PHONOLOGICAL AWARENESS DEVELOPMENT OF PRESCHOOL CHILDREN WITH COCHLEAR IMPLANTS

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Abstract

Purpose: The primary purpose of this study was to assess whether very early access to speech sounds provided by the cochlear implant enabled children with severe to profound hearing loss to develop age-appropriate phonological awareness abilities during their preschool years. A secondary purpose of this study was to examine whether preschool-age children with cochlear implants develop age-appropriate skills in speech perception, speech production, general language, receptive vocabulary, and print knowledge; skills that are assumed to provide the foundation for or, minimally, to covary with phonological awareness. A third purpose of this study was to examine which of these factors contribute uniquely to the variance in the phonological awareness abilities of these preschoolers.

Method: 24 children ages 36 to 60 months who had been utilizing their cochlear implant(s) for a minimum of 18 months (CI group) and 26 normal hearing peers (NH group) were enrolled in this study. Phonological awareness and print knowledge were assessed via the *Test of Preschool Early Literacy*. Speech perception was assessed via the Play Assessment of Speech Pattern Contrasts test, a measure that examines perception of speech pattern contrasts. Speech production was assessed by calculating Percent Consonants Correct from children's productions on the *Goldman-Fristoe Test of Articulation-2*. Total language and receptive vocabulary were assessed using the *Preschool Language Scale-4* and the *Peabody-Picture Vocabulary Test-4*, respectively.

Results: Children in the CI group were outperformed by their NH peers in the areas of phonological awareness, speech production, general language, and receptive vocabulary, but not print knowledge. For speech perception, the CI group consisted of significantly more non-perceiving children (children who demonstrated limited ability on the speech perception measure) than did the NH group. These non-perceiving children evidenced

significantly delayed skills in each area except print knowledge as compared to the perceiving subgroup. Despite differences in performance outcomes between the CI and NH groups, some children in the CI group were able to demonstrate skills above the mean of the NH group in each of the skill areas assessed. Statistical analyses indicated that phonological awareness scores were correlated with speech perception, speech production, and oral language scores for children in the CI group and with oral language scores for children in the NH group. The lack of a significant correlation between speech perception and phonological awareness for the NH group was due to a ceiling effect in the speech perception scores. Regression analyses indicated that for the CI group, speech production did not uniquely predict any significant variance in phonological awareness scores after accounting for general language abilities. The opposite was also true; general language abilities did not uniquely account for any significant variance in phonological awareness scores after consideration of speech production abilities. That is, the variance was shared. For the NH group, speech production abilities did not account for any significant variance in phonological awareness scores. However, general language scores did account for significant variance in phonological awareness abilities for the NH group.
Conclusions: This study indicates that age appropriate speech perception, speech production, oral language, and early literacy skills by school-age are reasonable goals for preschoolers who have been implanted for 18 months or more. However, the results in this study also indicate that many children with cochlear implants will lag behind hearing peers in these areas, making early language and phonological skills important areas of focus for programs of remediation.

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Chapter 1: Introduction

For over two decades, researchers have been documenting the improved speech perception abilities of children who are deaf and utilize cochlear implants (O'Donaghue, Nikolopoulos, Archbold, & Tait, 1999; Osberger et al., 1991; Snik, Vermeulen, Geelen, Brokx, & Van den Broek, 1997). Additionally, studies have documented the consequent improvement in speech production abilities (Blamey, Barry et al., 2001; Blamey, Sarant et al., 2001; Miyamoto, Kirk, Robbins, Todd, & Riley, 1996). Research has also indicated that with early use of cochlear implants, many children who are deaf have been able to develop language and literacy skills that are within normal limits (i.e., within one standard deviation of the mean) when compared to their peers with normal hearing (Crosson & Geers, 2001; Geers, 2004; Moeller, 2000; Spencer, Barker, & Tomblin, 2003). For those children who communicate using oral language, these improvements are often apparent before entry into elementary school (Geers, Moog, Biedenstein, Brenner, & Hayes, 2009; Sarant, Holt, Dowell, Rickards, & Blamey, 2009). Literacy studies are only beginning to emerge and have almost exclusively examined the reading skills of school-age children (DesJardin, Ambrose, & Eisenberg, 2009; Geers, 2002; Spencer et al., 2003). Thus, they evaluate the interaction between cochlear implant use and formal literacy instruction. It is well known, however, that children with normal hearing begin developing emergent literacy skills, such as phonological awareness, well before their formal literacy instruction begins (Bradley & Bryant, 1983; Chaney, 1998; Lonigan, Burgess, Anthony, & Barker, 1998; Wood & Terrell, 1998). Despite the importance of phonological awareness on later reading skills among young hearing children, little is known about the development of phonological awareness skills in children with cochlear implants, especially in relation to other phonological and lexical skills. In fact, there are no published studies that have examined the phonological awareness skills of deaf preschoolers with cochlear implants as compared to their hearing peers. The main objective of this study is to address this gap.

There are four related factors that indicate that the phonological awareness skills of young children with cochlear implants might be an area of special weakness and an area in great need of investigation. First, the primary goal of cochlear implantation is to provide children with an ability to perceive speech, thus allowing them to develop oral language and literacy abilities. However, cochlear implants cannot fully normalize children's auditory experiences, and thus children with cochlear implants typically demonstrate deficiencies in speech perception (Kirk, Miyamoto, Ying, Perdew, & Zuganelis, 2002; Miyamoto et al., 1994). Indeed, the speech perception skills of children with cochlear implants have been documented as being equivalent to the speech perception skills of hearing aid users with severe hearing losses (Blamey, Sarant et al., 2001; Eisenberg, Kirk, Martinez, Ying, & Miyamoto, 2004). Second, children with cochlear implants typically remain delayed in the acquisition of speech and language skills. Specifically, the speech production skills of children with cochlear implants are often significantly delayed, even after the children have had years of experience with their cochlear implant, and even when they are compared to younger children whose age is matched with the deaf children’s duration of cochlear implant experience (Chin, 2003; Chin & Kaiser, 2000). Similarly, oral language is often not age-appropriate in young children with cochlear implants prior to school entry (Geers et al., 2009). Third, among hearing preschoolers, these skills (speech perception, speech production, and oral language) are correlated with the phonological awareness abilities (Bird & Bishop, 1992; Chaney, 1994; McBride-Chang, 1995; Metsala, 1999; Preston & Edwards, 2009; Rvachew, 2006; Rvachew & Grawburg, 2006; Rvachew, Ohberg, Grawburg, & Heyding, 2003; Silvin, Niemi, & Voeten, 2002; Smith & Tager-Flusberg, 1982). Additionally, recent studies have indicated that the phonological awareness abilities of school-age children with cochlear implants are delayed in comparison to those of their peers with normal hearing (DesJardin et al., 2009; James, Rajput, Brinton, & Goswami, 2007; James et al., 2005; Schorr, Roth, & Fox, 2008). Taken together, these factors place children with cochlear implants at significant risk for educationally relevant delays in the development of phonological awareness skills.

This study is designed to assess whether very early access to speech sounds provided by the cochlear implant enable children to develop age-appropriate phonological awareness abilities in their preschool years. Additionally, this study will examine whether preschool-age children with cochlear implants develop age appropriate skills in speech perception, speech production, general language, receptive vocabulary, and print knowledge that are assumed to provide the foundation for or, minimally, to covary with phonological awareness. This study will also examine which of these factors contribute uniquely to the variance in the phonological awareness abilities of these preschoolers.

Phonological Awareness

Phonological awareness refers to the awareness of the abstract units of speech including syllables, onset and rime units, and individual phonemes. This awareness can be demonstrated by performance on tasks involving a variety of cognitive manipulations including tapping out the syllables or phonemes in a word and blending or breaking apart the syllables, onset-rime units, and phonemes that make up words. Although phonological awareness was once thought to be a skill that developed with the onset of literacy instruction, we now have evidence from multiple studies indicating that even preschool children who have never received instruction in literacy often have emerging phonological awareness skills (Anthony et al., 2002; Chaney, 1992, 1998; Fox & Routh, 1975; Foy & Mann, 2006; Lonigan et al., 1998; Wood & Terrell, 1998). Additionally, for children with normal hearing, we know that phonological awareness skills are crucial in predicting beginning reading ability. Studies beginning with those by Lundberg, Olofsson, and Wall (1980) and Bradley and Bryant (1983) have provided evidence that children who are better at skills associated with phonological awareness, such as the ability to recognize when words rhyme and the ability to identify initial sounds of words, are more likely to develop better reading skills than those for whom these skills are absent or inconsistent (see Harris & Beech, 1998). This idea was confirmed by three independent national syntheses of reading research (Adams, 1990; National Reading Panel, 2000; Snow, Burns, & Griffin, 1998).

Factors Correlated with Phonological Awareness

Considering that phonological awareness skills have a significant effect on reading skills, it is important to identify the factors that are correlated with and may contribute to the development of phonological awareness skills. Factors covering a wide variety of areas have been explored in the literature. For example, research has demonstrated that children of lower socioeconomic status (SES) are at a disadvantage for developing strong phonological awareness abilities, and that older children demonstrate more advanced phonological awareness abilities than younger children (McDowell, Lonigan, & Goldstein, 2007; Nittrouer, 1996). Similarly, research has demonstrated that aspects of the home literacy environment such as shared book reading, a teaching focus in the home, and exposure to print can positively impact phonological awareness abilities (Burgess, 1997; DesJardin et al., 2009; Foy & Mann, 2003). This section, however, will not focus on environmental factors, but rather on phonological and linguistic correlates of phonological awareness.

Speech Perception

Speech perception or "the process of transforming a continuously changing acoustic signal into discrete linguistic units" (Rvachew & Grawburg, 2006, p.76) has been identified in several studies as being highly correlated with and, in longitudinal studies, predicting phonological awareness (Chiappe, Chiappe, & Siegel, 2001; Foy & Mann, 2001; McBride-Chang, 1995, 1996; Rvachew, 2006). This makes sense considering that both speech perception and phonological awareness require a strong internal representation of phonological structure. Foy and Mann (2001) found that preschool children's scores on four of five measures in a speech discrimination task were significantly correlated with their phonological awareness scores. Similarly, Rvachew (2006) identified speech perception abilities during preschool as one of the variables that explained significant variance in phonological awareness abilities during kindergarten for children with speech-sound disorders.

McBride-Chang (1996) examined five possible models to characterize the relationship of speech perception, phonological processing (which included measures of phonological awareness, naming speed, and verbal memory), and word reading for third and fourth grade children. She found that the model that provided the best fit involved the influence of speech perception on reading being mediated by its relationship with phonological processing abilities. Drawing on the results of this study and others, Chiappe et al. (2001) designed a study to examine the direction of the relationship between speech perception and phonological awareness. When using a categorical perception task to assess speech perception in a group of first grade children, they found that impairments on the speech perception task appeared to play a causal role in deficits in the area of phonemic awareness. On the other hand, phonemic awareness did not explain group differences on the speech perception measure.

Speech Production

Although the causality conclusions drawn by McBride-Chang (1996) and Chiappe et al. (2001) have advanced knowledge about the relationship between phonological awareness and speech perception, neither of these studies considered the influence of speech production, another skill that requires a strong internal representation of phonological structure. Speech production has been tied to phonological awareness for groups of children with and without speech sound disorders.

Bird, Bishop, and Freeman (1995) studied the phonological awareness abilities of a group of boys who had been diagnosed as having developmental speech impairments to the phonological awareness abilities of an individually matched control group. Approximately two-thirds of the participants in the experimental group also had additional language impairments. The authors found that both the children with additional language impairments and the children without additional language impairments did not perform as well on the phonological awareness measures as the control group. Similarly, Rvachew and colleagues (2003) matched a group of 4-year-old children with developmental speech sound disorders to a group of typically developing children for receptive language skills, age, SES, and emergent literacy knowledge. They found that the children with developmental speech sound disorders demonstrated poorer phonological awareness skills than their typically developing peers.

In a recent study, Mann and Foy (2007) examined speech production and phonological awareness in a diverse group of preschool children. They found that children who made no consonant errors on the study's consonant inventory had stronger phonological awareness abilities than children who had normal or delayed speech production abilities. Carroll and her colleagues (2003) examined phonological awareness in a non-disordered preschool population. They used their results to develop a model to explain the relationship of phonological awareness with several other variables including speech production. They found that articulation was one of two variables that had a significant, independent longitudinal influence on the development of phoneme awareness.

General Language

The relationship between phonological awareness and general oral language abilities has also been explored in the literature. Cooper and his colleagues (2002) examined the role of kindergarten oral language ability (which included measures of receptive and expressive vocabulary, syntax, and morphology) on phonological awareness for 51 children in first grade. They found that letter-word identification and general oral language at kindergarten were responsible for 52% of the variance in phonological awareness at first grade. The authors also examined this relationship for a subgroup of 30 nonreaders (children who were unable to read any words on a word identification measure and who scored zero on a word attack measure). For this subgroup, the best-fit model only included oral language as a predictor of first grade phonological awareness. Specifically, general oral language alone accounted for 42% of the variance in phonological awareness. Lonigan (1998) found similar results with four- and five-year-old children. Receptive and expressive language (as measured by vocabulary and general language measures) were significantly correlated with rhyme oddity, alliteration oddity, blending, and elision. However, for two- and three-year-old children, significant correlations did not exist between the language and phonological awareness measures.

Chaney (1992) explored the relationship of overall metalinguistic performance (via five measures of phonological awareness, five measures of word awareness, and two measures of structural awareness) to children's speech perception, speech production, general language, word knowledge, and sentence structure abilities. She found that, when controlling for age, children's general language abilities, vocabulary knowledge, and sentence structure abilities were significantly correlated with overall metalinguistic performance. When considering only the five tests of phonological awareness, she still found significant correlations with general language ability and word knowledge. Interestingly, she found that speech perception and speech production were not significantly correlated with any of the metalinguistic areas (phonologic awareness, word awareness, or structural awareness).

Receptive Vocabulary

Many researchers have hypothesized that receptive language is the aspect of oral language that is most strongly related to phonological awareness. Indeed, several studies have confirmed that receptive vocabulary ability contributes to phonological awareness skill level (Gibbs, 2004; Lonigan, 2006; Metsala, 1999; Rvachew, 2006; Smith & Tager-Flusberg, 1982). Gibbs (2004) found that even after controlling for age, vocabulary scores and memory span made separate and significant contributions to the phonological awareness abilities of five- to seven-year-olds. Metsala (1999) found that the 50 preschool-age children with the best receptive vocabulary skills consistently scored better on both an isolation task and a phoneme-blending task than children with weaker vocabulary skills. Similarly, Rvachew (2006) found that for a group of children with speech sound disorders, pre-kindergarten receptive vocabulary size explained a significant amount of variance in phonological awareness abilities at the end of kindergarten. Lonigan (2006) reported that for preschool children from upper to middle class homes, receptive vocabulary scores contributed significantly or marginally significantly to scores on five of six phonological awareness measures completed nine months later.

