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Phonological Awareness and Print Knowledge of Preschool Children with Cochlear Implants

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Abstract

Purpose—To determine whether preschool-age children with cochlear implants have age-appropriate phonological awareness and print knowledge and to examine the relationships of these skills with related speech and language abilities.

Method—24 children with cochlear implants (CIs) and 23 peers with normal hearing (NH), ages 36 to 60 months, participated. Children's print knowledge, phonological awareness, language, speech production, and speech perception abilities were assessed.

Results—For phonological awareness, the CI group's mean score fell within 1 standard deviation of the TOPEL's normative sample mean but was more than 1 standard deviation below our NH group mean. The CI group's performance did not differ significantly from that of the NH group for print knowledge. For the CI group, phonological awareness and print knowledge were significantly correlated with language, speech production, and speech perception. Together, these predictor variables accounted for 34% of variance in the CI group's phonological awareness but no significant variance in their print knowledge.

Conclusions—Children with CIs have the potential to develop age-appropriate early literacy skills by preschool-age but are likely to lag behind their NH peers in phonological awareness. Intervention programs serving these children should target these skills with instruction and by facilitating speech and language development.

Prior to the advent of cochlear implants (CIs), the average high-school graduate who was deaf demonstrated a third to fourth grade reading level (Furth, 1966; Krose, Lotz, Puffer, & Osberger, 1986). Now, however, studies consistently report that as a group, school-age children with CIs demonstrate reading comprehension scores that are near or within the average range as compared to their hearing peers (i.e. within 1.5 standard deviations of the

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mean of their NH peers) (DesJardin, Ambrose, & Eisenberg, 2009; Geers & Hayes, 2011; Johnson & Goswami, 2010; L. J. Spencer & Oleson, 2008).

Despite these impressive gains in literacy outcomes for children with CIs as a group, many children with CIs continue to struggle with literacy skill development. Geers and Hayes (2011) reported that over three times as many high school students with CIs scored more than 1 standard deviation below the mean on a standardized reading test than would be anticipated for children with normal hearing (i.e. 53% as compared to 16%). The findings in this study also illustrated the high levels of individual variability in literacy outcomes for children with CIs; 36% of the students were judged to be reading at a level commensurate with their hearing peers (i.e., beyond a 9th grade equivalency score) whereas another 17% of the students were still reading below the fourth grade level. The remaining 46% of the sample demonstrated consistent reading growth, but remained delayed in comparison to their hearing peers (i.e., grade equivalencies between the 4th and 8th grades).

Early identification of children with CIs who are at risk for literacy struggles is essential, as it allows us to plan interventions that will maximize children's potential for literacy success, thus minimizing the likelihood that they will experience significant delays in literacy throughout their school years. Currently, we know little about the early literacy skills of preschoolers with CIs who have had the advantages of early implantation and advanced CI technology. Thus, the main purposes of the current investigation were to examine the development of two key pre-literacy domains, phonological awareness and print knowledge, among deaf preschoolers who have worn CIs for at least 18 months and to determine whether and how these skills are related to these children's oral language, speech production, and speech perception abilities.

Phonological Awareness

Phonological awareness refers to an individual's understanding that speech is made up of abstract units, including syllables, onset and rime units, and individual phonemes. This understanding underlies children's developing ability to perform sound manipulations, such as blending of sounds into words and segmenting words into sounds. These tasks require that children recognize, discriminate, and manipulate the sounds of language and thus tap a variety of cognitive skills, including phonological working memory (Anthony & Francis, 2005; Gillam & van Kleeck, 1996). Although phonological awareness reflects a deep level of meta-phonological knowledge and a broad set of complex skills, children as young as 3 years of age demonstrate early phonological awareness skills when demands on cognitive resources are controlled (Chaney, 1992; Maclean, Bryant, & Bradley, 1987). As children enter school and begin receiving literacy instruction, their phonological awareness becomes progressively more refined (e.g., moving from words to syllables and phonemes). At the same time, their manipulations of phonological units become increasingly sophisticated (e.g., moving from identification of syllable onsets ["What sound does this word start with?"] to elision of phonemes in the syllable onset or coda [e.g., "What's zoom without /m/?"]) (Lonigan, Burgess, Anthony, & Barker, 1998).

Hearing children with deficits in speech production and perception, as well as those with weaknesses in vocabulary and grammar, are at risk for delayed phonological awareness abilities (Magnusson & Nauclér, 1993; Manis et al., 1997; Nittrouer, 1996; Peterson, Pennington, Shriberg, & Boada, 2009; Preston & Edwards, 2010). Researchers have hypothesized that deficits in these areas may be tied to a common cause; weaknesses in a child's ability to develop strong phonological representations (Munson, Edwards, & Beckman, 2005; Preston & Edwards, 2010). Phonological representations reflect the phonological structure of words in long-term memory, allowing children to retrieve the phonological form of the word at a later date. According to the lexical restructuring hypothesis (Metsala, 1997a, 1997b), infants initially store words as whole phonetic units. As their lexicon grows, words with similar articulatory and acoustic patterns begin to cluster. As a result, children begin to abstract phonological regularities across words and become more attuned to phonological detail. Consequently, their representations begin to take on a less holistic and more segmental shape, beginning with syllables and moving to phonemes (Metsala & Walley, 1998; Walley, Metsala, & Garlock, 2003; Werker & Curtin, 2005). Without well segmented representations of syllables and words, young children do not have the basis for developing skill on phonological awareness tasks, such as blending sounds into words or analyzing words into their phonemic components.

