KBIT-2* were administered after the phonological awareness tasks. Tympanometric screening was the final assessment procedure included in the battery. This was saved until last because the researchers thought it would be easier to complete after the child had developed rapport with the clinician during the earlier testing as a way to alleviate any anxiety the child might have about having the tympanometric probes placed.

All testing was conducted by three second-year graduate student clinicians at the University of Maryland Speech and Hearing Clinic. All three graduate student clinicians were familiar with the tests that were included in the test battery and were proficient in administering and scoring the chosen tests. To avoid examiner bias, the examiners were kept unaware of the children’s performance on speech-in-noise perception measures as infants until all testing had been completed and all test scores had been verified.

Sessions were recorded in a quiet room by the clinicians using a various models digital voice recorders and a digital video recorder so that scoring errors could be amended if necessary. Participants were monitored for fatigue and were given breaks as needed. Administration of all tasks took approximately one-and-a-half

hours per participant. Performance data were collected and recorded during all the testing sessions, and tests were scored immediately after each testing session was completed. After all tests for each child were scored according to the procedures outlined in each test's administration and scoring manuals, raw scores and standard scores (when applicable) were calculated and entered into a Microsoft Excel database where they were kept until testing for all 47 participants was complete. As previously mentioned, six of the 47 children who were tested later had their data removed from this database based on the tympanometry results described earlier. This left 41 sets of test scores in the database.

In order to insure the reliability of the scores obtained by the researchers, all score sheets were reviewed by the individual child's test administrator at the conclusion of testing to ensure that the child's age was correctly calculated, the child's raw scores had been correctly tallied, and that the raw scores had been correctly converted into correct standard scores, where applicable. Following this, 30% of the score sheets were checked by a different researcher to verify the accuracy of the age calculations, raw score tallies, and standard score conversions. All changes proposed by the second researcher checking a score sheet were discussed with the original examiner until a consensus was reached. Inter-judge reliability measures for this score verification procedure are not available. Additionally, the scores in the Excel spreadsheet were verified by two of the researchers by comparing the test protocol forms to the scores in the spreadsheet prior to running any of the statistical analyses.

Chapter 3: Data Analysis and Results

For the purposes of this study, performance as infants on Newman's (2005) measure of speech-in-noise perception served as the independent variable.

Performance on the phonological awareness tasks (i.e., raw scores from the eight measures of phonological awareness) served as the dependent variable measures for the current study.

As mentioned before, because of the age range of the children who participated in this study and a lack of standardized measures of phonological awareness that provide norms for children below the age of 5 years, the seven subtests of the *PAT* were unable to be transformed to standard scores. The *Yopp-Singer* is not a norm-based assessment and, as such, yields no standard scores. As a result, raw scores from all eight assessments were used for comparisons. As previously mentioned, the score for each phonological awareness subtest was the total number of items correct on that subtest. For all of the *PAT* subtests, a score of 10 was the highest possible score that could be earned. The *Yopp-Singer* contained 22 items, and therefore, a score of 22 is the highest possible score that could be earned.

Descriptive statistics for four groups of participants based on 1) whether they had participated in the generally successful or unsuccessful studies and 2) whether individuals in these studies were classified as "Pass" or "NoPass" can be found in Table 3.

Table 3: Descriptive statistics for phonological awareness subtests

Test	Pass/NoPass	Successful			Unsuccessful		
		N	Mean	St Dev	N	Mean	St Dev
Rhyme Discrimination	Pass	13	9.54	0.66	8	8.75	2.06
	NoPass	10	8.9	1.6	9	9	1.5
Rhyme Production	Pass	13	8.31	2.06	8	6.75	3.37
	NoPass	10	7.8	3.05	9	8	2.6
Blending Syllables	Pass	10	8.69	1.18	8	8.88	1.36
	NoPass	13	7.8	2.25	9	8.56	1.51
Blending Phonemes	Pass	13	4.46	3.55	8	4.25	3.69
	NoPass	10	3.6	3.09	9	5.44	3.71
Segmenting Syllables	Pass	13	5.38	3.02	8	6	2.98
	NoPass	10	6.8	2.78	9	5.44	2.55
Yopp-Singer	Pass	13	7.92	7.41	8	10.44	6.94
	NoPass	10	8.2	8.75	9	11	8
Deleting Compound Words and Syllables	Pass	13	6.08	2.6	8	5.75	2.61
	NoPass	10	7.7	1.49	9	7.22	0.972
Deleting Phonemes	Pass	13	4.92	3.5	8	4	2.726
	NoPass	10	4.4	3.53	9	5.11	3.41

