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Exploring the Language and Literacy Outcomes of Pediatric Cochlear Implant Users

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Abstract

Objective—The principal goal of this study was to investigate the relationship between language and literacy (i.e., reading and writing) skills in pediatric cochlear implant users. A peripheral objective was to identify the children's skills that were in need of remediation and subsequently to provide suggestions for remedial programming. It was predicted that the robust language skills often associated with children who have cochlear implant experience would facilitate the development of literacy skills. It was further proposed that the language and literacy skills of pediatric cochlear implant users would approximate the language and literacy skills of children with normal hearing.

Design—Sixteen pediatric cochlear implant users' language and literacy skills were evaluated and then compared with a reference group of 16 age-matched, normal-hearing children. All 32 participants were educated in mainstream classes within the public school system in the Midwest. The "Sentence Formulation" and "Concepts and Directions" subtests of the *Clinical Evaluation of Language Fundamentals-3* test were used to evaluate receptive and expressive language skills. Reading comprehension was evaluated with the "Paragraph Comprehension" subtest of the *Woodcock Reading Mastery Test*. Performance measures for the writing analyses included productivity, complexity and grammaticality measures.

Results—Children with cochlear implants performed within 1 SD of the normal-hearing, age-matched children on measures of language comprehension, reading comprehension and writing accuracy. However, the children with cochlear implants performed significantly poorer than the children with normal hearing on the expressive "Sentence Formulation" subtest. The cochlear implant users also produced fewer words on the written narrative task than did the normal-hearing children, although there was not a significant difference between groups with respect to total words per clause. Furthermore there was a strong correlation between language performance and reading performance, as well as language performance and total words produced on the written performance measure for the children using cochlear implants.

Conclusions—The results of this study suggest that the language skills of pediatric cochlear implant users are related to and correlated with the development of literacy skills within these children. Consequently, the performance of the cochlear implant users, on various language and literacy measures, compared favorably to an age-matched group of children with normal hearing. There were significant differences in the ability of the cochlear implant users to correctly utilize grammatical structures such as conjunctions and correct verb forms when they were required to formulate written and oral sentences. Given this information, it would be appropriate for their

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educational or remedial language programs to emphasize the use and development of these structures.

The link between speech perception, speech production and the development of language is a tight one (Jusczyk, 1997). Furthermore, a solid foundation in language is an essential key to the development of literacy skills (Kamhi & Catts, 2002). This paper presents outcome data that examined the relationship between reading, writing and language skills in two age-matched groups of children. One group consisted of children who had normal hearing from birth and the other group consisted of children who were identified as prelingually deaf and received cochlear implants before the age of 6. Cochlear implants are auditory prostheses that bypass damaged hair cells in individuals with sensory-neural hearing losses and apply electrical stimulation directly to the auditory nerve. The resulting auditory experience provided by cochlear implants is substantially different from that obtained through acoustic stimulation of the auditory system. Despite early concern that this stimulus would not be sufficient for children to develop speech and language skills (Crouch, 1997; Lane, 1992), there is now considerable evidence that children are able to make use of this stimulus for speech and language acquisition. It has been shown that the speech perception skills of deaf children significantly improve after they receive a cochlear implant (O'Donoghue, Nikolopoulos, Archbold, & Tait, 1999; Snik, Vermeulen, Geelen, Brokx, & van der Broek, 1997; Young, Grohne, Carrasco, & Brown, 1999). In concert, research shows that the speech production skills of deaf children also improve after implantation (Allen, Nikolopoulos, & O'Donoghue, 1998; Brown & McDowall, 1999; Ertmer & Mellon 2001). Finally, several studies have shown that spoken language development is also benefited by experience with a cochlear implant (Blamey, et al., 2001; Bollard, Chute, Popp, & Parisier, 1999; Connor, Hieber, Arts, & Zwolan, 2000; Miyamoto, Kirk, Svirsky, & Sehgal, 1999; Moeller, 2000; Tomblin, Spencer, Flock, Tyler, & Gantz, 1999).