There are reasons to expect the phonological representations of children with CIs to be especially weak or underspecified, resulting in delayed phonological awareness for this group. First, children with CIs have well documented delays in the acquisition of vocabulary (Hayes, Geers, Treiman, & Moog, 2009; Houston, Carter, Pisoni, Kirk, & Ying, 2005; Houston & Miyamoto, 2010). As noted, vocabulary development drives the refinement of phonological representations (Gathercole & Baddeley, 1990; Metsala, 1999; Walley et al., 2003). Thus delays in this area that are evidenced by children with CIs are likely to hinder their development of phonological awareness skills. Second, many children with CIs have significant delays in speech perception and speech production (Blamey et al., 2001; Chin, 2003; Chin & Kaiser, 2000; Kirk, Miyamoto, Ying, Perdew, & Zuganelis, 2002; Miyamoto et al., 1994). Although it is clear that some phonological awareness skills can develop independently of speech production skill (Gillon, 2005; Nathan, Stackhouse, Goulandris, & Snowling, 2004; Rvachew & Grawburg, 2006), many children with speech-only deficits exhibit difficulty with phonological awareness, presumably because of imprecise, unstable, or inadequately segmented phonological representations (Bird & Bishop, 1992; Peterson et al., 2009; Preston & Edwards, 2010). Third, the electrical stimulation provided by CIs of even the most modern design cannot fully represent all aspects of the speech signal (e.g., spectral resolution). This limitation in the processed signal delivered by the implant, particularly in the context of other contributing factors (e.g., auditory deprivation), may be expected to impact negatively the strength and accuracy of the phonological representations of children with CIs and, as a result, their development of phonological awareness as well.

We currently know little about early phonological awareness skill development of preschool-age children with CIs who utilize updated cochlear implant technology and who received CIs at relatively young ages. However, there are studies of school-age children with CIs, many of whom were implanted after school entry, or utilized older cochlear implant technology. These studies indicate that although children with CIs can develop some degree of phonological awareness, they are consistently outperformed by their NH peers in this area (DesJardin et al., 2009; Geers & Hayes, 2011; James, Rajput, Brinton, & Goswami, 2008; James et al., 2005; Johnson & Goswami, 2010; Schorr, Roth, & Fox, 2008). Additionally, it has been established that, as with hearing children, children with CIs who have weak phonological awareness abilities are likely to be delayed in their word reading and reading comprehension development (Geers & Hayes, 2011; Johnson & Goswami, 2010). The current study was designed to compare the phonological awareness skills of preschoolers who received their CIs at relatively young ages and have had the advantage of relatively new CI technology with those of their NH peers.

Print Knowledge

Print knowledge is an umbrella term that encompasses children's concepts of print and their alphabet knowledge (Justice, Bowles, & Skibbe, 2006). Thus, this term typically refers to one's understanding of the forms and functions of written language and of letters and their corresponding sounds. Children's print knowledge can be measured with a variety of tasks that assess knowledge of book reading conventions, letters and their corresponding sounds, the relationships between written and spoken words, and abstract words regarding literacy (e.g., *word, sentence, reading*). Although the skills included under the rubric of print knowledge have typically been measured separately, there is evidence to indicate that they are interrelated and are all components of the larger construct of print knowledge (Justice & Ezell, 2002; Lomax & McGee, 1987).

Print knowledge has a reciprocal relationship with phonological awareness; however, there is evidence that it represents a fundamentally separate construct (Burgess & Lonigan, 1998; Lonigan, Burgess, & Anthony, 2000). Additionally, each construct uniquely predicts the probability of later reading difficulties, indicating that a deficit in either of these areas may put a child at risk for limited literacy achievement (Catts, Fey, Zhang, & Tomblin, 2001). Print knowledge emerges as the child begins to interact with print in everyday environments prior to the onset of systematic literacy instruction (Mason, 1980; Sulzby, 1985; Vukelich, 1994). This exposure occurs in a variety of contexts, including at the breakfast table as parents draw their child's attention to the label on the cereal box, during adult-child book reading interactions, and through educational television programming targeting alphabet knowledge (Bus, Van Ijzendoorn, & Pellegrini, 1995; Foy & Mann, 2003; Minton, 1975; Neuman, 1999; Neuman & Celano, 2001). Children's knowledge of the names and sounds of letters are further developed through explicit instruction and practice with the alphabet (Ehri, 1987).