Of note in Table 3 are the high mean scores on several of the subtests (e.g., Rhyme Discrimination, Rhyme Production, and Blending Syllables). Ceiling effects may have impacted these tests and may indicate that the skill may have been already acquired by most of the children of the age tested in the study. Second, it is important to realize that several of the subtests have high standard deviations. For the Rhyme-Production subtest, for example, the range within 1 standard deviation of the mean for those who did not pass in the successful studies would be from 4.75 to 10, a very broad range. The high variability in scores on each subtest combined with the low number of items per subtest would make finding significant differences between groups very difficult.

Also, it is interesting to note that the “Pass” group only performed better than the “NoPass” group on 5 of the 8 subtests among those who initially participated in the successful studies and on only 2 of the 8 of the subtests among those who initially participated in unsuccessful studies as illustrated in Figure 2. This superficial examination of group result patterns does not support the hypothesis that individuals

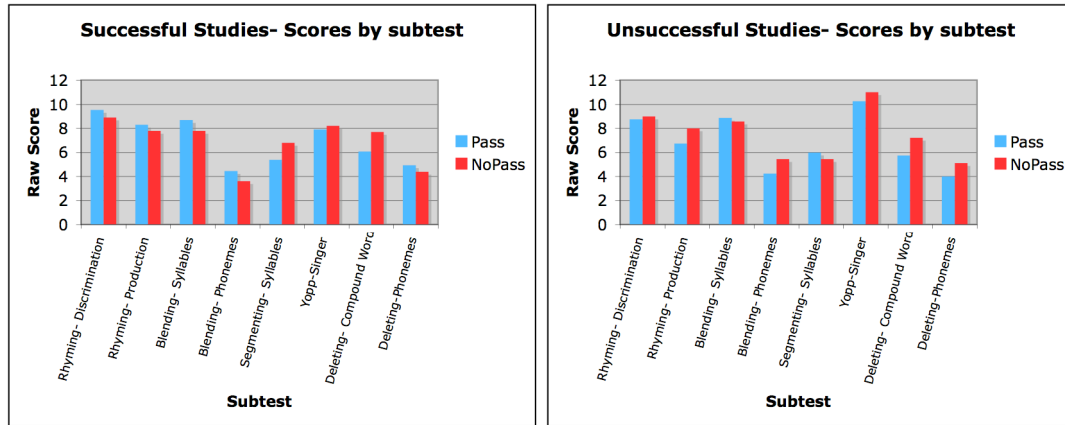


Figure 2: Mean scores by subtest for successful and unsuccessful studies (maximum score is 22 on the Yopp-Singer and 10 on all others subtests)

with better speech perception in noise as infants will grow up to have better phonological awareness skills.

Statistical analyses of the composition of the groups was conducted using SPSS version 16.0 to determine if non-linguistic factors differed between groups to an extent that they needed to be considered in analysis of the phonological awareness data. Initially, the researchers were concerned about using raw scores to make comparisons between groups, as the number of items a child is able to get correct would be expected to increase as a function of increased age. If one group was significantly older than the other group (i.e., if the “Pass” group was older than the “NoPass” group), the older group would be expected to answer more items correctly than the younger group and therefore would be expected to have a higher score than the younger group. This would interfere with detecting the true relationship between infant speech perception and phonological awareness ability. Likewise, a child with higher nonverbal intelligence may perform better than a child with lower nonverbal

intelligence child simply because a more intelligent child might perform better on any test and not because of anything to do with their speech perception ability. While a correlation between nonverbal IQ and phonological awareness may be interesting, it would not provide any information relevant to the hypothesis of this thesis. The comparison of scores on the *K-BIT 2* and of age is illustrated in Figure 3.