Print Knowledge

Print knowledge is an area of early literacy that is often explored with preschool children. However, investigators typically examine the relationship of print knowledge and phonological awareness with later reading ability as opposed to examining the relationship to one another. For example, Catts and colleagues (2002) found that knowledge of letter names was the single best predictor of subsequent reading achievement. Chaney's 1992 study is one of the few studies that directly examined the relationship between phonological awareness and print knowledge. She found a strong relationship between 3-year-old children's performances on the phonological awareness measure and measures of print awareness and general language development. Burgess and Lonigan (1998) also directly studied the relationship between phonological awareness, which they termed phonological sensitivity (measured by a rhyme oddity detection task, an alliteration oddity task, a blending task, and an elision task), and print knowledge (measured by a letter-name knowledge task and a letter-sound knowledge task). The authors found that the 4- and 5-year-old children with stronger letter knowledge were more likely to have stronger phonological awareness abilities one year later. However, they also found that stronger phonological awareness abilities at the beginning of the study led to stronger print knowledge one year later. Thus, phonological awareness and print knowledge were found to have a reciprocal relationship.

Cochlear Implants and Literacy

Recent investigations have documented the positive impact of cochlear implant use on literacy development. For example, Spencer, Tomblin, and Gantz (1997) found that a group of cochlear implant users between 7 and 17 years of age were reading, on average, at or within 8 months of their grade level. Similarly, Spencer and colleagues (2003) found that a group of students with cochlear implants performed within one standard deviation of their peers with normal hearing on measures of reading comprehension. Although these studies report results that are a dramatic departure from what has previously been viewed as the norm for literacy levels of children who are deaf, they also provide evidence that the reading skills of children with cochlear implants have not been fully normalized in comparison to their hearing peers. For example, in the 2003 study by Spencer et al., despite the cochlear implant group's relatively strong performance, the scores of these children still differed significantly from those of the normal-hearing group. In the 1997 study, although many children were performing close to grade level, over a quarter of the children were reading at levels that were 30 months or more below their grade levels. The overall delays in reading skill and the wide variability in reading ability evidenced in these studies provides motivation for examining potential contributors to reading delays. One such potential contributor is limited phonological awareness abilities.

To date, I am aware of four published studies that have examined the impact of cochlear implant use on some aspect of the phonological awareness skills of deaf children, albeit with children who had already begun receiving formalized literacy instruction (DesJardin et al., 2009; James et al., 2007; James et al., 2005; Schorr et al., 2008). Several other studies have examined at least some aspect of phonological awareness development for children with hearing loss including children who utilize cochlear implants and children who wear hearing aids. However, these studies did not separate the results from the two groups (Colin, Magnan, Ecalle, & Leybaert, 2007; Easterbrooks, Lederberg, Miller, Bergeron, & Connor, 2008; Most, Aram, & Andorn, 2006).

James and colleagues (2007; 2005) similarly examined children with cochlear implants and children with hearing aids in their studies of phonological awareness, but the authors directly compared the groups. Specifically, they compared elementary school-age children with at least 3 years of cochlear implant use to a group of hearing aid users with severe hearing losses and a group of hearing aid users with profound hearing losses. Although the cochlear implant group scored above chance on all three phonological awareness tasks, their performance was equal to or worse than the hearing aid users with severe hearing losses on all three measures and equal to or worse than the hearing aid users with profound losses on two of the three measures. The authors also found that children implanted under three and a half years of age performed better on the phonological awareness tasks than their peers who received their implants between 5- and 7-years of age.

DesJardin, Ambrose, and Eisenberg (2009) examined the phonological awareness abilities of 16 children ages six to nine. They found that the group achieved an average standard score of 86 on the *Phonological Awareness Test* (Robertson & Salter, 1997). Although this score is within one standard deviation of the mean for the test, it is significantly lower than the mean score of 100. The authors also examined the relationship between children's phonological awareness scores and children's oral language abilities three years earlier. They found that children's expressive language abilities at the early point accounted for 39.8% of the variance in children's phonological awareness abilities 3 years later. The authors did not examine the relationship between phonological awareness and speech perception, speech production, or print knowledge.

Schorr and colleagues (2008) looked at the speech articulation, semantics, metalinguistic, and metasemantic knowledge of a group of 5- to 14-year-old children with cochlear implants. Within the metalinguistic category, they used an elision measure, which is one of the more challenging formats for assessing phonological awareness. They found that 85% (33 of 39) of the children scored within one standard deviation of the mean on the elision measure. This was a higher percentage of children scoring within one standard deviation of the mean than for any of the other nine phonological and linguistic tests they utilized, however there was still a significant effect for group on the elision measure with the NH group outperforming the CI group. In their analyses, they examined whether IQ, SES, and speech perception were significant predictors of elision ability for each group. They found that none of these three skills significantly predicted performance on the elision measure for the NH group. However, SES was a significant predictor of elision ability for the CI group.

Spencer and Oleson (2008) did not specifically examine phonological awareness; however, they did examine the relationships of speech perception and speech production with literacy. The authors assessed the speech perception and speech production abilities of 72 children who had been utilizing their cochlear implant for 48 months. An average of 41 months later, the authors assessed the literacy abilities of those same children (via word and passage comprehension measures). The authors found that 59% of the variance in the reading abilities of children with cochlear implants at Time 2 could be explained by their speech perception and speech production skills at Time 1. The authors did not assess oral language abilities or phonological awareness abilities at either time point. Thus, it is unclear whether the relationship of speech perception and speech production with word and passage comprehension might have been mediated by phonological awareness. It is also unclear whether speech perception and speech production would have accounted for such a high level of variance in literacy abilities if the authors had controlled for children's oral language abilities at Time 1.

Cochlear Implants and Factors Correlated with Phonological Awareness

These studies illustrate the need for exploration of the many phonological and linguistic factors that may predict the development of phonological awareness skills in children with cochlear implants. One could certainly hypothesize that these factors would be the same factors that predict the development of phonological awareness in children with normal hearing. If this is the case, children with cochlear implants may be at a disadvantage for phonological awareness development considering reports of discrepancies between the speech perception, speech production, general language, and receptive vocabulary abilities of children with cochlear implants and children with normal hearing (Blamey, Barry et al., 2001; Blamey, Sarant et al., 2001; Chin, 2003; Chin & Kaiser, 2000; Eisenberg et al., 2006; Geers et al., 2009). Indeed, the results of the studies by James and colleagues (2007; 2005), Desjardin and colleagues (2009), and Schorr and colleagues (2008) indicated that children with cochlear implants are at a disadvantage for phonological awareness, whether as a result of delays in these areas or not. The following sections summarize the research findings for children with cochlear implants in each of the areas that were identified as correlates of phonological awareness for children with normal hearing.

Speech Perception

It is clear that cochlear implants cannot provide children with a normal auditory system or normal auditory experiences (Kirk et al., 2002; Miyamoto et al., 1994). Harrison, Gordon, and Mount (2005) noted that because the cochlear implant electrode array can only stimulate a limited part of the cochlear nerve array, cochlear implant users receive a very limited information set compared to persons with normal hearing. This input is limited in terms of both spectral and temporal information. Pisoni and colleagues (1997) noted that, as a result of these abnormalities, children with cochlear implants may perceive and represent spoken words in terms of broad phonetic categories due to an inability to reliably discriminate minute phonetic differences. This is concerning given that “poorly specified underlying phonological representations will result in difficulties during listening, speaking, and phonological awareness tasks” (Sutherland & Gillon, 2007, p. 229).

Speech perception has been the primary outcome measure used to assess the efficacy of cochlear implants to date, with studies indicating that speech perception abilities are equivalent between children with cochlear implants and children with severe hearing losses who use hearing aids. For example, Blamey, Sarant, and colleagues (2001) found similar trends and distributions on speech perception measures for their participants with cochlear implants and their participants with severe hearing losses who utilized hearing aids. Similarly, Eisenberg et al. (2004) found that the children with cochlear implants in their study performed similarly to children with hearing aids (average threshold of 78 dB HL) on measures of speech recognition.

These limited speech perception abilities may be contributing to the observed deficiencies in speech and language abilities for children with cochlear implants. Indeed, the speech perception abilities of children with cochlear implants have been found to be strongly correlated with their speech production and spoken language abilities. For example, Blamey and colleagues (2001) found that performance on an open-set speech perception measure was more highly correlated with school-age children’s receptive vocabulary abilities than their demographic information such as age at implantation and duration of deafness. Eisenberg and colleagues (2002) also used open-set speech perception tests to assess word and sentence recognition for school-age children with cochlear implants. They found strong relationships between children's receptive vocabulary abilities and their performance on the speech perception tests. Pisoni and colleagues (1997) examined the performance of a group of high-performing school-age children with cochlear implants on the lexical neighborhood test, a word recognition task that is often used as a measure of speech perception. They found that performance on this measure was highly correlated with performance on the receptive vocabulary, general oral language, and speech intelligibility measures.

Each of the previously mentioned studies used speech perception measures that were heavily dependent on language. However, Pisoni and colleagues (1997) also incorporated a minimal pairs test to assess phoneme identification – a task that is less language-laden than most other speech identification tests developed for children. They administered this measure to both high-performing and low-performing children with cochlear implants. For each group, they found that perception of manner and voicing cues was significantly correlated with children's receptive vocabulary and general receptive and expressive oral language abilities. Interestingly, perception of place cues did not show this same relationship with language abilities, most probably because place of articulation is the speech feature that is most susceptible to hearing loss (e.g. Boothroyd, 1984).

Results from these studies indicate that the speech perception abilities of school-age children with cochlear implants are limited in comparison to their normally hearing peers. Additionally, the studies have shown that there is a strong relationship between language and speech perception abilities in school-age children with cochlear implants. A much smaller number of studies have examined the speech perception abilities of preschool age children with cochlear implants, presumably because most speech perception tests are heavily dependent on general language abilities and preschool children with cochlear implants typically have limited language skills (Eisenberg et al., 2006). Thus, we know little about speech perception development in this early group and how those abilities might relate to speech production, oral language, and phonological awareness abilities.

Speech Production

As indicated in the Pisoni et al. (1997) study, significant correlations have been identified between the speech perception skills and speech production skills of school age children with cochlear implants. Similar to what has been shown for speech perception, speech production is typically delayed in children with cochlear implants. Chin (2003) and Chin and Kaiser (2000) demonstrated that the phonological production skills of children with cochlear implants as a group are significantly delayed, even after they have had multiple years experience with their cochlear implant, and even when they are compared to younger children whose age is matched with the deaf children's duration of cochlear implant experience. Blamey, Barry, and colleagues (2001) completed a longitudinal study with children who were implanted under five years of age. They compared their data with published data for groups of children with normal hearing and found that children with cochlear implants demonstrated a slower rate of growth and overall more limited skills in the areas of speech intelligibility and speech production than children with normal hearing. Tomblin and colleagues (2008) found that children with cochlear implants demonstrated improvement in their speech production skills over the first six years of cochlear implant use, but then their progress tapered off until they reached a plateau after approximately eight years of cochlear implant use. Most of the participants in their study still had substantial room for growth. We are beginning to develop an understanding of the pattern of speech development for elementary age children with cochlear implants, but we have very limited knowledge regarding the speech production skills of preschool age children with cochlear implants.

Oral Language

Recently, a number of studies have focused on the oral language skill development of relatively young children with cochlear implants. For example, Geers and colleagues (2009) reported on the language abilities of 153 children who were between the ages of 5-years and 6-years, 11-months and had been implanted, on average, under 2 ½ years of age. They found that 50% of the children scored more than one standard deviation below the mean for receptive vocabulary, 42% for expressive vocabulary, 53% for total receptive language, and 61% for total expressive language. Schorr and colleagues (2008) assessed the language abilities of 5- to 14-year-old children with cochlear implants using similar procedures. They found that 49% of the children scored more than one standard deviation below the mean for receptive vocabulary, 34% for expressive vocabulary, and 41% for morphology and syntax. These results further highlight that, although many children with cochlear implants develop age appropriate language abilities, many other children with cochlear implants do not. Indeed, extreme variability exists in individual performances on outcome measures.

Print Knowledge

Although the previous sections have outlined how skills that are correlated with phonological awareness may be delayed or abnormal for children with cochlear implants, the case for print knowledge may be somewhat different. Although there are no direct studies of the print knowledge development of preschool children with cochlear implants, two recent studies have indicated that this may be an area with which children with cochlear implants have relatively little trouble. First, DesJardin and colleagues (2009) administered the *Woodcock–Johnson-III Diagnostic Reading Battery* to a group of 16 elementary school-age children with cochlear implants. They found that the group scored slightly above the mean of the standardization sample on the letter-word identification subtest. The group's performance on this subtest indicated that the children were not having difficulty with letter knowledge. However, this group had already received extensive literacy instruction at school, which may have directly resulted in the age-appropriate letter and word identification abilities. In another study, Easterbrooks and colleagues (2008) administered this same subtest to children in preschool, kindergarten, and first grade. However, their study combined data from children with hearing aids (*n*=16) and cochlear implants (*n*=28). Nonetheless, their results are similar to those of the DesJardin et al. group. They found that in both the spring and fall semester, the children scored above the mean on this test.

Despite these two studies, we still do not have a clear picture of the print knowledge abilities of preschool children with cochlear implants prior to the onset of literacy instruction. Additionally, there is reason to be concerned about this skill because studies have indicated that oral language predicts print knowledge and, as previously outlined, oral language skills are largely delayed in children with cochlear implants. For example, Lonigan, Burgess, and Anthony (2000) found that for the preschool children with normal hearing in their study, oral language significantly predicted letter knowledge ability 18 months later. Similarly, in a study comparing preschool children with language disorders to preschool children with typically developing language, Gillam and Johnston (1985) found that general language ability was correlated with print knowledge. Given these results, there is reason to believe that print knowledge might be delayed in preschool children with cochlear implants due to their potential delays in oral language.

Summary

The weaknesses, or potential weaknesses, in speech perception, speech production, oral language, and print knowledge of preschoolers with cochlear implants are concerning in their own right. Additionally, knowledge of the relationships between skills in these areas and phonological awareness suggest that deficits in phonological awareness are likely for preschool children with cochlear implants. Furthermore, deficits in this area would place children with cochlear implants at even more significant risk for problems with literacy.