Relationships between oral language and print knowledge have been observed for preschool-age children with typically developing language skills (Chaney, 1994; Dickinson, McCabe, Anastasopoulos, Peisner-Feinberg, & Poe, 2003; Justice et al., 2006). In addition, preschool-age children with NH who have language impairments have been shown to exhibit delays in print knowledge development (Boudreau, 2005; Catts et al., 2001; Gillam & Johnston, 1985). However, oral language abilities are not always predictive of print knowledge. For example, McGinty and Justice (2009) found that, for a group of preschoolers with specific language impairment, the support and instruction provided by mothers during book-reading interactions served as a predictor of print knowledge whereas the children's oral language ability did not. This may be due to the fact that letter knowledge, phonics, and concepts of print are highly constrained in scope; that is, they involve a small and finite number of explicit elements or concepts that can be mastered by young children over a relatively short period of time (Paris, 2005). Highly constrained skills, like alphabet knowledge, are generally easier to teach directly than less constrained skills, like phonological awareness. Thus, print knowledge may be more accessible to children with language impairments than phonological awareness.

There are no studies that directly compare the print knowledge abilities of preschool-age children with CIs to their NH peers. Two studies, however, have assessed print knowledge along with sight word reading, another highly constrained early literacy skill, by utilizing letter-word identification tasks. Easterbrooks et al. (2008) administered a letter-word identification task and a non-normed letter-sound identification task to 44 3- to 6-year-old children with hearing loss, many of whom had CIs. The group scored above the normative mean on the letter-word identification task. Additionally, the children's performance on both tasks was significantly correlated with their performance on an expressive language task (*rs* = .52 and .55). Similarly, DesJardin et al. (2009) administered a letter-word identification task to a group of 16 school-age children with CIs. They found that the group scored above the normative mean on this task, even though they demonstrated expressive language scores that were more than 2 standard deviations below the mean of the normative sample. Despite the stark differences in children's abilities in these two areas, letter-word identification scores were significantly correlated with expressive language scores (*r* = .63). These studies indicate that, although performance on language measures and letter-word identification measures are correlated, limitations in language abilities do not preclude children with hearing loss from demonstrating age-appropriate abilities on this task.

The current study examines the print knowledge skills of children with CIs more directly, by examining the knowledge of print concepts, letter names, and letter-sound correspondences in a younger sample of children who were implanted early and use relatively updated cochlear implant technology. Additionally, this study examines the relationships between print knowledge and related speech and language skills.

Objectives

The main objective of this study was to evaluate the phonological awareness skills and print knowledge of a group of preschool-age children who were implanted by 36 months of age and had been utilizing their CIs for at least 18 months at the time of testing. Given previous findings indicating that school-age children with CIs are typically outperformed by their hearing peers on measures of phonological awareness, we predicted that the children with CIs in this study would also be outperformed by their NH peers. We expected children in the CI group to perform more similarly to their NH peers on the print knowledge task than on the phonological awareness task because print knowledge abilities are more constrained than phonological awareness skills. A better understanding of how phonological awareness and print knowledge develop in this population of early CI users may allow us to identify young children with CIs who are at special risk for later literacy delays and to develop strategies for facilitating early development of phonological awareness and print knowledge among this population.

A secondary objective was to examine whether and how speech and oral language skills contribute to variance in the phonological awareness and print knowledge abilities of children with CIs. It was expected that, because the development of phonemically segmented phonological representations (which is necessary for phonological awareness) is reliant on vocabulary abilities, the measures of language would account for considerable variance in phonological awareness. Additionally, previous findings indicate that speech production and speech perception are related to phonological awareness, presumably because all three skills are reliant on or contribute to children's development of strong phonological representations. Therefore, the measures of speech perception and speech production were also expected to account for considerable variance in phonological awareness. We were less certain about predictions regarding the relationships between speech and language skills and print knowledge. Although most available evidence involving children with CIs indicates that expressive language skills are correlated with print knowledge, these studies have primarily examined letter-word identification, as opposed to a full spectrum of print skills, including print concepts and letter knowledge.

Method

The methods for this study were approved by the Institutional Review Boards at the University of Kansas and the House Research Institute. The basic plan was to identify a group of preschool-age children with bilateral deafness who had used a CI for at least 18 months, and to compare their phonological awareness and print knowledge skills with those of a group of sameage, typically developing children with normal hearing.

Participants

Twenty-four children participated in the cochlear implant group (CI group). All children either received audiological services at the House Research Institute (HRI) Children's Auditory Research and Evaluation (CARE) Center or attended 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 CI for a minimum of 18 months, no additional disabilities, and a primary home language of English. Although no IQ measure was administered to the children in this study, most of the children underwent testing with a developmental psychologist experienced with children with hearing loss prior to receipt of their CI and were judged to be typically developing (with the exception of delays related to their hearing loss). Additionally, no concerns were reported regarding the cognitive development of any children in the CI group by children's CI teams or parents. No a priori criteria were established regarding whether the children used sign, speech, or a combination of the two, but all CI participants were reported to be using oral language as their primary mode of communication at the time of testing. The CI group consisted of 13 females and 11 males. Parent report on ethnicity and race indicated that eight of the 24 children were Hispanic, two were of Asian descent, one was African American, and the others were white, non-Hispanic. Eleven of the 24 children in the CI group were utilizing two CIs at the time of the evaluation. Of these, three children received their two CIs simultaneously and the remaining eight received their two CIs sequentially.