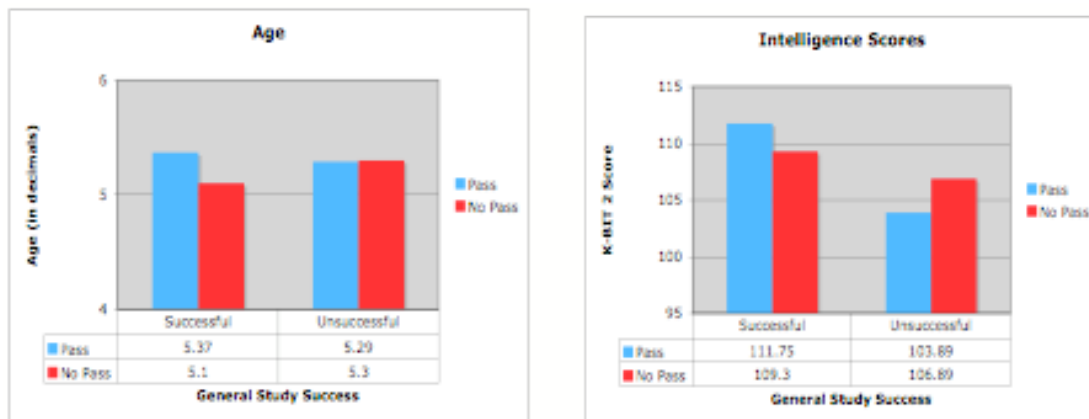


Figure 3: Mean age and mean K-BIT 2 score comparisons

Because age and IQ are both non-linguistic factors that could be expected to impact test performance and that could obscure phonological awareness differences, particularly when using raw scores, t-tests were conducted to determine if significant differences existed in these areas between individuals who passed and those who did not pass as infants in both the generally successful studies and the generally unsuccessful studies. The mean ages for participants in the successful studies were 5.37 years for those in the “Pass” group and 5.1 years for those in the “NoPass” group. In the unsuccessful studies, the mean age was 5.29 for the “Pass” group and 5.3 years for the “NoPass” group. For the successful studies, the mean KBIT-2 score for the “Pass” group was 111.75 and mean score for the “NoPass” group was 109.3.

For the unsuccessful studies, the mean KBIT-2 score was 103.89 for the “Pass” group and 106.89 for the “NoPass” group. No significant differences were found between those who passed as infants and those who did not pass as infants in either the generally successful or generally unsuccessful studies at the $p < .05$ level. Results of these t-tests are reported in Table 4.

Table 4: T-test results for group differences on age and K-BIT 2 scores

	Age				K-BIT Score		
	<i>t</i>	<i>df</i>	sig. (2-tailed)		<i>t</i>	<i>df</i>	sig. (2-tailed)
Successful Study	-1.314	21	0.203		-0.371	20	0.715
Unsuccessful Study	0.219	16	0.829		0.536	16	0.599

As the differences between the groups were found to be not statistically significant, the researchers decided that there was no need to covary age or nonverbal intelligence in further analyses. Despite the fact that raw scores were used in these analyses and phonological awareness raw scores would be expected to be impacted by differences, especially in age, based on these statistical results one would expect that raw score differences resulting from age or nonverbal intelligence would “wash out.”

Two separate multivariate analyses of variance (MANOVAs) were completed to identify differences in phonological awareness for both the generally successful studies (the 5 months at 10 dB and 13 months at 5 dB experiments) and the generally unsuccessful studies (5 months at 5 dB and 9 months at 5 dB experiments).

Phonological awareness subtest scores were the dependent variables and performance as an infant (Pass vs. NoPass) was the independent variable. No significant differences in any of the phonological awareness scores were found at the $p < .05$ level

based on Pass-NoPass performance of the children whether they were in the generally successful group (Wilks's $\lambda = .483$, $F(8,14) = 1.873$, $p = .145$) or the generally unsuccessful group (Wilks's $\lambda = .625$, $F(8,8) = .600$, $p = .757$). In other words, whatever the infant's performance was within any of the earlier experiments of speech-in-noise perception, there was no relationship between the earlier speech-in-noise perception performance and performance on the measures that were used in this study to assess phonological awareness abilities. In the generally successful group, in which infants who did not succeed were the exception to the group in that they demonstrated relatively poorer speech-in-noise perception than the general population tested, those who were able to recognize their names in noise and those who were unable to recognize their names in noise did not score significantly different from each other on the phonological awareness tasks. Similarly in the generally unsuccessful group, where infants who succeeded were the exception to the group by having demonstrating speech-in-noise perception abilities that were relatively better than those of the general population tested, no significant differences in performance were noted on these phonological awareness measures based on the infants "Pass-NoPass" status.

Chapter 4: Discussion

This study attempted to investigate the relationship between performance on Newman's (2005) study investigating infant speech perception in noise and later phonological awareness ability as measured on a total of 8 subtests. This study did

not find a significant relationship between this measure of infant speech-in-noise perception and later performance on a variety of measures of phonological awareness.