Preliminary Study

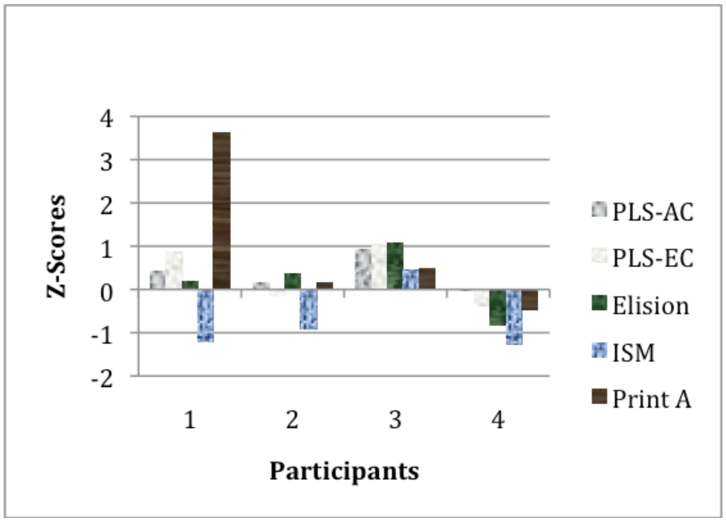
Phonological Awareness of Children with Moderate Hearing Losses

Prior to this study, one small pilot project was conducted to collect information about the early development of phonological awareness skills among young hard of hearing children and the relationship of those skills to children’s language skills. Two girls and two boys between the ages of 38 and 58 months with moderate hearing losses participated in this study. Children with moderate hearing losses were included in this preliminary study because of the research pointing toward reading delays even for children with only mild to moderate hearing losses (Davis, Elfenbein, Schum, & Bentler, 1986). The children were administered the *Preschool Language Scale-4* (*PLS-4*) (Zimmerman, Steiner, & Pond, 2002) and the *Preschool Comprehensive Test of Phonological and Print Processing (Pre-CTOPPP)* (Lonigan, Wagner, Torgesen, & Rashotte, 2002), a pre-publication version of the *Test of Preschool Early Literacy* (*TOPEL*) (Lonigan, Wagner, Torgesen, & Rashotte, 2007).

One objective of the investigation was to determine whether these preschoolers with moderate hearing impairments, all of whom were utilizing the oral modality and were identified within the first year of life, were significantly behind their hearing peers in oral English and phonological awareness skills. Results from this study indicated that these children were not significantly behind their peers in oral English. All participants had language abilities within normal limits. Likewise, for the Print Awareness (Print A) subtest of the Pre-CTOPPP, no child had a z score below -.48.

As seen in Figure 1-1, the situation was somewhat different with respect to the measures of phonological awareness. Three of the four children had z-scores near -1.0 on the Initial Sound Matching (ISM) test and one child also had an Elision z-score that was more than one standard deviation below the mean. Thus, it appeared that at least some of the children were having difficulty in the development of phonological awareness skills, an area that would appear to be especially dependent on the auditory skills that are these children's greatest weaknesses. This result fits with findings from current research demonstrating that oral language and phonological awareness can develop independently, at least in part (Catts, Adlof, & Weismer, 2006).

Figure 1-1: Results by participant.



Perhaps the most striking finding in the study, however, was how well at least some of the children performed in the study on the phonological awareness tasks. One participant was well above the mean for Elision and Initial Sound Matching. Furthermore, Elision scores were just below or above the mean for three of the four participants. These findings were encouraging because they suggested that children with moderate hearing losses that are treated relatively early might develop normal language *and* normal phonological awareness skills by kindergarten. Such findings also bode well for later reading skills.

An additional finding was that the phonological awareness skills of these preschoolers were at least moderately correlated with their language abilities in the same way that has been shown within the hearing population. The three subtests of the Pre-CTOPPP that were included in the analysis (Print Awareness, Initial Sound Matching, and Elision) were all either moderately or highly correlated with the *PLS-4* Auditory Comprehension composite (Spearman rank order correlations ranging from 0.63 to 1.0). The *PLS*-4 Total Score was at least moderately correlated with Elision and Print

Awareness (Spearman rank order correlations of 0.60).

Although this pilot study included a very small number of participants who differed significantly in their level of hearing loss and their use of sensory aids from the participants in the current study, valuable information was gained. The preliminary study indicated that some children with hearing losses were able to develop measurable phonological awareness skills in the preschool years. However, the preliminary study also indicated that some children with hearing losses were not developing adequate phonological awareness skills despite having strong oral language skills. This finding, which fits with recent research indicating that oral language and phonological awareness can develop separately to some extent, made clear the need for studies of early language and phonology development in children with hearing loss.

Summary

Considering the knowledge that phonological awareness in the preschool years is a strong predictor of later literacy development in the typically hearing population, it is important to gain a better understanding of the phonological awareness abilities of preschool children with cochlear implants. Four different findings in the research literature led us to suspect that children with cochlear implants are at some risk for not developing phonological awareness at the same rate as children with normal hearing. First, we know that, although the goal of cochlear implantation is to provide children with sufficient access to the speech spectrum for the purpose of enabling development of age-appropriate speech perception abilities, not all children are able to develop these skills. Second, we know that other phonological and linguistic skills that are related to the development of phonological awareness, including speech production and oral language, are often delayed in children with cochlear implants. Third, we know that phonological awareness abilities are correlated with speech perception, speech production, general language, receptive vocabulary, and print knowledge in children with normal hearing. Finally, recent studies have indicated that some school-age children with cochlear implants are unable to develop age-appropriate phonological awareness abilities (DesJardin et al., 2009; James et al., 2007; James et al., 2005; Schorr et al., 2008). If indeed preschool children with cochlear implants are at risk for not developing adequate phonological awareness skills, determining those factors that contribute to the variance in their phonological awareness abilities will be critical for creating interventions designed to facilitate the development of age-appropriate literacy skills.

Research Questions and Predictions

Research Question 1: Can preschool children who have been using cochlear implants for a minimum of 18 months reach the same levels of phonological awareness ability as their hearing peers before the onset of literacy instruction?

Prediction: Children with cochlear implants have been reported to be functioning within one standard deviation of the mean of their peers with normal hearing on a wide variety of speech, language, and literacy outcome measures. However, a significant group difference typically exists on these measures. Additionally, vast differences in individual performance have been reported for children with cochlear implants on these various outcome measures. Thus, although development in phonological awareness was expected to be impressive for some children, it was predicted that the phonological awareness abilities of children in the CI group would be significantly delayed in comparison to children with normal hearing. It was also anticipated that there would be significant individual differences, with *some* children in the CI group reaching the same levels of phonological awareness as even their most skilled hearing peers, but many others still lagging well behind.

Research Question 2a: How do the speech perception, speech production, general language, receptive vocabulary, and print knowledge skills of preschool-age children with cochlear implants compare to those of their normally hearing peers?

Research Question 2b: How do these skills individually relate to phonological awareness for the CI group as opposed to the NH group?

Prediction: It was expected that the abilities of the children in this study would mirror those of children in other studies; that is, although some children were expected to perform similarly to children with normal hearing, it was predicted that the group as a whole would be significantly delayed in each of the assessed areas. It was also predicted that, because these skills are correlated with phonological awareness for the normally hearing population, they would also be correlated with phonological awareness for children with cochlear implants. However, it was anticipated that speech perception and speech production would share a special relationship with phonological awareness for the CI group due to the heavy dependence of these skills on strong underlying phonological representations.

Research Question 3a: Which variables account uniquely for a significant amount of variance in the phonological awareness abilities of preschool children with cochlear implants?

Research Question 3b: Are these the same variables that account uniquely for significant variance in the phonological awareness abilities of their peers with normal hearing?

Prediction: It was predicted that speech perception and/or speech production, the two skills that theoretically are the most heavily reliant on internal representations of phonological structure, would uniquely predict a significant amount of variance in phonological awareness scores after consideration of oral language performance for the CI group but not necessarily the NH group.

Chapter 2: Method

Subjects

Twenty-four children participated in the cochlear implant group (CI group). All children were either receiving audiological care at the House Ear Institute (HEI) Children's Auditory Research and Evaluation (CARE) Center or attending a free summer program for children with hearing loss at the John Tracy Clinic. Children were recruited for the study if they met the following criteria: 36 to 60 months of age, bilateral severe to profound prelingual, sensorineural hearing loss, utilization of a cochlear implant for a minimum of 18 months, no additional disabilities, and no home language other than English. Although no criteria were outlined regarding whether the children used sign, speech, or a combination of the two, all children who met the criteria for this project and whose parents elected to enroll in the study were reported to be using oral language as their primary mode of communication at the time of testing. The group consisted of 13 females and 11 males. Parent report on ethnicity indicated that 8 of the 24 children were Hispanic.

Twenty-six children with normal hearing were assigned to the control group (NH group). The NH group was recruited from preschool-age siblings accompanying their sister or brother with a hearing loss to the HEI CARE Center, via children, relatives, or friends of HEI employees, and from flyers handed out at area preschools. All children in the NH group were reported as having passed a hearing screening or were screened for hearing loss. As with children in the CI group, all participants in the NH group were 36 to 60 months of age, reported to have no additional disabilities, and lived in homes where the primary language was English. The group consisted of 14 females and 12 males.

Parent report on ethnicity indicated that 10 of the 26 children were Hispanic.

Table 2-1: Characteristics of the CI and NH groups.

	CI Group		NH Group		Between Groups			
	Mean (SD)	Range	Mean (SD)	Range	*t*	*p*	*d*	*d* 95% CI
Age at Testing (mos.)	49.54 (6.60)	36-59	45.54 (7.86)	36-59	1.94	0.06	0.55	$^{-}$0.02-$^{+}$1.11
Maternal Education (yrs.)	15.18 (3.02)	9-20	15.69 (2.38)	11-21	-0.66	0.17	$^{-}$0.19	$^{-}$0.76-$^{+}$0.38

Results from independent samples t-tests confirmed that the groups were not significantly different for age at testing and maternal education, utilizing an alpha of .05. However, the significance level for the difference between groups for age at testing narrowly missed the criterion. Furthermore, Cohen's *d*, a measure of effect size, was 0.55, which may be interpreted as a medium-sized effect. Thus, despite the fact that the difference between groups does not meet conventional criteria for rejecting the null hypothesis, the children in the control group should be viewed as slightly younger than the children in the CI group.

This difference in ages likely occurred as a direct result of the recruitment procedures. For the NH group, any child between the ages of 36 and 60 months who fit the other criteria for enrollment was recruited for the study. However, for the CI group, any child who was between the ages of 36 and 60 months, had been utilizing a cochlear implant for at least 18 months, and who fit the other criteria for enrollment was recruited for the study. Many children with cochlear implants do not receive their cochlear implant until well after 18 months of age, making these children ineligible for the study until they were past 36 months of age. When closely examining the groups by age, two children in the CI group were under 41 months of age and ten children in the NH group were under 41 months of age. When considering the mean age of the children ages 41 months and up, the groups were almost identical in mean age (CI: 50.68, NH: 50.56).

Despite being an average of approximately 50 months old, the CI group had a hearing age of approximately 28 months (i.e. they had been utilizing their CI for an average of 28 months) (SD=6.98, Range 18-39). The average age at which the group received their cochlear implant was approximately 21 months (SD=6.93, Range 12-36). Eleven of the 24 children in the CI group were utilizing two cochlear implants at the time of the evaluation. Of these, three children received simultaneous bilateral cochlear implants and the remaining eight received sequential bilateral cochlear implants.

Although all children were utilizing oral language as their primary communication modality at the time of the evaluation, some children were also being exposed to a minimal amount of sign language or had been exposed to sign language in the past. To quantify communication mode, parents were asked to report the communication modality used by the family to communicate with their child during each year of their child's life: "sign only," "mostly sign," "equal sign and speech," "mostly speech," or "speech only." These categories were assigned a score of 1, 2, 3, 4, and 5, respectively. Thus, for a child who was 4 years old and who had been exposed to speech only for the first year of life (a score of 5), equal sign and speech for the following year (a score of 3), and speech only for the next two years (a score of 5), the child's communication mode would be recorded as a score of 4.5. All but one child had a score of 3 or above (with the remaining child having a score of 2.6). Ten children had scores of 5, indicating that they had not been exposed to sign language at any point. The median score for the group was 4.25.

Fifteen of the 24 children in the CI group were administered the *Bayley Scales of Infant Development* (Bayley, 1993) during the CI candidacy process. The group achieved a mean score of 93 for the Mental Development Index (MDI) and a mean score of 98 for the Psychomotor Development Index (PDI). Although the former score seems low, it is actually relatively high considering that many of the items on the MDI are reliant on a child's auditory-oral skill development and that this subscale was administered prior to children receiving their cochlear implant. Thus, most children in the sample would have received a score of zero on items such as "turns head to sound," "responds to spoken request," and "imitates word," among others.

Procedure

For children in both groups, one or two testing sessions lasting a total of approximately two hours were conducted at the HEI CARE Center. Three children had recently been administered one or more of the standardized measures within three weeks prior to their enrollment in this study. Those measures were not re-administered due to concerns regarding reliability and instead their scores from the recent administration were utilized.

Test Measures and Rationale

Phonological Awareness

Phonological awareness was measured via the Phonological Awareness subtest of the *Test of Preschool Early Literacy* (*TOPEL*) (Lonigan et al., 2007). The *TOPEL* has three subtests: Definitional Vocabulary, Print Knowledge, and Phonological Awareness. The latter two subtests were utilized in this study. The Phonological Awareness subtest measures word elision and blending abilities. The *TOPEL* was chosen because it is the only standardized test designed to assess the phonological awareness skills of children as young as 36 months of age. Additionally, the test is designed so that even young children can understand the tasks. All of the phonological awareness tasks begin with training items and pictorial stimuli. Additionally, both the elision and blending activities begin at the word level to help children become accustomed to the task before moving into stimuli involving processes at the phoneme level. Furthermore, the *Comprehensive Test of Phonological Processing*, which is a test of phonological skill developed by the authors for children ages 5 and up, has been commonly used to assess phonological awareness for a number of years (Wagner, Torgesen, & Rashotte, 1999).

The authors of the *TOPEL* reported three types of reliability coefficients for the standardization sample: test-retest, internal consistency, and inter-scorer differences. Test-retest reliability coefficients, which are representative of time sampling error, ranged from 0.83 to 0.89 for subtest scores. Internal consistency reliability coefficients, which are representative of content sampling error, were reported as ranging from 0.86 to 0.95 for the subtest scores for 3- and 4-year-old children in the standardization sample. Interscorer reliability coefficients, which are representative of error related to differences between scorers, were high, ranging from 0.96 to 0.97 for the subtests.