Twenty-six children with normal hearing were recruited to participate in the control group. Three of these children were unable or unwilling to complete the full test battery. Their data were excluded from all analyses, resulting in a total of 23 normal hearing participants (NH group). The NH group was composed of preschool-age siblings accompanying their sister or brother with a hearing loss to the HRI CARE Center, children whose parents responded to flyers handed out at area preschools, and relatives and friends of HRI employees. All children in the NH group were reported as having passed a preschool hearing screening or were screened for hearing loss at the CARE Center. All participants in the NH group were 36 to 60 months of age, were reported to have no additional disabilities and lived in homes in which the primary language was English. Thus, the group consisted of 12 females and 11 males. Parent report on ethnicity and race indicated that 8 of the 23 children were Hispanic and the rest were white, non-Hispanic.

We planned for the two groups to be roughly equivalent in both age and maternal education (utilized to represent socioeconomic status). Results from independent samples t-tests confirmed that the groups were not significantly different for either variable. These and additional characteristics of the CI and NH samples are presented in Table 1.

Procedures

For children in both groups, one or two testing sessions lasting a total of approximately 2 hours were conducted at the HEI CARE Center. Sessions included breaks between testing, as needed. Reinforcers (e.g., stickers) were utilized to encourage children to participate throughout the session. The Test of Preschool Early Literacy (TOPEL, Lonigan, Wagner, Torgesen, & Rashotte, 2007) was utilized to assess phonological awareness and print knowledge. This is the only norm-referenced test available to assess the phonological awareness abilities of children as young as 3 years of age. The Phonological Awareness subtest includes 12 elision items (e.g., "Point to team without /m/." and "Say playground without ground.") and 15 blending items (e.g., "What word do these make: Hot – dog?" and "What word do these sounds make: F - ox?"). The Print Knowledge subtest includes 12 print concept items (e.g., "Which can you read?"), 16 lettername items (e.g., "Which one is M?"

and “What is the name of this letter?”), and eight soundletter correspondence items (e.g., “Which one makes the /b/ sound?” and “What sound does this letter make?”). Each subsection of both subtests begins with items utilizing a multiple choice response format and moves to items requiring free responses, with the exception of the print concepts items which all utilize a multiple choice format. To ensure that children understand the tasks, the elision and blending sections each include four practice items (two with a multiple choice format and two with a free choice format) on which children receive feedback to their responses. Additionally, children are engaged in tasks requiring manipulation of compound words (e.g., hotdog) before moving to more difficult items involving blending or elision of individual phonemes.

The testing sessions also involved administration of five measures designed to assess children’s speech and oral language abilities. The Auditory Comprehension subscale and the Expressive Communication subscale of the Preschool Language Scale-4 (PLS-4; Zimmerman, Steiner, & Pond, 2002) were administered to examine language comprehension and expression, respectively. The Peabody Picture Vocabulary Test-4 (PPVT-4; Dunn & Dunn, 2007) was given to assess receptive vocabulary and the Goldman Fristoe Test of Articulation-2 (GFTA-2; Goldman & Fristoe, 2000) was administered to examine the children’s speech production skills. These are commonly administered standardized tests that have been reported on widely in the literature on children with CIs.

Speech perception was measured using a non-standardized instrument: the Play Assessment of Speech Pattern Contrasts (PLAYSPAC) (Boothroyd, Eisenberg, & Martinez, 2006; Eisenberg, Martinez, & Boothroyd, 2007). This test was chosen because, unlike other speech perception tests for this age group, it does not rely heavily on children’s linguistic or speech production abilities. The PLAYSPAC measures children’s ability to perceive six English speech pattern contrasts (vowel height and place, and consonant voicing, manner, and place [front and rear]). 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 phonemic contrast (e.g., [a:da:] for vowel height) is introduced. 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 (Green & Swets, 1966). To calculate the d’, hit and false alarm rates were determined for each of the six contrasts and then averaged across the contrasts for each child.

We expected the NH group to outperform the CI group on the speech and language tasks. The performance of each group on the five tasks is reported in Table 1. Due to time constraints, the PPVT-4 could not be administered to one child in the CI group. We excluded this child from analyses involving PPVT-4 scores, reducing the number of participants in the CI group to 23 for this measure. Additionally, due to examiner error, one child in the CI group did not produce four words on the GFTA-2. Rather than excluding this participant from our analyses, the missing sound productions were scored correct or incorrect by assuming that they would have been produced in a manner consistent with the child's production of the same sounds in other positions or of phonetically similar sounds in the same position. Raw and standardized scores were then calculated as is typical for the GFTA-2. As shown in Table 1, independent samples *t*-tests confirmed that the NH group significantly outperformed the CI group for language comprehension, language expression, receptive vocabulary, and speech production, as was anticipated, *d*s > 1.25. Because of floor and ceiling effects, the data for speech perception did not meet the assumptions of normality for either group. Therefore, a Mann-Whitney U-Test was conducted to compare the groups’ performance on the speech perception task. The test confirmed that the NH group significantly outperformed the CI group on this measure, $p = .045$.