When parents are faced with the “cochlear implant decision” for their children, a driving factor in their decision is their “frustration with the child's communication skills” (Kluwin & Stewart, 2000). Improved speech perception and production skills lay the foundation for closing this communication gap; thus it is speech perception and production that are typically hailed as principal benefits of the device. Subsequently, secondary benefits regarding academic and social development can also be expected. One such domain that may benefit is that of literacy development.

The Stages of Reading Proficiencies

Before further discussion of the perception-production-language-literacy link in pediatric cochlear implant users, it is important to have an understanding of this paradigm's literacy component in normal-hearing children. Chall (1979) identified 5 stages of reading development that can be observed in children with hearing. She reported that in the initial stages of reading, which begin from birth and extend through ages 6 or 7 yr (72 or 84 mo), the reader is gaining control over the syntax and semantics of language and relying on their own world knowledge. In these stages the child progresses from making the connection that words are made up of sounds, to developing a letter/sound relationship. In the second stage of reading, which develops at around age 7 or 8 yr (84 or 96 mo), Chall states that the child progresses from decoding words to gaining fluency. She stresses that at this stage, children are not yet using reading as a tool to learn. It is between the ages of 8 and 14 yr (96 and 168 mo) that children reach the critical third stage, where they are now able to use “reading to learn”. They develop both top-down (i.e., from meaning to print) and bottom-up (i.e., from print to meaning) processing skills. In the fourth stage of reading, children between the ages of 14 to 18 yr (168 to 216 mo) begin to comprehend written information from multiple viewpoints. Finally in the fifth stage of reading, which typically develops around 18 yr (216 mo) of age, the reader is able to analyze and synthesize knowledge using a high level of abstraction.

Numerous studies show that reading is closely linked to spoken language development. Specifically, it appears that children who enter school with poor spoken language are at substantial risk for later reading problems (Bishop & Adams, 1990; Catts, Fey, Zhang, & Tomblin, 1999; Felton & Wood, 1989). Writing development is also tied to spoken language development as well as reading development (Berninger, 2000; Catts & Kamhi, 1998; Nippold, 1998). Catts, Fey, and Proctor-Williams (2000) completed a longitudinal study of the relationship between language, reading and writing skills in children as they progressed from kindergarten through 4th grade. Their results indicated that phonological processing and oral language skills significantly contributed to achievement in the early stages of reading at 2nd grade with an even stronger effect by 4th grade. Preliminary writing data also revealed a relationship between language and writing skills. The authors found that children with lower language scores on standardized tests wrote shorter sentences, had less clausal density and made more grammatical errors.

The interdependence of spoken language, reading and writing skills is further illustrated in research conducted with deaf children (Lichtenstein, 1998; Musselman, 2000). Numerous studies with children and adolescents who are deaf show that developing reading proficiency has been a long-standing challenge for these people. As a result most of these children complete high school with reading levels no greater than that of hearing children performing at the fourth-grade level (Allen, 1986; DiFrancesca, 1972; Kroese, Lotz, Puffer, & Osberger, 1986), and 30% of deaf students can be classified as functionally illiterate upon graduation (Traxler, 2000). These results are not unexpected. Paul (1998) commented that … educators are faced with the possibility that most deaf students will not only be functionally illiterate, but also will not have acquired adequately a first language, which is necessary for the development of literate thought. (p. 63).

It has been observed that Chall's stage three is the point at which deaf children's reading skills tend to plateau (e.g., Allen, 1986; Marschark & Harris, 1996; Struckless & Marks, 1966). This plateau may reduce their ability to “read to learn”, thus limiting their ability to acquire new knowledge. Deaf children who fail to reach this third stage of reading will also lack the ability to use both top-down and bottom-up processing. As a result they fail to learn how to select and to activate strategies that aid in comprehension, especially from a single viewpoint. It is crucial for one to master these level-three skills. Once these skills are mastered a child is then capable of learning and analyzing information from multiple viewpoints.