Speech Perception

Speech perception was measured using the Play Assessment of Speech Pattern Contrasts (PLAYSPAC) test (Boothroyd, Eisenberg, & Martinez, 2006; Eisenberg, Martinez, & Boothroyd, 2007). The PLAYSPAC is part of a progressive test battery that has been developed at the House Ear Institute to measure children’s ability to perceive speech pattern contrasts (vowel height and place, and consonant voicing, manner, and place). The PLAYSPAC utilizes a conditioned play paradigm whereby a string of repeated vowel consonant vowel (VCV) utterances ([u:du:]) is presented through the loudspeaker, and the child is trained to engage in a motor activity, such as putting a block in a bucket, when a phonetic contrast (e.g. [a:da:] for vowel height) is introduced. Test trials commence as soon as the child is conditioned. The stimulus presentation is computer-controlled. The tester registers all motor responses into the computer, including those that occur outside of a response window designated by the computer software (i.e., false alarms). The number of trials is determined by the computer program, which is designed to continue testing until a confidence level of 90% is reached or until 5 trials have been completed, whichever occurs first. The confidence level, derived from probability theory, takes into account the number of trials and responses occurring within and outside of the hypothetical response window, and indicates confidence that the responses did not occur by chance.

For the purposes of this study, the child's performance is reported according to signal detection theory, or d-prime (d'), analysis to accommodate response bias. To calculate this, both hit and false alarm rates were calculated for each of the six contrasts and then averaged across the six contrasts for each child. The hit rate is the number of times the child correctly identified the presentation of a phonetic contrast divided by the total number of contrasts presented. The false alarm rate is the number of times a child signaled the presence of a new stimulus despite no presentation of the phonetic contrast divided by the number of stimulus presentations that did not reflect a change. For the purposes of d', a hit rate cannot be 1.0 nor can a false positive rate be 0.0. Thus, a standard correction was calculated when necessary. For children who identified the phonetic contrast 100% of the time, the hit rate was calculated as 1-1/(2*n) with n being the number of trials administered. If there were no false alarms, the false positive rate was calculated as 1/(2*n) where n is the number of response windows or opportunities for false alarms.

The PLAYSPAC is the most age-appropriate test for the children being assessed in this investigation and is currently being used in studies at Indiana University and the University of Colorado at Boulder. The PLAYSPAC was chosen because it avoids many of the common problems associated with other early measures of speech perception. Specifically, the PLAYSPAC avoids concerns posed by tests such as the *Test of Auditory Comprehension* (Office of the Los Angeles County Superintendent of Schools, 1976), the *Mr. Potato Head Task* (Robbins, 1994), the *Pediatric Speech Intelligibility Test* (Jerger, Lewis, Hawkins, & Jerger, 1980), and the OLIMSPAC (Eisenberg, Martinez, & Boothroyd, 2003; Eisenberg et al., 2007), the results of which can be confounded by their dependence on language or speech production ability and may be susceptible to floor effects.

Speech Production

Speech production ability was represented by Percentage of Consonants Correct (PCC) scores (Shriberg & Kwiatkowski, 1982). These scores were calculated from children's productions on the *Goldman Fristoe Test of Articulation-2* (*GFTA-2*) (Goldman, 2000). The *GFTA-2* is designed to elicit 53 single-word responses in children as young as 2 years of age. These responses are intended to obtain productions of 23 of the 25 consonant sounds generally recognized as Standard English and 16 common consonant clusters. It is understood that some children may not know every stimulus word utilized by the *GFTA-2*. In these instances, following the directions provided in the *GFTA-2*, children were allowed to imitate the examiner's production of the word. However, attempts were made to prevent direct imitation (i.e. if the child could not identify the stimulus word "swimming," the examiner would say "This girl is swimming. She likes the water. What is she doing?"). The *GFTA-2* was chosen over most other articulation tests, such as the *Clinical Assessment of Articulation and Phonology* (Secord & Donohue, 2002) and the *Hodson Assessment of Phonological Processes-3* (Hodson, 2004), due to the relatively short administration time (5 to 15 minutes). The *Arizona Articulation Proficiency Scale, Third Edition* (Fudala, 2000) is as efficient as the *GFTA-2*, but its pictures lack color and generally seem less engaging for children in the age range of this investigation. Additionally, the *GFTA-2* is used more commonly in the research literature on phonological awareness and the research literature on cochlear implants than the previously mentioned tests (Chin & Kaiser, 2000; Rvachew et al., 2003).

All words on the *GFTA-2* were phonetically transcribed using IPA symbols in accordance with guidelines for Percentage of Consonants Correct (PCC) (Shriberg & Kwiatkowski, 1982). PCC reflects the number of consonants produced correctly over the number of consonants attempted. PCC was chosen for assessment of speech production ability for a number of reasons, including its use in studies of children with cochlear implants and of the relationship between speech production and phonological awareness (Clendon, Flynn, & Coombes, 2003; Connor, Craig, Raudenbush, Heavner, & Zwolan, 2006; Paatsch, Blamey, Sarant, Martin, & Bow, 2004; Rvachew & Grawburg, 2006).

PCC-Revised (PCC-R) (Shriberg, Austin, Lewis, McSweeny, & Wilson, 1997) is identical to PCC, except in its classification of distorted sounds as being correct. PCC was chosen over PCC-R because the scoring program utilized for calculating PCC only allows for sub analyses (e.g., PCC for consonants by manner) using PCC. Additionally, outcomes for PCC and PCC-R scores for each group were calculated and found not to differ in any significant way.

The transcribed words were entered into the Profile of Phonology (PROPH) module of *Computerized Profiling* (Long, Fey, & Channel, 2004) for automatic calculation of PCC and for automatic calculation of PCC for each set of consonants by manner of production. Interjudge reliability was calculated by having a second researcher transcribe and analyze 30% of the speech samples. Intra-class correlation coefficients (ICC) were calculated to determine the amount of variance that could be attributed to systematic subject differences, systematic differences between judges, and other nonsystematic error. Results indicated a single measures, absolute definition ICC of 0.98 for the PCC. These very large values indicate that the largest part of the variability in PCC scores is related to differences between subjects rather than to systematic differences between judges or interactions between judges and subjects. For the purposes of data analysis, the percentages were arcsine transformed to stabilize the variances.

General Language

The *Preschool Language Scale-4* (*PLS-4*) was administered to assess general language abilities. The *PLS-4* is a standardized norm-referenced language measure that allows for testing of both receptive and expressive language across the age span required for the study (Zimmerman et al., 2002). The *PLS-4* was chosen over other similar tests for three primary reasons. First, it includes test items for a wider age range of skills than some similar tests. Of specific concern was that the lowest performing children with cochlear implants might not meet the requirement for establishing a basal on tests such as the *Oral Written Language Scales* (*OWLS*) (Carrow-Woolfolk, 1996) and the *Clinical Evaluation of Language Fundamentals-Preschool* (*CELF-P*) (Wiig, Secord, & Semel, 2004). Second, the *PLS-4* was chosen over other similar tests because its manual provides data on a small sample of preschool-age children with hearing losses. The *PLS-4* was administered to 32 children between the ages of 3 years and 6 years, 11 months. Of these children, all had a hearing loss that was moderate to severe and 60% used at least some sign to respond to *PLS-4* tasks. The mean standard score for total language of the deaf and hard of hearing children was 66.5, compared to a mean score of 110.3 for their typically developing age-matched peers. This large difference in standard scores indicated that the *PLS-4* was highly sensitive to differences between groups of hearing and deaf and hard of hearing children in language associated with hearing impairment. It should be noted that this group is different from the group in the present study in that none of the children in the present study used sign to respond to the *PLS-4* tasks. However, a third reason for choosing this measure is that the *PLS-4* has been reported on in the research literature pertaining to children with cochlear implants who are relatively similar to those in the current study (Nikolopoulos, Archbold, & Gregory, 2005; Tomblin, Barker, Spencer, Zhang, & Gantz, 2005).

For children in the standardization sample, test-retest stability coefficients for the relevant ages and subtests ranged from 0.85 to 0.95. Inter-rater reliability was reported to be 99%. Internal consistency, indicated by Cronbach's coefficient alpha was also high, ranging from 0.90 to 0.97, indicating that the scales were highly homogenous. Finally, validity studies involving children with language impairments indicated that the specificity of the *PLS-4* is good to very good (.85-.96). Sensitivity is lower, however, ranging from 0.74 to 0.79.

Receptive Vocabulary

The measure of receptive vocabulary was the *Peabody Picture Vocabulary Test-4* (*PPVT-4*) (Dunn & Dunn, 2007). The *PPVT-4* was chosen over other one-word receptive vocabulary tests because of the prevalence of earlier versions of the *PPVT* being utilized in the research literature, including with children with cochlear implants (e.g. Blamey, Sarant et al., 2001; Connor, Hieber, Arts, & Zwolan, 2000; Miyamoto, Kirk, Svirsky, & Sehgal, 1999). Additionally, information was reported in the examiner's manual on a sample of 4- to 12-year-old children who utilized cochlear implants. The manual reported that the children with cochlear implants scored approximately two standard deviations below the general-population mean. In regard to reliability, the test-retest coefficient was 0.93 for children in the general standardization sample between the ages of two and four.

Print Knowledge

The Print Knowledge subtest of the *TOPEL* (Lonigan et al., 2007) was chosen because it measures early knowledge about written language conventions and form, as well as knowledge of the letters of the alphabet and the sounds they make. The Print Knowledge subtest of the *TOPEL* was chosen not only because the Phonological Awareness section of the *TOPEL* was selected, but also because of the simple directions and colored pictures accompanying the subtest.

Chapter 3: Results

Phonological awareness and several related phonological and linguistic skills were examined in preschool children with cochlear implants (the CI group) and a group of children with normal hearing (the NH group). This study examined three specific research questions.

Research Question 1

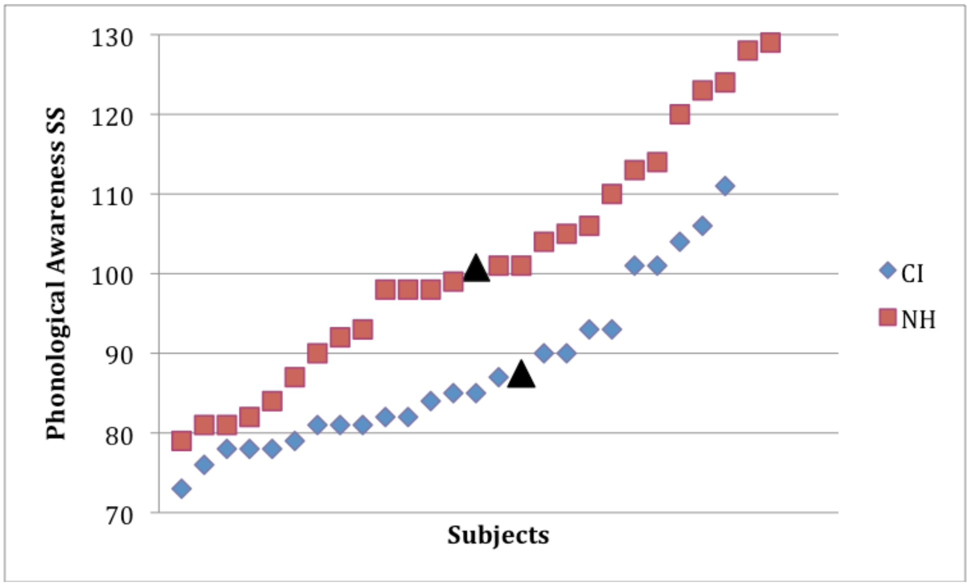
Can preschool children who have been using cochlear implants for a minimum of 18 months reach the same levels of phonological awareness ability as their hearing peers before the onset of literacy instruction?

To determine whether the CI group demonstrated phonological awareness scores that were on par with their peers with normal hearing, an independent samples t-test was used to analyze the standard scores (SS) from the Phonological Awareness subtest of the *TOPEL* (see Table 3-1). The mean SS of the NH group was found to be significantly higher than the mean SS of the CI group.

Table 3-1: Descriptive statistics and between group differences on phonological awareness scores as measured by the *TOPEL*.

CI Group		NH Group		Between Groups			
Mean (SD)	Range	Mean (SD)	Range	*t*	*p*	*d*	*d* 95% CI
87.46 (10.43)	73-111	100.77 (14.63)	79-129	¯3.68	.001	¯1.02	¯1.61-¯0.43

Figure 3-1: *TOPEL* phonological awareness scores, by group.



* The black triangle indicates the mean for each group.

As previously noted, the NH group was younger than the CI group. Considering the differences in age, a t-test was performed to compare the CI group's performance to a mean score of 100, the mean of the measure's standardization sample. The CI group's mean score was found to be significantly different from 100 ($t={}^{-}5.89$, $p=<.001$, $d={}^{-}0.82$).

In line with the hypothesis, the CI group was not performing as well as their NH peers (in the NH group or the standardization sample) in the area of phonological awareness. However, as a group, they scored within one standard deviation (SD) of the mean of the NH group and the standardization sample. When breaking down the scores further, three of the twenty-four children in the CI group had PA scores above the mean of the NH group. Additionally, another 10 children in the CI group performed within one SD of the NH group. However, this indicates that almost half of the children in the CI group scored more than one SD below the NH group mean. It was predicted that substantial differences in individual performance would be evident on this measure for the CI group. This was somewhat apparent, with three children in the CI group scoring above the mean of the NH group despite three other children achieving a raw score that was only one point above a score that would be attributed to chance alone on this partially multiple-choice measure.

To further delineate group differences, additional analyses were performed to compare the groups' raw scores for the twelve elision items and the fifteen blending items. Similarly, group performance was examined for the twelve syllabic awareness items and the fifteen phonemic awareness items. For each of these areas, the test included six multiple-choice items with one correct answer and three distracters. The remainder of the items required the child to generate an oral response. These comparisons are provided in Table 3.2.

Table 3-2: Descriptive statistics and between group differences for raw scores on aspects of the *TOPEL* Phonological Awareness subtest.