Results

To address our first objective, independent samples *t*-tests were performed with the standard scores from the Phonological Awareness and Print Knowledge subtests of the TOPEL (Lonigan et al., 2007). As indicated in Table 2, the CI group's mean score on the phonological awareness measure was slightly more than 1 standard deviation below the mean score of the NH group and this difference was statistically significant, $p < .001$. As illustrated in Figure 1, only three children in the CI group scored above the NH group mean for phonological awareness, with almost two thirds of the children in the CI group scoring more than 1 standard deviation below the mean of the NH group. In contrast, there were no significant between-group differences for print knowledge scores ($p = .705$), with over half the children in the CI group scoring above the mean of the NH group.

As a first step at addressing our second objective, zero-order correlations were calculated to examine the relationships for each group between print knowledge, phonological awareness, and the predictor variables (language comprehension, language expression, receptive vocabulary, speech production, and speech perception; see Table 3) for the CI group. Phonological awareness was significantly correlated with all five speech and language variables. Print knowledge was not significantly correlated with language comprehension, but was significantly correlated with the remaining four predictor variables. Phonological awareness and print knowledge were not significantly correlated with one another, however.

As shown in Table 3, the three spoken language variables were strongly correlated with one another within the CI group. To avoid multi-collinearity and to limit the number of variables used in analyses with our small sample, a single language composite score was calculated for each child. For all but one child, this score was the mean of the standard scores from the PLS-4 Auditory Comprehension subscale, the PLS-4 Expressive Communication subscale, and the PPVT-4. For the one child who did not have a PPVT-4 score, the language composite was calculated by averaging his scores from the two subscales of the PLS-4. We then calculated correlations between age at CI and length of CI experience with phonological awareness and print knowledge. No significant correlations were found, $rs = -.02$ to $.27$, $ps > .05$.

Multiple linear regression analyses were used to examine the contributions of the related skills to variability in the phonological awareness and print knowledge of the CI group. Semi-partial correlation coefficients were calculated to determine the unique contributions of each individual predictor variable (see Table 4).

For the first regression, TOPEL Phonological Awareness was entered as the criterion variable and the language composite, speech production, and speech perception variables were entered simultaneously as predictors. This model was significant ($F(3, 20) = 3.43$, $p = .037$), with the predictor variables accounting for 34% of the variance in the CI group's phonological awareness abilities. None of the predictor variables contributed unique variance to phonological awareness after accounting for the variance that was shared with the other predictors.

A second regression was conducted with TOPEL Print Knowledge entered as the criterion variable. Again, the language composite, speech production, and speech perception variables were entered simultaneously as predictors. Although language and speech variables correlated significantly with TOPEL scores on their own, this model combining all three variables was not significant, $F(3, 20) = 2.00$, $p = .146$.

Discussion

Phonological awareness and print knowledge are strongly predictive of later reading abilities and there are empirical and theoretical reasons to expect preschool-age children with CIs to be significantly delayed in one or both of these early literacy domains. Previous research has examined these domains of literacy primarily with school-age children with CIs, many of whom received their implants relatively late or utilized CI technology that is outdated in comparison to children who received CIs more recently (DesJardin et al., 2009; Johnson & Goswami, 2010; Schorr et al., 2008). Thus, we know little about the development of early literacy skills for preschool-age children who received CIs prior to 3-years of age. We intended to fill this information gap by comparing the phonological awareness and print knowledge skills of preschoolers with CIs to those of their NH peers and by examining the relationship of the CI group's speech and oral language performance with their performance in the early literacy domains.

Phonological Awareness

Although the average CI group member demonstrated the ability to manipulate phonological information, these children scored significantly lower on the TOPEL Phonological Awareness subtest than did the children in the NH group. The CI group's mean on the phonological awareness measure was slightly more than 1 standard deviation below that of the NH group mean and only three children in the CI group had phonological awareness scores at or above the mean for the NH group. This finding is consistent with previous research from schoolage children with CIs, who are generally older with later average ages of implant than the participants in the current study (DesJardin et al., 2009; Schorr et al., 2008; L. J. Spencer & Tomblin, 2009).