The difficulty that deaf children have in acquiring the third stage of reading development affects a host of academic areas, including writing. Many of the same factors that affect the reading process also affect the writing process because of their mutually supportive and connective natures (Dobson, 1989). In other words, reading and writing both use visual-symbol systems that originate with speech and are thus interdependent (Vygotsky, 1978).

The Development of Writing Proficiency

The writing skills of deaf children have been studied in such depth that it would be beyond the scope of this paper to review the literature in detail. Thus the major areas of writing research will be addressed, specifically the areas that centers on documenting the development of writing mechanics and the development of sentence structures (Harrel, 1957; Hunt, 1965; Loban, 1963; O'Donnell, Griffin, & Norris, 1967). These studies tracked growth of syntax in school-age children with normal hearing. It was found that during the elementary school years, early writing patterns seem to follow spoken language trends.

Early writing thus is marked by an increase in quantity and complexity of form. Children aged 9 to 15 yr (108 to 180 mo) old wrote sentences that evolved in structure; the sentences were initially conjoined and eventually became embedded.

The written language of hearing children and of deaf children has been studied throughout the years. The performance measures that are characteristically obtained when evaluating their syntax include productivity, complexity and grammaticality. To date, however, there is a dearth of research directly comparing the performance measures of hearing children with the performance measures of deaf children. Nonetheless, many studies have indirectly compared the writing skills of deaf children with the writing skills of hearing children. Heider and Heider (1940) found that compositions written by deaf children were composed of shorter sentences as compared with the compositions of hearing children. This study documented that on average, deaf children were 17 yr old (204 mo old) before they produced sentences that were comparable in length to compositions by 8-yr-old (96-mo-old) hearing children. Wilbur (1977) examined sentence complexity and found that deaf children tended to compose text using recurring phrases, rigid form and an abundance of subject-verb-object constructions. Similarly, Marschark, Mouradian, and Halas (1994) found that deaf children used fewer adjectives and adverbs, shorter and simpler sentences and fewer prepositions and conjunctions in their written language. Mykelburst (1964) and Perry (1968) evaluated the grammaticality of deaf children's writing via error analysis studies. They found that errors tended to be categorized as those of word addition, omission or substitution. Lichtenstein (1998) elaborated, stating that errors associated with use of function words are common (e.g., omission of articles, prepositions, copulas and pronouns). In addition he states that there are also numerous errors with inflectional morphology such as plurality, verb agreement and tense.

Understanding the Impact of Literacy Deficits

Quigley and Paul (1990) underscore the impact that literacy deficits have on the educational performance in deaf individuals. They attributed literacy deficits to decreased skills in using language and stated, “It seems apparent that many deaf children neither read nor write the English language even adequately, and this is reflected in low educational performance in general” (p. 22). This issue of developing “functional literacy” is one that will continue to be relevant for the population of deaf individuals because it is an outcome that can be independently measured and it has direct impact on ultimate life achievement. The inability to obtain a literacy level high enough to succeed in work settings has been cited as the primary reason for underemployment in deaf adults (MacLeod-Gallinger, 1992).

Given the relative importance of developing solid literacy skills, it is intrinsic to study the affect new technology, such as the cochlear implant, has on literacy development in the population of deaf individuals. Nonetheless previous research has yet to properly control for the empirical exploration of this topic (even with children who wear hearing aids). Past research on writing development has lacked a paradigm with matched sampling tasks, sampling conditions and chronological ages. Yet it is important that the elicitation tasks are similar (or, ideally, identical) for the groups studied in order to ensure the integrity of comparisons (Scott & Windsor, 2000). It is for this reason that the present paper includes age-matched comparison groups of hearing children and cochlear implant users. In addition, including a normal-hearing group allowed for standardization of reading, writing and language skills to a common reference group.