	CI Group		NH Group		Between Groups			
	Mean (SD)	Range	Mean (SD)	Range	*t*	*p*	*d*	*d* 95% CI
Elision	3.88 (2.07)	0-7	6.58 (2.64)	2-12	$^{-}4.00$	.000	$^{-}1.11$	$^{-}1.71$-$^{-}0.51$
Blending	6.54 (3.31)	2-14	7.23 (3.81)	0-15	$^{-}0.68$	.500	$^{-}0.19$	$^{-}0.75$-$^{+}0.37$
Syllabic Awareness	6.46 (2.98)	1-11	8.12 (2.50)	1-12	$^{-}1.80$	.079	$^{-}0.50$	$^{-}1.06$-$^{+}0.06$
Phonemic Awareness	3.94 (2.31)	1-10	5.69 (3.30)	2-15	$^{-}2.14$	.038	$^{-}0.60$	$^{-}1.16$-$^{-}0.03$

A large effect size and significant difference was observed for the difference between groups for elision (with a 95% confidence interval that did not include zero). However, no significant difference was found between groups on the blending items. A significant difference was observed between groups for phonemic awareness but not syllabic awareness. This is a sensible pattern, but it should be noted that the difference between groups for syllabic awareness only narrowly missed the criterion of .05. Additionally, the medium effect sizes for these comparisons were very similar: $^{-}0.5$ for syllabic awareness and $^{-}0.6$ for phonemic awareness. The difference in syllabic awareness would have been statistically reliable with only slightly larger samples.

Research Question 2

***a**: How do the speech perception, speech production, general language, receptive vocabulary, and print knowledge skills of preschool-age children with cochlear implants compare to those of their normally hearing peers?*

***b**: How do these skills individually relate to phonological awareness for the CI group as opposed to the NH group?*

Speech Perception

A Kolmogorov-Smirnov Test indicated that the speech perception variable did not fit the assumptions of normalcy for the NH group due to a strong ceiling effect that caused a negative skew. This was expected, as there is an underlying assumption that the NH subjects have normal auditory capacity. Consequently, a Levene's test for equality of variances indicated that the variance between the groups was not equal (p=.010). Thus, a Mann-Whitney U-Test was run to compare the groups' performance on speech perception. See Table 3-3.

Table 3-3: Descriptive statistics and differences between groups for speech perception scores.

	CI Group		NH Group		Between Groups
	Mean (SD)	Range	Mean (SD)	Range	*p*
Speech Perception	1.74 (1.06)	ˉ0.23-2.80	2.38 (0.61)	0.80-2.78	.105

No significant difference was found between the CI and NH groups on the speech perception measure. However, in an attempt to determine whether the difference between groups was masked by a ceiling effect, the raw data were compared for each group by individual speech pattern contrast (vowel height, vowel place, consonant voicing, consonant continuance, consonant place front, and consonant place rear). For each child, a score was assigned for each consonant contrast; one if the child met or exceeded a 90% confidence level and zero if this level was not achieved prior to the presentation of five trials. It should be noted that most children demonstrated some perception of each contrast. However, for the purpose of this comparison a stringent criterion of 90% confidence level was chosen to indicate detection of the speech pattern change. Six children in the cochlear implant group and one child in the NH group either failed to demonstrate the ability to detect any speech pattern contrasts or only demonstrated the ability to detect one of the vowel contrasts. The remaining 18 children in the CI group detected both vowel contrasts and at least one consonant contrast. Of those 18 children, 10 demonstrated the ability to detect all six speech pattern contrasts. Thus, the distribution was essentially bimodal with six children in a “non-perceiving CI subgroup” and the others performing variably, with most reaching the criterion for all six contrasts. A Fisher's Exact Test indicated that the CI group had significantly more non-perceiving children than did the NH group (*p*=.039).

A set of Fisher's Exact Tests was performed to determine whether CI-NH group differences were statistically significant for each of the six contrasts. When data from all of the children in the CI and NH groups were included, significant differences, favoring the NH group, were observed for vowel place (*p*=.043), consonant continuance (*p*=.020), and consonant voicing (*p*=.020). The groups did not differ statistically on the other contrasts, vowel height (*p*=.162), consonant place front (*p*=.141), or consonant place rear (*p*=.155). The same set of contrasts was analyzed with the non-perceivers in the CI group and the non-perceiver in the NH group removed. This reanalysis indicated that there were no significant differences found between groups on any of the six contrasts (*p*s > .15). In other words, when the scores of the children who demonstrated little or no ability to detect speech pattern contrasts were removed from the analyses, the CI-NH group differences were no longer apparent.

To address part b of the research question, Spearman's rho was calculated for the relationship between the speech perception scores and the phonological awareness scores for the full CI and NH groups. For the CI group, a moderate correlation was found for these two variables (*r*=.526, *p*=.008). Thus, for the CI group, scores on the speech perception measure accounted for 28% of the variance in the children's ranks for their phonological awareness scores. However, for the NH group, the correlation was very weak (*r*=.002, *p*=.993). This later finding was anticipated because of the limited variance in the scores of the NH group, with 19 of the children demonstrating the ability to accurately perceive all six speech pattern contrasts.

To examine more comprehensively the contribution of the non-perceiving children, the phonological awareness scores of the perceiving members of the CI group were compared to those of the non-perceiving members of the CI group using independent samples t-tests. As expected, the mean phonological awareness SS for the non-perceiving subgroup (*M*=79.17*, SD*=1.47) was significantly lower than that for the perceiving subgroup (*M*=90.22*, SD*=10.68) (*t*=$^{-}$2.49, *p*=.021, *d*=$^{-}$1.06). Next, an independent samples t-test was performed to compare the phonological awareness abilities of the perceiving children in the CI group and the perceiving children in the NH group. Even with the non-perceivers removed from each group, a significant difference emerged between the groups for phonological awareness ability (NH perceiving subgroup: *M*=102.13, *SD*: 14.29) (*t*=$^{-}$2.95, *p*=.005, *d*=$^{-}$0.93). Thus, although the non-perceiving CI subgroup was accounting for the lion's share of the below average phonological awareness performance of the CI group, the perceiving CI subgroup was still outperformed significantly by the perceiving children in the NH group.

Speech Production

To address research question 2a regarding the comparison between CI and NH groups in speech production, an independent samples t-test was used to compare group differences on the PCC measure. A significant difference was found between groups, indicating that the NH group had an advantage over the CI group on this measure. Additionally, the CI group's mean score was more than one SD below the mean of the NH group. See Table 3-4.

Table 3-4: Descriptive statistics and differences between groups for speech production scores.

	CI Group		NH Group		Between Groups			
	Mean (SD)	Range	Mean (SD)	Range	*t*	*p*	*d*	*d* 95% CI
Speech Production	56.67 (23.54)	22-97	76.88 (13.56)	49-97	$^{-}$3.27	.002	$^{-}$0.93	$^{-}$1.52-$^{-}$0.33

*Descriptive statistics are reported for untransformed data. The independent samples t-test was run on the transformed data following application of the arcsine transformation.

To further examine the differences in the speech production data between the CI and NH groups, the PROPH module of *Computerized Profiling* was used to determine the accuracy of different manners of consonant production. These data are reported in Table 3.5 as the mean number of correct productions divided by the number of opportunities to produce each manner of consonant.

Table 3-5: Descriptive statistics and between group differences for consonant manner.

	CI Group		NH Group		Between Groups			
	Mean (SD)	Range	Mean (SD)	Range	*t*	*p*	*d*	*d* 95% CI
Stops	66.36 (23.81)	22.2-100	87.68 (11.01)	68.0-100	$^{-}$3.48	.001	$^{-}$1.37	$^{-}$2.26-$^{-}$0.48
Nasals	63.84 (20.11)	26.7-100	80.06 (12.78)	40.0-100	$^{-}$2.59	.013	$^{-}$1.02	$^{-}$1.87-$^{-}$0.17
Fricatives	43.76 (26.16)	8.3-93.3	67.62 (19.43)	28.6-100	$^{-}$3.32	.002	$^{-}$1.30	$^{-}$2.19-$^{-}$0.42
Affricates	62.29 (36.41)	0-100	80.28 (26.19)	0-100	$^{-}$1.85	.070	$^{-}$0.73	$^{-}$1.56-$^{+}$0.10
Glides	75.65 (29.85)	0-100	92.71 (12.40)	60.0-100	$^{-}$2.47	.018	$^{-}$0.97	$^{-}$1.82-$^{-}$0.13
Liquids	52.50 (32.53)	0-100	69.60 (27.37)	25.0-100	$^{-}$1.84	.072	$^{-}$0.73	$^{-}$1.55-$^{+}$0.10

*Descriptive statistics are reported for untransformed scores. The independent samples t-test was run on the transformed data following arcsine transformations.

The greatest differences between groups were found for stops and fricatives. However, it should be noted that significant differences were found for all manners of consonants except affricates and liquids. For affricates and liquids, the significance level between groups only narrowly missed the criterion. Furthermore, the Cohen's *d* values could be interpreted as at least medium, indicating that despite the fact that the differences between groups did not reach significance at an alpha level of .05, the NH group produced these two manners of consonants with a greater accuracy than the CI group.

To address research question 2b regarding the relationship of speech production to phonological awareness skills, Pearson correlations were calculated for the relationship between speech production and phonological awareness for each group. For the CI group, a significant correlation was found between these two variables (r=0.45, p=.026), indicating that speech production accounted for 20% of the variance in phonological awareness scores. However, for the NH group, no significant correlation was found between the two variables (r=0.29, p=.171).

General Language

For research question 2a, which considers the comparison of the CI and NH groups in general language performance, an independent samples t-test was conducted to compare performance outcomes on the *PLS-4*. Results indicated that the NH group performed significantly better than the CI group in the area of general language. Additionally, the CI group's mean score was more than one SD below the mean score of the NH group.

Table 3-6: Descriptive statistics and differences between groups for general language scores.

	CI Group		NH Group		Between Groups			
	Mean (SD)	Range	Mean (SD)	Range	*t*	*p*	*d*	*d* 95% CI
General Language	84.00 (16.81)	50-121	111.81 (13.62)	84-134	¯6.45	<.001	¯1.80	¯2.45-¯1.14

As previously mentioned, the NH group was younger than the CI group. Additionally, for the oral language measures, the NH group demonstrated mean scores above the mean score of the standardization samples. Considering this, a t-test was used to compare the CI group's performance to a mean score of 100, the mean of the measure's standardization sample. The mean of the CI group was found to be significantly different from 100 (*t*=¯4.66, *p*<.001, *d*=1.00).

To further delineate the differences between groups on the *PLS-4*, independent samples t-tests were utilized to compare the groups on the measure's two composites: Auditory Comprehension and Expressive Language. Significant differences between groups were observed on both measures (Auditory Comprehension: *t*=¯5.65, *p*=<.001, *d*=¯1.59, and Expressive Language: t=¯6.85, *p*=<.001, *d*=¯1.94).

To address question 2b, Pearson correlations were calculated for the relationship between general language and phonological awareness for each group. For both groups, a significant correlation was found between these two variables. However, this correlation was stronger for the NH group (*r*=0.78, *p*=<.001) than for the CI group (*r*=0.54, *p*=.007). Thus, general language accounted for 61% of the variance in the phonological awareness scores for the NH group and 29% of the variance in the phonological awareness scores for the CI group.

Receptive Vocabulary

For research question 2a, which considers the comparison of the CI and NH groups in receptive vocabulary performance, an independent samples t-test was used to compare performance outcomes between NH and CI groups on the *PPVT-4*. A significant difference was found between groups, indicating that the NH group had an advantage over the CI group in the area of receptive vocabulary. However, it should be noted that the CI group's performance on the receptive vocabulary measure was, as a whole, within one SD of the mean for the NH group.

Table 3-7: Descriptive statistics and differences between groups for receptive language scores.

	CI Group		NH Group		Between Groups			
	Mean (SD)	Range	Mean (SD)	Range	*t*	*p*	*d*	*d* 95%CI
Receptive Vocabulary	91.43 (15.87)	61-127	111.65 (16.28)	67-140	¯4.39	<.001	¯1.24	¯1.85- ¯0.62

As with general language, due to the younger age of the NH group and the relatively high mean SS of the NH group, another t-test was used to compare the CI group's performance to a mean score of 100, the mean of the standardization sample. The mean of the CI group was found to be significantly different from 100 (*t*=¯2.59, *p*=.017, *d*=0.55).

To address research question 2b, Pearson correlations were calculated for each group to quantify the relationship between receptive language and phonological awareness. For both groups, a significant correlation was found between these two variables. However, as with general language, the correlation was somewhat stronger for the NH group (*r*=0.54, *p*=.004) than for the CI group (*r*=0.44, *p*=.037). Thus, receptive vocabulary scores accounted 29% of the NH group's phonological awareness scores and 19% of the variance in the CI group's phonological awareness scores.

Print Knowledge

An independent samples t-test was performed to analyze whether a significant difference existed between the NH and CI groups on the print knowledge subtest of the *TOPEL*. No significant difference was found between groups.

Table 3-8: Descriptive statistics and differences between groups for print knowledge scores.

	CI Group		NH Group		Between Groups			
	Mean (SD)	Range	Mean (SD)	Range	*t*	*p*	*d*	*d* 95% CI
Print Knowledge	105.29 (12.94)	83-125	106.77 (14.64)	78-144	$^{-}0.38$	.708	$^{-}0.11$	$^{-}0.66$-$^{+}0.45$

As with the previous standardized measures, an independent samples t-test was used to compare the means of the CI group and the measure's standardization sample. Although the CI group's mean score was not significantly different from 100 for print knowledge (t=2.00, p=.057, d=0.38), the p value for the difference of the CI group's mean SS from 100 only narrowly missed the criterion of .05. Thus, it appeared that the CI group had a small, but reliable, advantage over the children in the standardization sample on the *TOPEL* Print Knowledge subtest.

To determine whether group differences existed in the print knowledge data that were masked by looking at the subtest as a whole, the items on this measure were categorized as print knowledge (e.g. "Which one shows the name of the book?" "Which one is a letter?") or letter knowledge (e.g. "Which one is M?" "Which one says /b/?"). Independent samples t-tests showed that between-group differences were not statistically significant on the print knowledge items or the letter knowledge items (*t*=¯0.214, *p*=.831, *d*=¯0.06, and t=1.18, *p*=.244, *d*=0.33, respectively).

To target research question 2b, Pearson's *r* was calculated for the relationship of print knowledge and phonological awareness for each group. No significant correlations were found, although relatively low power appears to have been a factor for both groups (CI group: *r*=0.38, *p*=.071, NH group: *r*=0.33, *p*=.097).

Summary

As predicted, the CI group was outperformed by the NH group on the measures of speech production, general language, and receptive vocabulary. These effects were large, with *d*s between ¯0.93 and ¯1.80. Additionally, the 95% confidence intervals for the *d*s did not include zero, indicating that the true average score for the CI group lies somewhere below that for the NH group. For speech perception, although the mean scores of the groups on the speech perception measure were not significantly different, a bimodal distribution emerged for the scores of the CI group with the presence of a non-perceiving subgroup. This subgroup evidenced very limited speech perception abilities. Only a single child fit this profile for the NH group. Contrary to our predictions, the CI group was not significantly less successful than the NH group on the measure of print knowledge.