These findings contrast with McBride-Chang's (1995) model of reading acquisition that had previously suggested that infants acquire their phonological awareness abilities and reading abilities by building upon their innate speech perception skills. Although McBride-Chang's model did not account for the impact of noise, given the amount of time infants spend being exposed to language in the presence of background noise, it would seem as though speech-in-noise perception would be an even bigger factor in future language learning than speech perception in quiet settings. As such, it would be expected that infants with poorer speech perception in noise would go on to develop poorer phonological awareness skills. While the findings of this study are not consistent with McBride-Chang's (1995) model of reading acquisition or other research supporting the relationship between speech perception in noise and later language outcomes, there are several reasons why this might be the case.

Potential issues with the original study

One possibility that could have impacted the results of this study is that the original Newman (2005) study may not have accurately measured the speech-perception in noise ability of every individual participant. While the intent of the original study was to measure infant speech perception in noise, other factors may have influenced the group assignment of individual infants. It is entirely possible that factors such as attentiveness to the task, tiredness, hunger, amount of time parents

refer to the child by his or her name, or any other variety of factors could have influenced an individual's performance on the task in such a way that an infant with strong speech-perception in noise may have appeared to not recognize his or her own name in noise. This would possibly cause some infants to be classified as "Pass" or "NoPass" not according to their speech perception in noise abilities, but as a result of these other factors. While this did not appear to impact general group performance on the original task, if enough children who were inaccurately assigned to the "NoPass" group based on their performance in the original study were included in the current follow-up study, it could be difficult to find significant differences between the two groups.

A second possibility why no significant differences were found could be that a relationship between the two factors does exist and both measures accurately measured what they were intending to measure, but that the testing conditions in Newman's (2005) study did not capture differences in performance at the cutoff where speech-in-noise perception begins to impact phonological awareness skill acquisition. Perhaps had the children been tested at a different age or at a more or less challenging level of background noise the Pass-NoPass status of the participants would have been different and a relationship might have been found. This suggestion is addressed in Newman et al. (2006) where it is noted that, at some ages, poor performers were likely to have a "delay" in acquisition of the particular speech perception skill being measured rather than a lack of ability. As the participants in the Newman (2005) study were typically only tested at one age and one sound level, this type of determination cannot be made the children in our study. Creating a more

extensive database of infants with speech perception in noise ability data taken at a variety of ages and in a variety of noise levels may be a fruitful direction for future research.

Potential issues with the follow-up study

One issue with this current study that could have decreased the likelihood of finding a significant relationship between infant speech-perception in noise and phonological awareness could be the tests that were selected. Although the subtests spanned the range of phonological awareness abilities in an attempt to allow variability in performance, each individual subtest on the *PAT* had only one practice item and ten test items. Additionally, these test items varied considerably in difficulty level, with each subtest containing several items that most individuals with normal phonological awareness ability would be expected to easily get correct. This restricted the amount of variability. The *Yopp-Singer* had three practice items and 22 test items. The low number of trials per child meant that each child had only a few chances to demonstrate their ability on the task.

The second issue with the current study is that the phonological awareness subtests tests that examined earlier developing skills may have been impacted by ceiling effects. On these subtests, for example the rhyming discrimination subtest and the rhyming production subtest, most children performed at near 100% accuracy, resulting in very little score variation from child to child for these measures. While this could be seen as a flaw in the follow-up study's test selection, the results of the studies where more variation was found (i.e. the later-developing skills) and where children were not performing at ceiling did not support the hypothesis of this study

and instead frequently showed the “NoPass” group as infants performing better than the “Pass” group.

Potential that there is no relationship

It is entirely possible that no relationship exists between the two factors. While some research has indicated that infant speech perception is related to other language outcomes, it is possible that phonological awareness ability is completely independent from an individual’s ability as an infant to perceive speech in background noise. This possibility, concurrent with the research findings of Boets et al. (2007), suggests that speech-in-noise perception deficits do not necessarily result in difficulties in phonological awareness. Boets et al. attribute this either to the “limited role” of speech-in-noise perception ability on this area of development or to the ability of children with poorer speech-in-noise perception to overcome their disadvantage with the use of compensatory strategies. If Boets et al.’s theory is correct, then some children who performed better worse as infants could perform at the same level as children who performed better as infants through the acquired use of compensatory strategies.