Understanding the Language-Literacy Link

Given that spoken language serves as one of the important contributors to reading and writing development, it stands to reason that when a deaf child is equipped with an imperfect speech-perception-coding-production scheme, literacy proficiency is ultimately retarded. It follows that if use of a cochlear implant improves the aforementioned “scheme” (Cheng, Grant, & Niparko, 1999), we would also expect to see advancement in the literacy proficiency of pediatric cochlear implant users. Tomblin, Spencer, and Gantz (2001) found preliminary support for the hypothesis that increased literacy proficiency is associated with improved language skills. They reported that children with cochlear implants, who attended public schools and utilized speech and Signed English, obtained average standard scores of 91 on a measure of reading comprehension. These children also achieved higher language test percentile scores as they became older. These results suggest that cochlear implant use is associated with increased spoken language and reading performance of these children. In addition Crosson and Geers (2001) investigated the relationship between oral narrative production and reading comprehension in a group of cochlear implant users. They found that the ability to formulate an oral narrative predicted reading comprehension skills. Furthermore higher speech perception scores of the cochlear implant users were associated with their narrative production ability. When children had higher speech perception scores, their narrative ability corresponded with that of their hearing age mates with respect to use of referents and style.

In order to evaluate the language-literacy link in cochlear implant users, receptive and expressive language measures were included in this study. We hypothesize that stronger language skills, often associated with the use of a cochlear implant, will facilitate literacy development in cochlear implant users. The reading component of this paradigm has been examined in a preliminary manner in the pediatric cochlear implant literature (Spencer, Tomblin, & Gantz, 1997), but there has not been a study of the written language achievement of children with implants to date.

The purpose of this study was to document and compare the receptive, expressive and written language skills (i.e., reading and writing) of prelingually deaf, pediatric cochlear implant users with that of normal-hearing children who are of a similar age. The focus is specifically on the critical, third stage of reading development in cochlear implant users. Presently, published studies of language and literacy outcomes for children who receive cochlear implants are scarce. It is unclear what happens when pediatric cochlear implant users are faced with the challenge of applying their speech and language skills to the process of reading and writing. Regardless of whether an individual communicates primarily via a signed system, an oral system or a combination of both, it is a maxim that literacy skills are essential in order to succeed in today's highly literate and technically driven society. Consequently it is crucial that we gain a better understanding of the effects of cochlear implant use on literacy.

Finally this study directly compared language and literacy skills between cochlear implant users and a matched group of hearing peers. It utilizes identical measures and testing conditions, at a critical juncture in learning—the stage at which children are expected to move from learning to read to reading to learn (Chall, 1979). This is one of the first demonstrations of such a direct comparison.

Method

Participants with Cochlear Implants

Sixteen children, 6 girls and 10 boys, who were prelingually deaf (i.e., deaf before age two) and received cochlear implants between the ages of 30 mo and 76 mo, participated in this study. The average age of implantation for this group was 47 mo, (SD = 13 mo). The average length of experience with a cochlear implant was 71 mo (SD = 13 mo). All age computations were rounded to the nearest month at the time of follow-up appointment.

Upon testing, the average age of these children was 118 mo (SD = 7 mo). All participants were considered to be users of simultaneous communication who were mainstreamed into the public school program in their home communities. All the children used sign language interpreters throughout their school days in conjunction with their classroom teachers who used speech to communicate. The majority of these children were either the only deaf child in their class or one of a small group of deaf or hearing-impaired children in the entire school. These participants are referred to as the “cochlear implant group.”

Participants with Normal Hearing

Sixteen children, 7 girls and 9 boys, who had normal hearing participated in this study. The average age of this group was 118 mo (SD = 4 mo). All participants were members of a cohort of children, who were initially sampled while in kindergarten for an epidemiological study of specific language impairment (Tomblin, Smith, & Zhang, 1997). These 16 children continued as members of a cohort being followed in a longitudinal study of language and academic performance (Catts, et al., 1999; Tomblin, Zhang, Buckwalter, & Catts, 2000). The 16 participants for this group were sampled from the larger cohort to form a subgroup of children with average language and reading skills; thus none of the children in this subset were identified as having a language impairment. All participants attended public school in their home communities. These participants are referred to as the “normal-hearing group.”