For the CI group, significant correlations emerged between phonological awareness and each of the variables except for print knowledge, with the largest correlations being between phonological awareness and speech perception and general language. However, for the NH group, significant correlations only existed between phonological awareness and the two oral language measures: general language and receptive vocabulary. The lack of a significant correlation between phonological awareness and speech perception for the NH group was expected considering the strong ceiling effect and thus the lack of a normal distribution for the NH speech perception data.

Research Question 3

a: Which variables account uniquely for a significant amount of variance in the phonological awareness abilities of preschool children with cochlear implants?

b: Are these the same variables that account uniquely for significant variance in the phonological awareness abilities of their peers with normal hearing?

Prior to performing regression analyses to assess predictability of phonological awareness scores, correlations between all predictor variables were calculated. These are presented in Table 3-9 for the CI group and Table 3-10 for the NH group.

Table 3-9: Correlations among phonological and linguistic variables for the CI group.

	2	3	4	5
1. Speech Perception	0.56**	0.51*	0.53**	0.31
2. Speech Production		0.72**	0.73**	0.48*
3. General Language			0.90**	0.65**
4. Receptive Vocabulary				0.56**
5. Print Knowledge				

*. Correlation is significant at the .05 level (2-tailed).

**. Correlation is significant at the .01 level (2-tailed).

Moderate to large intercorrelations were observed for all variables for the CI group. The relationship between the general language measure and the receptive vocabulary measure was especially large.

Table 3-10: Correlations among phonological and linguistic variables for the NH group.

	2	3	4	5
1. Speech Perception[a]	.427*	-.143	.044	.194
2. Speech Production		.163	.191	.182
3. General Language			.759**	.286
4. Receptive Vocabulary				.281
5. Print Knowledge				

a. Spearman's rho is reported for the correlation between speech perception and the other variables because the speech perception data did not fit the assumptions of normalcy.

*. Correlation is significant at the .05 level (2-tailed).

**. Correlation is significant at the .01 level (2-tailed).

Although moderate to large intercorrelations were observed between all but one set of variables for the CI group, only two significant correlations were observed for the NH group. For both groups, there was a large correlation between the measure of general language abilities and the measure of receptive vocabulary skill.

Multiple linear regression was utilized to estimate the relationship between the phonological awareness variable and the phonological and linguistic variables for the CI group (see Table 3-11). First, due to the large correlation found for the relationship between speech perception and speech production, hierarchical linear regression analyses were conducted to evaluate whether speech perception uniquely accounted for variance in phonological awareness scores after consideration of speech production and vice versa. Speech perception abilities were not found to uniquely predict any variance in phonological awareness abilities after accounting for speech production abilities. Likewise, speech production abilities were not found to uniquely explain any variance in phonological awareness abilities after accounting for speech perception abilities. Because speech perception and speech production appeared to account for the same variance in phonological awareness abilities, it was only necessary for one of these two variables to be included in further analyses. Speech production was chosen as this variable because it could be used in regression analyses for both the CI and NH groups. Speech perception could not be used in analyses for the NH group because of the ceiling effect that resulted in the data not being normally distributed and thus in violation of the necessary assumptions for regression analyses.

Next, a hierarchical linear regression was conducted to ascertain whether general language uniquely accounted for variance in phonological awareness after consideration of receptive vocabulary and vice versa (See Table 3-11). Receptive vocabulary abilities were not found to uniquely predict any variance in phonological awareness abilities after accounting for general language abilities. However, general language abilities were found to uniquely explain significant variance in phonological awareness abilities after accounting for receptive vocabulary abilities. Because general language abilities appeared to account for the same set of variance as receptive vocabulary as well as additional unique variance, the general language variable was chosen as the linguistic variable for use in further analyses.

To examine the relationship of the CI group's phonological awareness abilities with their phonological and linguistic abilities, the speech production variable and the general language variable were utilized in hierarchical multiple regressions (see Table 3-11). Results indicated that speech production scores did not uniquely predict any significant variance in phonological awareness scores after accounting for general language scores. The opposite was also true; the general language scores did not significantly account for any variance in the phonological awareness scores after consideration of speech production scores. Thus, the variance was shared.

Table 3-11: Results of hierarchical multiple regression analyses for the CI group with the dependent variable set as TOPEL Phonological Awareness standard score.

Independent Variable	R^2	$R^2\Delta$	ΔF	p
Step 1: Speech Perception	.223	.223	6.307	.020
Step 2: Speech Production	.274	.052	1.492	.235
Step 1: Speech Production	.206	.206	5.703	.026
Step 2: Speech Perception	.274	.069	1.983	.174
Step 1: General Language	.314	.314	9.630	.005
Step 2: Receptive Vocabulary	.338	.123	0.704	.411
Step 1: Receptive Vocabulary	.192	.192	4.977	.037
Step 2: General Language	.338	.146	4.412	.049
Step 1: Speech Production	.206	.206	5.703	.026
Step 2: General Language	.296	.090	2.687	.116
Step 1: General Language	.287	.287	8.855	.007
Step 2: Speech Production	.296	.009	0.268	.610

The same steps were then followed for the NH group (see Table 3-12), with the exception of the analyses including speech perception. Again, receptive vocabulary did not uniquely account for any variance in the phonological awareness scores after consideration of general language. However, general language abilities did account for significant variance in phonological awareness scores after consideration of receptive vocabulary abilities.

Table 3-12: Results of hierarchical multiple regression analyses for the NH group with the dependent variable set as TOPEL Phonological Awareness standard score.

Independent Variable	R^2	$R^2\Delta$	ΔF	p
Step 1: General Language	.611	.611	37.750	.000
Step 2: Receptive Vocabulary	.616	.005	0.302	.588
Step 1: Receptive Vocabulary	.547	.300	10.265	.004
Step 2: General Language	.785	.317	18.994	.000
Step 1: Speech Production	.084	.084	2.005	.171
Step 2: General Language	.598	.515	26.880	.000
Step 1: General Language	.580	.570	29.122	.000
Step 2: Speech Production	.598	.028	1.482	.237

The only difference that arose between the CI and NH groups during these analyses was that the speech production variable alone did not account for any significant variance in the phonological awareness variable for the NH group, although it did for the CI group. This was expected given the significant correlation between phonological awareness and speech production for the CI group and the non-significant correlation found between phonological awareness and speech production for the NH group in earlier analyses.

Post-hoc Analyses

Influence of Maternal Education and Age

Maternal education was chosen as a proxy for socioeconomic status. The amount of education that the mother was reported to have participated in was translated into a number of years of education completed following kindergarten. Thus, a high school graduate would receive a score of 12 and a college graduate would receive a score of 16. For each group, on average, the mothers had more than a high school education. As reported in the methods section, no significant difference was found between groups for maternal education level (see Table 2-1). Pearson correlation coefficients were calculated to examine the relationship between phonological awareness and maternal education for each group. For the CI group, the correlation between phonological awareness and maternal education was not statistically significant (r=0.32, p=.145). However, for the NH group, a significant correlation between phonological awareness and maternal education was found (r=0.58, p=.002).

Children's age at the time of the first testing session was calculated in months. As mentioned in the methods, an independent samples t-test did not identify a significant difference between groups for age (see Table 2-1). However, due to the medium effect size (d=0.55) for the difference, it was concluded that a significant difference could well exist between groups for age of testing. Pearson correlation coefficients indicated that there was a significant correlation between age and phonological awareness *raw* scores for the CI group (r=0.67, p=<.001) and the NH group (r=0.40, p=.042). This relationship was anticipated. Therefore, as previously mentioned, phonological awareness *standard* scores were utilized in all the analyses. There was no significant correlation between age and the phonological awareness standard scores of the CI group (*r*=0.16, *p*=.446) or the phonological awareness standard scores of the NH group (*r*=0.16, *p*=.444). This was expected because standard scores are standardized according to age. The relationship between phonological awareness and hearing age may be more relevant and is examined later in this section.

Influence of Variables Related to Hearing Loss

Several variables have been associated with post-cochlear implant outcomes in previous research: the age at which a child was fit with hearing aids (e.g. Nicholas & Geers, 2006), the child's pure tone average (PTA) in his or her better ear prior to receipt of a cochlear implant (e.g. Nicholas & Geers, 2006), the age at which the child received his or her cochlear implant (e.g. Geers et al., 2009; Hayes, Geers, Treiman, & Moog, 2009), the duration of cochlear implant use (e.g. Geers et al., 2009; Nicholas & Geers, 2006), and mode of communication (e.g. Tobey, Rekart, Buckley, & Geers, 2004). Table 3-13 presents information on these variables and their correlations with TOPEL phonological awareness scores. The correlation reported for communication mode is Spearman's rho as opposed to a Pearson's correlation because the data are categorical (see the Methods section for information on the system for recording communication mode).

Table 3-13: CI group data for variables related to hearing loss and correlations with *TOPEL* phonological awareness scores.

	Mean (SD)	Range	*r*	*p*
Age at HA fitting (mos.)	7.09 (5.73)	0-22	-0.23	.282
Unaided Pre-CI PTA	104.56 (14.81)	68-125	-0.40	.084

Age at CI (mos.)	21.04 (6.92)	12-36	0.13	.553
Duration of CI use (mos.)	27.65 (6.98)	18-39	¯0.02	.947
Communication Mode	NA (Median=4.25)	2.6-5.0	0.17	.430

As shown in Table 3-13, none of the variables were significantly correlated with *TOPEL* phonological awareness scores. However, there appeared to be an advantage for children with more unaided residual hearing prior to receipt of a cochlear implant.

Hearing Age

In some research studies, children with cochlear implants are compared to peers who are matched for hearing age (e.g. Miyamoto, Houston, & Bergeson, 2005) rather than chronological age. Hearing age refers to the number of months a child has been wearing his or her cochlear implant following initial stimulation of the device. Although this study did not include a group of children matched for hearing age, the *PLS-4* could be utilized to make this kind of comparison. For each child in the CI group, raw scores were transformed into a SS by using the normative data for normally hearing children of the same chronological age as the child's hearing age. This procedure resulted in a CI group mean SS of 126 which was much higher than the CI group mean SS of 84 that was calculated when comparing the group to their chronological-age matched peers. To further examine the relationship between hearing age and *PLS-4* scores, a Pearson correlation was calculated. A coefficient of 0.11 was found (p=.608). Thus, there was a very weak and statistically nonsignificant relationship between hearing age and oral language abilities as measured by the *PLS-4*.

Non-Perceiving Speech Perception Subgroup

It seemed pertinent to examine the bimodality of the speech perception data for the CI group. First, the two subgroups (non-perceiving and perceiving) were compared using independent samples t-tests on demographic and hearing loss related factors that were outlined in the previous two sections. See Table 3-14.

Table 3-14: Descriptive statistics and differences between subgroups for demographic and hearing loss related factors.

	Non-Perceiving Subgroup (n=6)		Perceiving Subgroup (n=18)		Between Subgroups			
	Mean (SD)	Range	Mean (SD)	Range	*t*	*p*	*d*	*d* 95%CI
Age (mos.)	43.83 (4.79)	38-53	51.44 (6.09)	36-59	$^{-}$2.74	.011	$^{-}$1.25	$^{-}$2.23-$^{-}$0.26
Maternal Education	14.50 (3.08)	9-20	15.44 (3.05)	12-20	$^{-}$0.64	.530	$^{-}$0.12	$^{-}$1.04-$^{+}$0.80
Age at HA fitting (mos.)	5.33 (3.98)	2-11	7.71 (6.21)	0-22	$^{-}$0.87	.396	$^{-}$0.17	$^{-}$1.09-$^{+}$0.76
Unaided Pre-CI PTA	114.57 (10.76)	98-125	101.23 (14.72)	73-125	1.85	.080	0.84	$^{-}$0.11-$^{+}$1.79
Age at CI (mos.)	18.67 (4.84)	14-27	21.88 (7.47)	12-36	$^{-}$0.97	.340	$^{-}$0.44	$^{-}$1.37-$^{+}$0.49
Duration of CI use (mos.)	24.83 (3.00)	24-38	28.65 (7.75)	28-39	$^{-}$1.16	.259	$^{-}$0.52	$^{-}$1.46-$^{+}$0.41

The only significant difference that emerged between subgroups was for age at the time of the evaluation, with the non-perceiving subgroup being younger. However, the non-perceiving subgroup also appeared to have less residual hearing prior to implantation, although the difference was not significant at the .05 level due to the small *n*s in each group. A Mann-Whitney U-test was also conducted to examine whether the subgroups differed in communication mode. No significant difference was found between the subgroups (*p*=.273).

Considering that the non-perceiving CI subgroup did not perform as well as the perceiving subgroup on the measures of speech perception and phonological awareness, independent samples t-tests were used to compare the subgroups on the four remaining phonological and linguistic variables. See Table 3.15.

Table 3-15: Descriptive statistics and differences between subgroups for remaining phonological and linguistic variables.

	Non-Perceiving Subgroup (n=6)		Perceiving Subgroup (n=18)		Between Subgroups			
	Mean (SD)	Range	Mean (SD)	Range	*t*	*p*	*d*	*d* 95% CI
Speech Production*	40.35 (7.02)	29-46	64.19 (21.33)	33-97	$^{-}2.50$	.021	$^{-}1.14$	$^{-}2.11$- $^{-}0.16$
General Language	72.67 (9.37)	50-84	87.78 (17.20)	57-121	$^{-}2.03$	.054	$^{-}0.92$	$^{-}1.88$- $^{+}0.03$
Receptive Vocabulary	80.33 (9.91)	61-91	95.35 (15.91)	63-127	$^{-}2.15$	.043	$^{-}0.98$	$^{-}1.94$- $^{-}0.01$
Print Knowledge	102.17 (12.67)	84-117	106.33 (13.21)	83-125	$^{-}0.68$	.507	$^{-}0.31$	$^{-}1.24$- $^{+}0.62$

*Descriptive statistics are reported for untransformed data. The independent samples t-test was run on the transformed data following application of the arcsine transformation.

The *p* values reached or nearly reached the level of significance for the differences between the non-perceiving subgroup and the perceiving subgroup on the speech production, general language, and receptive vocabulary measures. No significant difference was found between subgroups for print knowledge. Thus, this subgroup of non-perceiving children was not only low performing for speech perception, but also for other phonological and linguistic skills, with the exception of print knowledge. An examination of the ranges for the non-perceiving subgroup and the means for the perceiving subgroup, as presented in Table 3-15, shows that no child in the non-perceiving subgroup achieved a score above the mean of the remaining children in the CI group for speech production, general language, or receptive vocabulary.