Scores on oral language, speech production, and speech perception tasks were moderately correlated with phonological awareness for the children with CIs. These results indicate that, despite the great strides they have made in language development due to CIs and related care, preschool-age children with CIs who are behind their NH peers in language, speech production, or speech perception ability are likely to fall behind in phonological awareness development, as well. The variance in phonological awareness accounted for by these predictors (34%), however, was shared among all of the variables. None of the three predictors made statistically significant unique contributions to variance in phonological awareness scores after controlling for the other two variables. These findings indicate that, although oral communication skills form an important linguistic base on which phonological awareness may grow, other factors not measured in our study, such as frequency and quality of parental teaching episodes, experience with literacy materials, and quality of preschool literacy experiences, likely play a significant role in the development of phonological awareness among children with CIs.

Print Knowledge

We anticipated that, because print knowledge is a more constrained skill than phonological awareness, the CI group would compare more favorably to their NH peers on this task than on the phonological awareness task. Our results confirmed this finding and indicated unequivocally that children with CIs can demonstrate age-appropriate print knowledge skills (DesJardin et al., 2009; Easterbrooks et al., 2008). Our CI group could not be differentiated from the NH group in their print knowledge abilities, despite the fact that they differed from the NH group by well over 1 standard deviation on each speech and language measure, *d*s > 1.25. Slightly more than half of the children in the CI group scored above the NH group mean on the TOPEL Print Knowledge subtest, indicating complete overlap between the distributions.

There were moderate positive relationships between the performance of the CI group on the print knowledge task and each of the speech and language tasks, except language comprehension. However, when combined in a regression analysis, these variables did not account for significant variance in children's print knowledge skills. Given that print knowledge abilities are positively correlated with later literacy skills, the fact that age-appropriate performance on at least some print knowledge tasks does not require age-appropriate speech and language skills bodes well for the potential reading achievement of these children.

Implant Related Variables

Although our questions did not directly address the relationship between implant related variables and children's early literacy skills, it is important to note that length of CI experience and age at CI were not significantly correlated with early literacy abilities, despite findings to this effect in some (James et al., 2008) but not all (Schorr et al., 2008) related studies. The lack of significant correlations linking early literacy skills with implant issues in this study may be related to the relatively small range in ages at receipt of CI (12 to 36 months). The only two children who received their implants after 28 months of age had significant residual hearing prior to receiving a CI. These two children also continued to benefit from a hearing aid in their non-implanted ear.

Study Limitations

There were several weaknesses in this study that limit the strength of our general findings and the clinical implications we can draw from them. First, the number of children in each group was relatively small for the purposes of finding group differences and performing regression analyses. In every regard, though, our key findings are compatible with those found in other studies of similar issues (DesJardin et al., 2009; Easterbrooks et al., 2008; Johnson & Goswami, 2010). Second, the PLAYSPAC, which was utilized to assess speech perception, had substantial ceiling effects. Unfortunately, other available speech perception measures also have inherent weaknesses, including a heavy reliance on children's speech production abilities or language abilities. Use of multiple measures of speech perception is warranted in future studies. Third, our language measures were heavily biased toward vocabulary, thus allowing us to gain little insight into the relationship between grammatical abilities and early literacy abilities for children with CIs. Inclusion of measures of grammatical abilities in future studies may be warranted, as early weaknesses in grammatical skills are related to later reading disability for children with normal hearing (Catts et al., 2001; Scarborough, 2001), and syntax and morphology are areas of special difficulty for children with CIs (Schorr et al., 2008; P. E. Spencer, 2004; Young & Killen, 2002).

Another limitation to this study is that we did not administer an IQ measure to either group. Some studies have indicated that children with higher nonverbal IQ scores are likely to demonstrate stronger early literacy skills than children with lower nonverbal IQ scores (Bryant, MacLean, Bradley, & Crossland, 1990; Lonigan et al., 2000), although other studies have not reported the same findings (McGinty & Justice, 2009). We attempted to screen out children with limited intelligence from both groups by asking the parents about developmental concerns, and, in the case of the CI group, asking children's CI teams to report any concerns regarding cognitive development. Additionally, as previously noted, the majority of children in the CI group underwent testing with a developmental psychologist experienced with children with hearing loss prior to receipt of their CI and were judged to be typically developing (with the exception of delays related to their hearing loss). However, we were unable to explore the contributions of nonverbal IQ to early literacy development or confirm that all children demonstrated typical development in this area.

Finally, it also would have been ideal to have information on children's early literacy experiences, including whether they were exposed to direct instruction in phonological awareness or print knowledge through intervention services or preschool education. Children's home literacy experiences have been shown to be positively correlated with their early literacy outcomes (Foy & Mann, 2003; Levy, Gong, Hessels, Evans, & Jared, 2006; Purcell-Gates, 1996), as has their receipt of direct literacy instruction in classrooms (Ehri et al., 2001; Phillips, Clancy-Menchetti, & Lonigan, 2008; van Kleeck, Gillam, & McFadden, 1998). Additionally, some studies have indicated that the home literacy environments of children with language impairments may differ from those of children with normal hearing (Marvin & Wright, 1997), indicating that delays in early literacy skills may be, in part, due to differences in early experiences. Although we did not collect information on the early literacy environments of children in this study, there is no reason to believe that the literacy experiences of children in either group would differ from those of other similar children. Thus, our findings likely serve as an accurate depiction of the early literacy skills of children with CIs as compared to their peers with normal hearing. However, our results do not speak to whether the early literacy environments of children with CIs differed from those of their peers with normal hearing and, if they did, to what extent those differences promoted or impeded children's development of phonological awareness and print knowledge.