While it is certainly possible that there is no relationship between speech perception and later phonological awareness skills, this is not to suggest that previous performance on the Newman (2005) study may not be related to other areas of behavior and/or language performance. For example, in this study, a significant effect was found between performance on the Newman (2005) study and attention as measured on the *Brown ADD Scales* (Brown, 2001), a parent-survey designed to assess a child’s attention abilities.

Potential intervening issues

As mentioned before, Boets et al. (2007) attribute the limited role of speech perception in noise to later phonological awareness partly to the use of compensatory strategies. While the potential for no relationship between speech-perception in noise and later phonological awareness ability has already been discussed, the role of compensatory strategies has not been. If compensatory strategies are being used successfully by some children, it would not be surprising for individuals with poorer speech-perception in noise as infants to perform as well as infants with better speech-perception in noise on measures of speech perception in noise as they may simply come to the same answer in a different way.

The role of socioeconomic status may also have impacted the findings of this study. It has been well-established that children from higher SES groups are at an advantage in language development in comparison to individuals from low SES (Graham & Hartfield, 2006). While the impact of SES on phonological awareness measures has not been established, one would expect SES to impact this area comparably to other language development measures. The participants in this study were all of relatively high SES (as measured by maternal education). Perhaps these participants had poor enough speech-in-noise perception to significantly impact their phonological awareness performance, but were able to overcome these weaknesses by additional or higher quality language exposure and stimulation in their environments that individuals with higher SES are afforded. It is possible that had this study's participants been selected from lower socioeconomic groups, the "NoPass" children in these groups may have demonstrated significant differences resulting from the

combined effect of decreased speech-in-noise perception ability *and* the reduced amount of high-quality language exposure and stimulation than individuals who had better speech perception in noise. Given that additional and high quality language exposure and stimulation can compensate for relatively poor infant speech-in-noise ability, a relationship between speech perception in noise and phonological awareness may exist, but may have been hidden or masked because of the language exposure and stimulation that the high socioeconomic “NoPass” children tested in the current study received.

Finally, research by Fyhri and Klæbo (2006) suggests that individuals, particularly in “small-to-medium” sized cities (presumably such as the Maryland suburbs from which this study’s participants were drawn), tend to select houses in areas with less noise. This is important to consider when interpreting the results of this study as the impact of poor speech perception in noise would only be actualized if the child was regularly learning language in a situation where he or she must perceive speech in noise. The population tested in this study happened to have abnormally high SES, as measured by level of education of the primary caregiver, which would increase the likelihood that the children would live in less noisy environments and therefore be less impacted by any comparative weaknesses in speech-perception in noise than lower SES children.

Chapter 5: Directions for future research

As mentioned above, further research addressing the relationship between infant speech-in-noise perception and phonological awareness at different ages, socioeconomic levels, and levels of background noise as infants and at older ages of

follow-up testing may be revealing and of interest. The reliability of the Newman (2005) measurements of speech perception in noise when applied on an individual rather than group basis, the role of compensatory strategies, the role of SES, and the amount of background noise exposure the child experienced while attempting to learn language skills has not adequately been addressed by this study and may be interesting to address in future research.

Also, as suggested by Newman et al. (2006), performing similar testing with children at increased risk for specific language impairment may reveal a stronger impact of speech perception than testing children expected to be in the “normal” range. Children who are at an initial disadvantage compared to their peers may be more vulnerable to any factors that impact the child’s ability to access quality language learning.

Furthermore, while this study was fortunate enough to recruit participants who happened to not differ in age between groups, future studies should consider testing only children who can be scored using standardized tests to minimize the role of age on scores. If this is not possible, it is suggested that researchers attempt to recruit individuals only within a tighter age range to reduce possible variation in scores as a result of age. This should make differences between the performances of individual children easier to detect and to interpret.

Depending on the age of the child being tested, it is important to keep in mind the role ceiling and floor effects may play in the results of the study. It may make more sense to focus on a smaller number of language outcomes and to more specifically target the performance areas that one would expect would be challenging

for the age group of children being studied, but not so challenging that the children are unable to perform the task. If fewer areas were assessed, more items for each area could be created and administered, and might result in greater sensitivity of measurement based on different levels of ability. For now, it appears as a great deal more research is needed before a conclusive determination of the relationship between infant speech-perception in noise and phonological awareness can be made.

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