The question arose as to whether the difference found between the CI and NH groups for these measures would have existed had the non-perceiving children not been enrolled in the study. It was already established that the speech perception scores for the three speech pattern contrasts that had originally been found to be different between groups were no longer reliably different when the scores for the non-perceiving children in each group were removed. However, it was also established that the difference between groups continued to exist between the phonological awareness scores of the NH group and the CI group when the non-perceiving children were eliminated. The independent samples t-tests confirmed that there also continued to be a significant difference between groups for speech production (*t*=$^{-}$2.17, *p*=.036, *d*=$^{-}$0.70), general language (*t*=$^{-}$5.68, *p*=<.001, *d*=$^{-}$1.80), and receptive vocabulary (*t*=$^{-}$4.02, *p*=<.001, *d*= $^{-}$1.27) with the non-perceivers removed. An independent samples t-test was not conducted for group differences for print knowledge after removal of the non-perceiving children because the difference between the full CI group and the full NH group was not significantly different nor was the difference between the print knowledge abilities of the non-perceiving subgroup and the remainder of the children in the CI group.

Chapter 4: Discussion

In this study, the phonological awareness abilities of a group of preschool children who are deaf and utilize cochlear implants were examined prior to the onset of formal literacy instruction. Understanding the phonological awareness development of this group is especially important because of the well established relationship between early phonological awareness abilities and later reading abilities of children with normal hearing. Understanding those factors that may explain the variance in phonological awareness for children with cochlear implants at this early stage may enable this population of children to avoid the plateau in reading skills that often occurs for children who are deaf. It may also increase the numbers of children who reach optimum levels of literacy attainable through the use of cochlear implants.

It was hypothesized that phonological awareness abilities may be especially delayed in children with cochlear implants because of the heavy reliance of this skill on a strong underlying representation of phonological structure and the impact of the abnormal auditory experience of deaf children who utilize cochlear implants on these representations. Indeed, speech perception, a skill that is heavily reliant on accurate phonological representations and the skill most directly impacted by cochlear implantation, has been documented as being delayed in this group. Similarly, other skills that are correlated with phonological awareness for children with normal hearing have been documented as being delayed for children with cochlear implants. These include speech production and oral language abilities. This study represents the first investigation on the phonological awareness abilities and related skills of preschool children with cochlear implants in comparison to their peers with normal hearing.

Between Group Differences for Phonological Awareness

As expected, the CI group scored significantly lower on the phonological awareness measure than did their peers with normal hearing (both in the NH group and in the standardization sample for the measure). This is not surprising considering that the CI group's "hearing age" is 28 months, indicating that they have had optimal access to sound for approximately 19 months less than their peers in the NH group (mean age of 46.5 months). It is important to note that the cochlear implant does not restore hearing to normal and that the sound processed through the device is very limited in spectral content when compared to an ear which hears normally. Thus, it is particularly impressive that the CI group's mean score of 87.46 was within one SD of the means of the NH group and the measure's standardization sample.

The results reported for phonological awareness in this study are very similar to those reported by Schorr and colleagues (2008) and DesJardin and colleagues (2009) for school-age children. In the Schorr et al. study, after controlling for SES and nonverbal intelligence, the NH group outperformed the CI group on the measure used to assess phonological awareness (an elision task). However, as in the current study, the CI group's mean SS was within one standard deviation of the NH group's mean SS. In the DesJardin et al. study, the authors found that despite a significant difference between the mean phonological awareness SS of the children with cochlear implants in their study and the mean SS of the test's standardization group, the CI group's mean SS was within one standard deviation of the mean of the standardization sample.

Both the DesJardin et al. (2009) study and the current study also demonstrated that noteworthy individual variability existed for the phonological awareness abilities of the CI group. In the current study, three children in the CI group scored above the mean of the NH group and five children scored above the mean of the standardization sample. However, three other children achieved a raw score of four on the phonological awareness measure, a measure on which a score of three would be attributed to chance alone. In the DesJardin et al. study, the standard deviation for the group's performance on the phonological awareness measure was especially large (SD of 22.06 as opposed to a SD of 15 for the standardization sample). Of course, when comparing these two studies, it must be noted that the subjects in the DesJardin et al. study were much older and covered a wider range of ages than the subjects in this study (mean age of 89.6 months and SD of 12.29 months and as opposed to a mean age of 49.54 months and a SD of 6.6 months in the current study). The participants in the DesJardin et al. study had also been using their cochlear implants for much longer and for a wider range of time than participants in the current study (mean length of 63.4 months and a SD of 10.68 months as opposed to a mean length of 27.65 months and a SD of 6.98 months, respectively). Additionally, DesJardin and colleagues used the *Phonological Awareness Test* (*PAT*), which is very different from the *TOPEL*. The *PAT* was utilized to assess rhyming, segmentation, isolation, deletion, blending, and graphemes, as opposed to only deletion and blending as in the *TOPEL*.

Interestingly, in the current study, no significant difference was found between the NH group and the CI group on items requiring children to blend syllables and phonemes. However, a significant difference was found between groups for the elision task. Furthermore, the effect size for the difference between groups on this task was large. This is in contrast to the findings of DesJardin and colleagues (2009). In that study, the CI group's SS for the blending subtest was substantially lower than for the deletion subtest. It is unclear why that finding arose. However, the results of the current study make sense, given the previous finding that elision tasks are among the most difficult phonological awareness tasks, especially for young children (Stanovich, Cunningham, & Cramer, 1984; Yopp, 1988).

Speech Perception

If indeed the delayed phonological awareness abilities of this group could largely be attributed to a weakness in the underlying representation of phonological structure, it would be assumed that the children would also have delayed speech perception abilities. Although a Mann-Whitney U-test did not indicate a statistically significant group difference using an alpha level of .05, a Fisher's Exact Test did indicate that children in the CI group were more likely to be non-perceivers (i.e. demonstrate at least 90% accuracy for two contrasts or less) than their NH peers. The speech perception abilities of the non-perceivers accounted for the lions share of the difference in speech perception scores between the CI and NH groups. When the non-perceivers were taken out of the analysis, the CI and NH groups did not appear to differ substantially for any of the six speech pattern contrasts on the PLAYSPAC. Despite there being six children in the CI group who could be classified as non-perceivers, it should be noted that there were ten children who were able to demonstrate perception of all six speech pattern contrasts. Thus, many children in the CI group demonstrated excellent speech perception skills on this measure.

The non-perceiving subgroup appeared to differ from the perceiving subgroup in more than just their speech perception abilities. The non-perceiving subgroup also performed less accurately than the perceiving subgroup on the measures of phonological awareness, speech production, general language, and receptive vocabulary. In fact, every child in the non-perceiving subgroup was found to have a score that was below the full CI group mean for speech production, general language, and receptive vocabulary. This speaks to the usefulness of the PLAYSPAC as a speech perception measure.

Although a poor performance on the speech perception measure indicated that a child was likely to perform poorly on the other outcome measures, the opposite was not necessarily the case. That is, a child who scored well on the speech perception measure would not necessarily have demonstrated strong skills on the other measures. Bird and Bishop (1992) indicate that children with phonological disorders may have difficulty not with discriminating sounds, but with categorizing speech sounds and segments. If this were also the case for children with cochlear implants, the speech perception measure used in this study would not have picked up on that deficit. It makes sense that if a child had difficulty individually representing phonemes (e.g. storing sounds individually as opposed to by speech segment), the child would have had difficulty on the phonological awareness measure. Indeed, this was exactly the problem Pisoni and colleagues (1997) suggested children with cochlear implants would demonstrate. The authors noted that children with cochlear implants may perceive and represent words in terms of broad phonetic categories due to difficulties reliably discriminating minute phonetic differences as a result of accessing sound via the cochlear implant.

Speech Production

In the area of speech production, the NH group had a clear advantage over the CI group. On average, they accurately produced 20% more consonants than the CI group.

The NH group's advantage over the CI group was evident for each manner of consonant production. However, the groups evidenced the same hierarchy of difficulty: glides, stops, nasals, affricates, liquids, and fricatives, with glides being the easiest to produce accurately and fricatives being the most difficult. This hierarchy is not surprising, considering that glides, stops, and nasals are among the earliest sounds that hearing children acquire (Stoel-Gammon, 1985). The biggest difference arose between groups for affricate and stop production. This is also not surprising considering that children with hearing loss historically have had difficulty with continuant sounds and with stops produced in the velar position. Tye-Murray, Spencer, and Woodworth (1995) examined the speech production abilities of 28 children who utilized cochlear implants. They found that the children regularly substituted stops for continuant sounds (e.g., /d/ for /s/, and /b/ for /v/). They also found that children produced velar sounds (all of which are stops) with much less accuracy than bilabials, labiodentals, and alveolars, despite the fact that many of the more anteriorly produced sounds are continuants.

The speech production scores of the children in the CI group varied drastically, especially as compared to the NH group. The children in the CI group had PCC scores ranging from 22 to 97 whereas the NH group had scores ranging from 49 to 97. Several of the low scores in the CI group were children who belonged to the non-perceiving CI subgroup. These six children all scored below the mean of the CI group; however, even with these children taken out of the analyses, the CI group's mean score for speech production was significantly below that of the NH group.

Oral Language

Despite the differences apparent between groups in the areas of phonological awareness, speech perception, and speech production, none of these three phonological variables emerged as the measure for which the children with cochlear implants were the most delayed in comparison to the NH group. Instead, the effect size was the largest for the difference between groups on the general language measure. Similarly, of all the standardized measures, the CI group achieved the lowest mean SS on the general language test, the *PLS-4*. The effect size was second largest for the differences between groups on the receptive vocabulary measure. There is some support for larger delays in oral language development than phonological development in the literature on children with cochlear implants. Schorr, Roth, and Fox (2008) found that 85% of the 5- to 14-year old children in the CI group performed in the average range for speech production and 89% scored within normal limits on the phonological awareness measure (an elision task). However, only 59% did so for morphology and syntax and 51% did so for vocabulary. Similarly, DesJardin and colleagues (2009) found significantly lower mean standard scores for general language than for phonological awareness (74 vs. 86 respectively). Thus, despite not having predicted that this group would have more difficulty with oral language skills than phonologic skills in comparison to their hearing peers, there are a few examples of this type of finding.

In general, there are many reasons that developing general oral language abilities within the average range may be more difficult than developing speech perception, speech production, phonological awareness, or even receptive vocabulary abilities within the average range, if indeed this is the case. For example, it is possible that for young children with cochlear implants, the problem originates with deficits in speech perception, which then sets off a chain reaction. Children with poor speech perception skills will have difficulty with other phonological skill development, such as speech production and phonological awareness, which rely to a large extent upon perceptual skills. Similarly, these children will evidence delays in vocabulary development. Due to the interdependence of lexicon and grammar (Marchman & Bates, 1994), delays in vocabulary will likely cause delays in grammatical development. Thus, as children catch up to their normally hearing peers in the areas of speech perception and speech production, they may still be delayed in skills that were impacted later in the chain.

Print Knowledge

Print knowledge emerged as the one measure for which the CI group did not perform significantly worse than their hearing peers. In fact, the lowest performing child in the CI group performed better than the lowest performing child in the NH group, and the mean for the CI group was .33 SDs *higher* than that of the standardization sample. This did not fit the prediction, in which it was anticipated that the CI group's print knowledge skills would be delayed in comparison to their peers with normal hearing. It is possible that the CI group performed well on this measure because this is a very concrete skill for parents to work on with their children. Indeed, a majority of the children in the CI group in this study currently attend or have attended one of two oral-deaf programs in the Los Angeles area, both of which place a strong emphasis on teaching parents to be the "teachers" for their children. It may be that this teaching emphasis has paid off especially well in areas parents feel confident about teaching, such as print knowledge. However, this is purely speculative and cannot be confirmed from the data collected in this study. Whether or not it is true, however, it is clear that a heavy emphasis on print and print-related knowledge is not sufficient to motivate typical development of phonological awareness, speech, and language among children with cochlear implants. Children with cochlear implants can make substantial progress in print-related abilities and still have skills in these other areas that lag well behind those of their hearing peers.

Relationship of Phonological and Linguistic Variables to Phonological Awareness

Correlational analyses confirmed that speech perception, speech production, general language, and receptive vocabulary were all correlated with phonological awareness for the children in the CI group. Although general language and receptive vocabulary were also correlated with phonological awareness for the NH group, speech perception and speech production were not. It was not surprising that a significant correlation did not exist for speech perception and phonological awareness for the NH group because of the lack of variance in the speech perception scores. The lack of a significant correlation between speech production and phonological awareness for the NH group also was not surprising. Rvachew (2006) failed to find a significant correlation between prekindergarten speech production abilities and kindergarten phonological awareness abilities when controlling for prekindergarten speech perception abilities. The correlations between phonological awareness and speech perception and production that were found in the current study were expected for the CI group. Theoretically, speech perception, speech production, and phonological awareness all rely on a child's representations of phonological information. If the child evidences a deficit in this ability, as would be expected due to the abnormal auditory experience of children with cochlear implants, it could impact skill development in all three areas, as well as other phonologic and linguistic areas.

Interestingly, the strongest correlation with phonological awareness for both groups was found for general language. There is some support for this in the literature regarding normal hearing children. For example, Cooper and colleagues (2002) found that although IQ, family literacy, socioeconomic status, and the child's primary language did not predict children's phonological awareness abilities in kindergarten or first grade, their oral language abilities did. In that study, the correlation coefficient between kindergarten oral language and later phonological awareness was 0.70. The strength of this correlation falls between the correlations found in the current study for the CI and NH groups (r=0.54 and r=0.78, respectively). Other studies have also documented correlations between phonological awareness and oral language for children with normal hearing, although they have not always been as high as in the Cooper et al. study or the current study. For example, Lonigan and colleagues (1998) reported correlations between receptive language, expressive language, blending, and elision for several age groups by socioeconomic status. The 3- and 4-year old children in the middle-income sample may have been most comparable to the children in the current study. The correlation coefficients between language and phonological awareness ranged from 0.11 to 0.30. Several of these correlations were significant, however, they are not as large as those found in the current study or the Cooper et al. study.

Hierarchical linear regression indicated that, for the CI group, speech perception did not uniquely account for any variance above and beyond that accounted for by speech production and vice versa. Additionally, for the CI and NH groups, although receptive vocabulary did not account for any variance in phonological awareness scores beyond that accounted for by general language, general language uniquely accounted for more variance than was explained by receptive vocabulary. For both groups, a hierarchical linear regression was conducted entering speech production as the phonological variable and general language as the linguistic variable. For the CI group, neither variable uniquely accounted for variance after the other variable was considered. In contrast, for the NH group, speech production did not account for any variance on its own. However, general language accounted for a significant amount of variance.