Clinical Implications

Notwithstanding these limitations, our results have several clinical implications. First, prior to the advent of CIs, many curricula and instruction techniques utilized with deaf students avoided inclusion of sound-based instruction, such as phonics, due to the assumption that they could not access this information. For example, instead of teaching sound-letter correspondences, teachers might focus on whole-word recognition (Fletcher-Campbell, 2000). Given that half of the children in the CI group demonstrated phonological awareness skills that were within 1 standard deviation of the TOPEL normative sample mean, our results indicate that children with CIs can indeed access phonological information. Thus, preschool-age children with CIs should be challenged to use and expand their phonological resources as part of their (emergent) literacy education.

Second, the provision of strong literacy environments and thoughtfully planned early literacy instruction in isolation may not be adequate for promoting strong phonological awareness abilities for some young children with CIs. The current study indicated that children's early literacy abilities, especially those involving phonological awareness, were tied to their oral language, speech production, and speech perception abilities and that, for many children, these areas were delayed in comparison to their peers with NH. However, no one oral communication skill was found to be more important for phonological awareness development than the others. Thus, professionals should target the development of age-appropriate skills in language, speech production, *and* speech perception by or before school entry to provide a strong underlying basis for the development of age-appropriate early literacy skills for children with CIs.

Third, children with CIs should be on par with hearing peers in their print knowledge skills. Even children who have weak oral language skills should be able to learn and eventually master the fairly constrained information referred to as print concepts and alphabet knowledge. There is evidence that children who are at risk for reading deficits, including those with language disorders, can acquire such print knowledge through participation in shared book reading with an adult who makes reference to print concepts and alphabet properties (Justice & Ezell, 2002; Lovelace & Stewart, 2007; Zucker, Justice, & Piasta, 2009).

Finally, it may be easy for professionals to overlook the performance gaps that exist between preschoolers with CIs and those with NH in speech, language, and early literacy if they compare children with CIs to their length of CI experience as opposed to their chronological age. Indeed, when children's scores on the PLS-4 were calculated by their length of CI experience as opposed to their chronological age, the children appeared to be performing as well as their younger hearing-age peers. However, for children who receive their cochlear implants by 36 months of age and have been using CIs for at least 18 months, the goal must be performance on par with their chronologically age-matched peers prior to kindergarten entry. Considering the results of this study, this goal is readily obtainable for many children with CIs and, with constantly improving CI technology, intervention services, and educational programming, it may be feasible for most other children with CIs as well.

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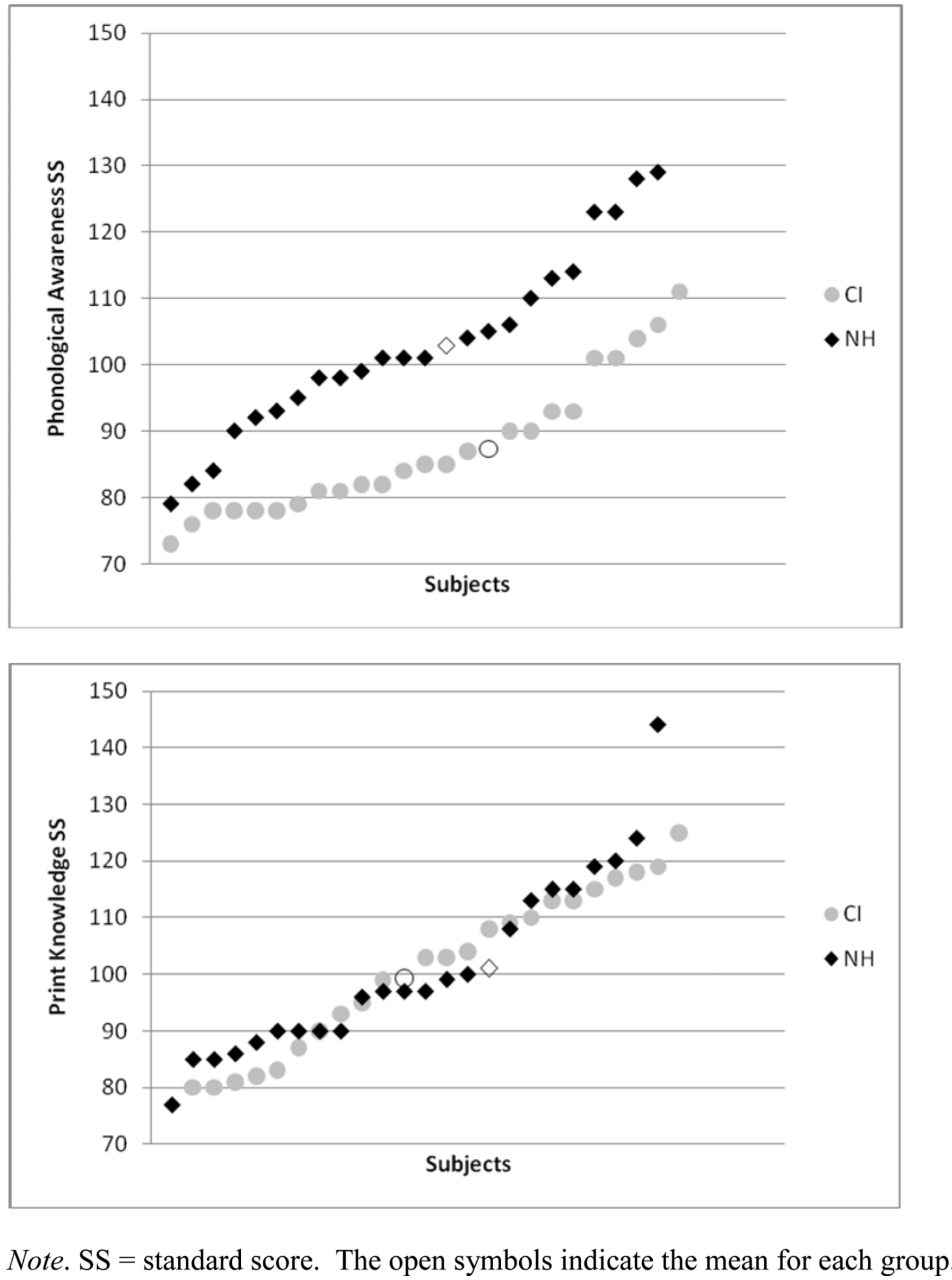