The results of these regression analyses indicated that, for the CI group, adding either the phonological or linguistic variable after entering the other variable did not account significantly for any additional variance. Thus the variance was shared between the two domains. However, for the NH group, the variance was uniquely accounted for by the linguistic variables. This was not exactly as predicted. It appears that speech perception and speech production did not necessarily have a special relationship for the CI group, as they did not uniquely account for any variance after consideration of language ability. These results imply that to encourage phonological awareness development, an equal focus on phonological and linguistic skill will be necessary.

Relationship of Other Variables to Phonological Awareness

In an attempt to determine whether there were other factors that might help explain the variance in the phonological awareness scores of the CI group, several demographic factors and factors related to hearing loss were considered.

One of these was maternal education, a component of SES. In the literature on hearing children, there is conflicting information about the relationship of SES and phonological awareness. Although some authors have found a relationship (e.g. Lonigan et al., 1998; McDowell et al., 2007; Nittrouer, 1996), this has not held true for all studies (e.g. Cooper et al., 2002; Rvachew & Grawburg, 2006). In the current study, SES (as measured by maternal education) was significantly correlated with phonological awareness scores for the NH group, but not for the CI group. The lack of a significant correlation between SES and phonological awareness is consistent with the findings of the DesJardin et al. (2009) study, in which no relationship between these factors was observed for children with cochlear implants. However, both of these findings contrast with the finding of Schorr and colleagues (2008). The results of that study indicated the presence of a relationship between SES and scores on an elision measure for the CI group but not for the NH group. It is unclear why this may have differed between the current study and the Schorr et al. study; however, it is possible to speculate as to why SES did not emerge as a correlate of phonological awareness for the CI group in this study and the DesJardin et al. study, which was also conducted at the House Ear Institute. As previously mentioned, most oral deaf children in the Los Angeles area who utilize cochlear implants are, at least in their preschool years, enrolled in one of two oral-deaf programs that are provided to parents at no cost. These programs focus extensively on teaching the parents to facilitate the language and listening skills of their children. Thus, differences in maternal input that would have existed due to SES may have been eliminated as lower SES parents were taught skills that are typically demonstrated by higher SES parents.

In addition to the demographic factors of age and maternal education, several variables related to hearing loss were also considered. No significant correlations were found between phonological awareness scores and age at hearing aid fitting, unaided pure tone average prior to cochlear implantation, age at cochlear implantation, duration of cochlear implant use, or communication mode. However, the unaided pre-cochlear implant pure tone average did approach significance, and likely would have reached significance with a slightly larger number of participants in each group. This indicated that children with more residual hearing in their better ear prior to implantation tended to performed slightly better on the phonological awareness measure. For most children, the ear with the least residual hearing is implanted, thus allowing the child's "best ear" to be aided. Several children had residual hearing in their better ear that, with appropriate amplification, could have given them access to the speech spectrum prior to implantation. Thus, they likely had more access to speech before implantation and continued to have acoustic access to speech (as opposed to the electrical stimulation of the cochlear implant) in one ear. This finding is consistent with findings of previous studies that have indicated that children with more residual hearing prior to implantation demonstrate better outcomes (Gordon, Twitchell, Papsin, & Harrison, 2001; Nicholas & Geers, 2006).

Limitations

There are a numerous limitations to this study. First, the number of children in each group is relatively small for the purposes of finding group effects and performing regression analyses. As previously mentioned, there were many occasions in which a medium effect size was found but the difference between groups did not reach significance. This appeared to be a result of limited power due to the relatively small number of subjects in each group. However, it also is possible that these effects are the result of Type I errors associated with the large number of comparisons made in this study.

Second, the primary groups differed in age. As indicated earlier, this was likely a result of the recruitment criteria. Although the standardized tests helped to eliminate any effect of age, this might have been more of a concern with the non-standardized measures (for speech perception and speech production). It should be noted that the NH group was younger than the CI group as opposed to older. Thus, the NH group's abilities may have been lower than those of a well age-matched group. This may have led to an underestimation of the differences between groups.

Another concern regarding the NH group was that this group had higher mean scores than the standardization sample on both of the oral language measures. There may be several explanatory factors, one of which is the recruitment methods. Eleven of the subjects in the NH group were either children of staff at the House Ear Institute or were directly recruited through personal connections of the staff at the House Ear Institute. Additionally, ten subjects in the study were enrolled after their parents responded to a flyer at their local preschool. The remaining five children were siblings of a child with a hearing loss who was being seen at the CARE Center. One could speculate that the parents recruited via local preschools or via employees at HEI who were able to take the time to participate in this study may have included an elevated number of stay-at-home parents. Stay-at-home parents are able to spend an above average amount of time providing their child with direct language stimulation. Similarly, one could speculate that the parents who took the time to bring their children to HEI specifically to participate in this study placed an especially high-value on research and education (which may also influence their parenting style). However, this cannot be confirmed from the data in this study.

Another limitation of this study is that a measure of nonverbal IQ was not administered to children at the time of their participation in the study. Without confirmation that the children with CIs were average in intelligence, one could speculate that the NH group performed as well as they did on the assessment measures because they had higher than average cognitive abilities. Similarly, one might propose that the CI group underperformed as compared to the NH group because of cognitive limitations. At least in the latter instance, there are two reasons that this likely is not the case. First, as mentioned in the methods, over 60% of the children in the CI group were administered the *Bayley Scales of Infant Development* (Bayley, 1993) prior to receiving their cochlear implant. The group achieved a mean score of 93 for the Mental Development Index (MDI) and a mean score of 98 for the Pyschomotor Development Index (PDI). Although the MDI score appears low, it is actually relatively high considering the many items on the MDI that are reliant on a child's auditory-oral skill development and considering that this subscale was administered prior to children receiving their cochlear implant. Additionally, the CI group's strong performance on the measure of print knowledge likely would not have occurred had this group been intellectually disabled. In regard to the NH group, if the NH group had a cognitive advantage over the standardization sample, we might have expected the NH group to demonstrate emergent literacy skills that were advanced in comparison to those of the standardization sample. However, they did not do so. Their mean SS for the phonological awareness measure was less than one point above the mean SS for the standardization sample. Additionally, their mean score for the print knowledge measure was not significantly higher than the mean score for the CI group.

This study also did not include a variable regarding children's exposure to direct training in the area of literacy. The preschools attended by the children with cochlear implants likely differed significantly from the preschools attended by the children with normal hearing. It is possible that the preschools the children with normal hearing attended had more of a focus on academic readiness whereas the preschools attended by the children with cochlear implants were more focused on language and speech development. However, it is also possible that children with cochlear implants have an advantage over the children with normal hearing because of the services the children with CIs receive from speech language pathologists and other aural habilitation specialists. Future studies should quantify the amount of explicit literacy training the children get at school and at home and determine the contribution of this factor to outcomes in phonological awareness and related abilities.

Another limitation of this study is that only one measure was utilized for each variable. Thus, when referring to "general oral language," in actuality, the *PLS-4* scores are being referenced. Although the *PLS-4* is strongly correlated with other language measures (per the *PLS-4* manual), the results may have looked somewhat different if a different measure of language was used, especially a measure drawn from spontaneous language samples. The use of only one measure per variable was perhaps most problematic for the speech perception variable. The measure that was chosen, the PLAYSPAC, had substantial ceiling effects for this age group and these developmental groups. Additionally, although this measure was purposefully chosen because of its limited demands on children's language knowledge and speech production abilities, that makes this test different from most tests currently being reported on in the research literature regarding speech perception, thus making comparisons with other studies difficult.

In order to avoid these types of limitations in the future, studies should strive to include a larger number of children in each group and to have groups that are as similar as possible in terms of age and background factors. Additionally, future studies should include measures of nonverbal IQ, not only for the purposes of comparing groups, but also to examine the relationship of nonverbal IQ with phonological awareness. Studies should also examine children's exposure to direct literacy training, both in the preschool and home settings. Finally, studies should include more than one measure of each skill area. For example, a speech perception measure without the strong ceiling effect found with the measure used in this study would be critical. However, use of a speech perception measure such as the one used in this study will also be critical because more advanced speech perception measures may include a floor effect.

The aforementioned changes to future studies will result in stronger studies that give more complete answers to those proposed in the current study. However, there are new questions that should also be addressed. For example, a longitudinal study looking at this population would be especially interesting. Such a study would provide further insight to the relationships between phonological awareness and related skills. Additionally, such a study would allow researchers to see which children are closing the gap between their abilities and those of their hearing peers and which children appear to be falling further behind their hearing peers with time. Such a study should include measures of early reading abilities such as word attack, reading vocabulary, and reading comprehension.

Another direction for future studies would be in the area of intervention. Such studies should not only examine whether children's phonological awareness abilities can be improved via direct intervention, but also which types of interventions are most effective. For example, interventions that directly target phonological awareness versus those that target the underlying factors that are believed to result in poor phonological awareness abilities should be compared.

Clinical Implications

One of the most significant findings of this study was that although the CI group differed from their NH peers in the areas of phonological awareness, speech perception, speech production, general language, and receptive vocabulary, many children in the CI group demonstrated impressive skills in each of these areas. In fact, for each of these variables, between one and seven children scored above the mean of the NH group. This is especially noteworthy considering the NH group's relatively high scores on the standardized measures as compared to the standardization sample and the young hearing age of the CI group members. Also impressive was the fact that over half of the children in the CI group demonstrated print knowledge skills above those of the NH group mean. Similarly, for the speech perception measure, ten of the 24 children in the CI group demonstrated perception of all six of the speech pattern contrasts in this task. These results are quite a departure from those reported for young children with profound hearing loss prior to the advent of cochlear implants. They indicate that, although not all children with cochlear implants are currently developing age appropriate phonological and linguistic abilities prior to entering school, this is a reasonable goal for many, if not most, children with CIs who receive their cochlear implant prior to three years of age and who have had at least 18-months of experience with their implant.

On the other hand, this study indicated that some children with cochlear implants continue to have difficulty with the most basic speech perception tasks and this difficulty impacts their outcomes in a variety of phonological and linguistic areas. The presence of this non-perceiving group and their performance on the outcome measures illustrates that when speech perception skills do not progress at a reasonable pace, other important outcomes are negatively affected. Future studies of young children with cochlear implants should examine which factors are related to children demonstrating such poor speech perception abilities. From this study, it was unclear whether this was primarily the impact of the non-perceiving subgroup's relatively young age (as compared to the perceiving subgroup), task specific factors (e.g. the heavy reliance of the PLAYSPAC on a child's abilities to continuously attend to the task), or whether there is something else underlying this poor speech perception development.

This study points toward several key areas to address to help children achieve age appropriate phonological and linguistic abilities. First, the performance of the non-perceiving subgroup of children with cochlear implants has further established the critical role of speech perception abilities in the development of other phonological and linguistic skills. Thus, professionals working with children with cochlear implants should assess their speech perception abilities early and often to ensure that children are making progress in this area. When possible, these tests should directly tap children's speech perception abilities without relying heavily on children's speech production or language abilities, thus allowing the professional to ensure that a child's performance on the test is truly indicative of a child’s speech perception abilities. The PLAYSPAC appears to be a valid measure for this purpose early in a child’s speech perception development. However, as children approach ceiling performance on the PLAYSPAC test, transition to another speech perception measure will need to occur.

After the non-perceiving children were removed from the NH and CI groups, between-group differences were still evident on the speech production and oral language measures. Thus, the ability to accurately detect changes in speech pattern contrasts is not sufficient for the development of age appropriate phonological and linguistic skills. This indicates that, in addition to focusing on speech perception development, professionals working with young children with cochlear implants must also directly address oral language development. A focus on this skill is important given the strong relationship between oral language and phonological awareness that was identified in this study. This is especially critical considering the relatively large gap that was found between the general language abilities of the children in the cochlear implant group and those of the children with normal hearing. It may be easy for professionals to overlook the severity of this gap if they compare children to their hearing age as opposed to their chronological age. Indeed, when children’s scores on the *PLS-4* were compared to their hearing age as opposed to their chronological age, the children appeared to be performing extremely well. However, the goal must be for children to perform on par with their chronologically age matched peers. Again, considering the results of this study, this is feasible for children who are identified and implanted relatively early and who have had at least 18 months experience with their cochlear implant.

For children receiving their services through the school district, it may be necessary to help the child's team understand that children with cochlear implants have the potential to develop age appropriate phonologic and linguistic skills. This is especially the case when services are provided by the school district because in many school districts children need to demonstrate scores of at least 1.25 SD below the mean or lower on standardized tests to qualify for services. If children with cochlear implants reach this cut-off point and services are terminated, we cannot expect them, as a group, to ever fully achieve age-appropriate abilities as compared to their hearing peers.

As could be discerned from the findings outlined in this study, extreme variability continues to exist in the phonological and linguistic abilities of preschool children with cochlear implants. Although this may have been expected, it was interesting that the variability, at least for phonological awareness, could not be attributed to socioeconomic status or many of the traditional variables considered when examining variance in the outcomes of children with cochlear implants: age at implantation, amount of experience with a cochlear implant, or communication mode. The only factor that appeared to explain some variance was pre-implant pure tone average. Considering this, the variable of residual hearing should be considered, among other factors, when determining the required frequency and intensity of aural habilitation services as well as when counseling parents regarding possible outcomes following implantation.

Other variance may be accounted for by factors that were not examined in this study. For example, it may be that additional variance is accounted for by parenting factors such as parental efficacy, environmental factors such as the home literacy environment, cognitive factors such as working memory, biological factors such as central auditory pathway development, or service factors such as the type, frequency, efficacy, and focus of aural habilitation and speech language intervention being provided to the child. Until these factors are further explored, the professionals working with the child must address any potential concerns in these areas to the extent possible.

Conclusions

The data from this study indicate that preschool children with CIs can develop phonological awareness skills grossly within the average range prior to the onset of formalized literacy instruction. It is important to note, however, that many children were not able to do so and, as a group, the children with cochlear implants were significantly behind their hearing peers in this area of development. Additionally, the CI group was lagging behind the NH group on the measures of speech production, general language, and receptive vocabulary. Similarly, children in the CI group were more likely than their peers in the NH group to demonstrate severely limited speech perception abilities. The delay in general language was especially large, which was disconcerting considering the strong correlations between oral language and phonological awareness in this study and, in general, the relationships of these skills with later literacy development. This study indicates that age appropriate speech perception, speech production, oral language, and early literacy skills by school-age are within reach for preschoolers who have been implanted for 18 months or more. However, the results in this study also indicate that many children with cochlear implants will lag behind hearing peers in these areas, making early language and phonological skills important areas of focus for programs of remediation.

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