Figure 1.
Individual performance of subjects in each group on the TOPEL Phonological Awareness and Print Knowledge subtests (Lonigan et al., 2007).
Note. SS = standard score. The open symbols indicate the mean for each group.

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Table 1

Characteristics of the CI and NH groups

	CI group		NH group		Between groups		
Variable	***M***	***SD***	***M***	***SD***	***t***	***p***	***d***
Age at testing (months)	49.46	(6.54)	46.61	(7.72)	1.37	.178	0.40
Maternal education (years)	15.18	(3.02)	16.00	(2.34)	1.02	.314	0.30
Age at CI (months)	20.96	(6.94)					
CI experience (months)	27.65	(6.98)					
Language comprehension (SS)	85.83	(17.66)	112.17	(11.86)	5.98	<.001	1.75
Language expression (SS)	84.79	(13.80)	112.78	(12.14)	7.37	<.001	2.15
Receptive vocabulary (SS)	91.39	(15.88)	114.09	(15.58)	4.89	<.001	1.44
Speech production (SS)	83.21	(18.66)	102.43	(11.14)	4.31	<.001[a]	1.25
Speech perception (d-prime)	1.89	(1.00)	2.51	(0.41)	NA	.105[b]	NA

Note. SS = standard score, with a mean of 100 and a standard deviation of 15.

[a]Equal variances not assumed.

[b]Mann-Whitney U-test.

Table 2

Descriptive statistics and between group differences on the TOPEL Phonological Awareness and Print Knowledge subtests (Lonigan et al., 2007).

	CI group		NH group		Between groups		
Variable	***M***	***SD***	***M***	***SD***	***t***	***p***	***d***
Phonological awareness (SS)	87.33	10.53	102.96	13.97	4.34	<.001	1.26
Print knowledge (SS)	99.25	16.90	101.09	16.09	0.38	.705	0.11

Note. SS = standard score, with a mean of 100 and a standard deviation of 15.

Table 3

Correlations among variables for the CI group.

	1	2	3	4	5	6	7
1. Phonological awareness	-	.14	.53**	.52**	.46*	.44*	.52**
2. Print knowledge		-	.33	.50*	.47*	.46*	.44*
3. Language comprehension			-	.86**	.85**	.72**	.45*
4. Language expression				-	.89**	.78**	.58**
5. Receptive vocabulary					-	.75**	.51*
6. Speech production						-	.46*
7. Speech perception[a]							-

[a]Spearman's rho is reported for the correlations between speech perception and the other variables.

* $p < .05$.

** $p < .01$.

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Table 4

Results of linear regression analyses predicting phonological awareness and print knowledge for the CI group.

Predictor	Regression 1: Phonological awareness (R^2 = .34)				Regression 2: Print knowledge (R^2 = .23)			
	β	t	p	sr^2	β	t	p	sr^2
Language composite	.324	1.06	.301	.04	.243	0.74	.468	.02
Speech production	.066	0.23	.820	<.01	.271	0.88	.390	.03
Speech perception	.287	1.33	.197	.06	-.006	-0.03	.978	<.01

Note. For both regressions, all predictor variables were entered simultaneously in one step. sr^2 is the squared semi-partial correlation coefficient, which represents the percentage of total variance in the criterion variable accounted for by each individual predictor variable with the other variables controlled.