All participants were matched according to their ages at the time of testing (t (30) = 0.797, p > .05). All participants were tested individually in a quiet room with an experimenter present.

Test Measures

Language—The “Formulated Sentences” and “Concepts and Directions” subtests of the *Clinical Evaluation of Language Fundamentals-III* (*CELF-3*) (Semel, Wiig, & Secord, 1995) were administered as a measure of the participants' expressive and receptive language skills. These tests were administered to all children according to the directions outlined in the test manual. For the children within the cochlear implant group, all testing was completed in both speech and Signed English. Two of the children in the cochlear implant group did not receive the *CELF* because they participated before this test was added to the evaluation battery.

Reading Comprehension—The “Passage Comprehension Test” from the *Woodcock Reading Mastery Tests Revised Form* (*WRMT*) (Woodcock, 1987), was used as a measure of reading comprehension. The “Passage Comprehension Test” is a modified cloze procedure that assesses a child's ability to comprehend a short passage that was two to three sentences in length. This subtest required that the child comprehend the entire passage in order to complete the sentence with the correct word. The cochlear implant group was allowed to answer in sign, voice and sign or voice only.

Writing—Writing samples were elicited using a procedure developed by Fey and Catts (Reference Note 1). Each participant was provided with four sets of pictures each depicting the setting, a problem and a resolution that could elicit a narrative. The children were asked to choose one of these picture series to write about. The children then briefly scanned a prototype story containing a brief narrative that included a problem and a resolution. This prototype was written about one of the unselected, remaining series. The children were subsequently asked to write about their own three-picture series. No time limit was given for the task, however most children were finished writing within 15 to 20 minutes.

In keeping with traditional studies of written language formulation, performance was assessed using characteristic measures evaluating writing syntax; they included productivity, complexity and grammaticality measures. The written narratives were thus analyzed with regard to sentence complexity and form. Transcriptions followed conventions that would allow the texts to be analyzed using the *Systematic Analysis of Language Transcripts* computer program (*SALT*) (Miller & Chapman, 1999). To obtain sentence productivity and complexity measures, utterances were segmented into T-units using guidelines provided by Hedberg and Westby (1993). Words per T-Unit were calculated and total words were calculated via *SALT*.

In order to examine sentence formulation skills, the grammatical role of each word was coded according to the following word classes: nouns (singular and plural), pronouns, verbs (present and past tense, auxiliary, "do" form and modal), determiners, adjectives, adverbs, conjunctions and prepositions. Also coded were deletions of obligatory forms, errors involving agreement and incorrect marking of tense.

Interrater reliability was calculated for eight, randomly sampled, written narratives (25% of all transcripts). Original manuscripts from the children were re-entered into the *SALT* file database and coded by the second rater. When compared with the original files, mean word-by-word reliability was 94% with a range across the 8 transcripts from 85% to 99%. For the coding of T-units, mean reliability was 95% with a range of 86% to 100%.

Results

Language Test Measures

The results of the language performance measures (i.e., "Formulated Sentences" and "Concepts and Directions" subtests of the *CELF-3*) for each of the two groups are presented as follows. The mean standard score for the cochlear implant group on the "Formulated Sentence" subtest was 5.14 (SD = 2.38), while the mean standard score for the normal-hearing group was 10.25 (SD = 3.09); a *t*-test demonstrated that these means were significantly different [t (27) = −5.02, $p < .0001$]. The mean standard score for the cochlear implant group on the "Concepts and Directions" subtest was 7.17 (SD = 2.48) while the mean standard score for the normal-hearing group was 9.44 (SD = 3.32); these means were also significantly different [t (28) = −2.06, $p < .05$]. The top two bars (light gray) on the graph in Figure 1 depict the standardized scores of the cochlear implant group placed on an equal-interval scale by converting them into *z*-scores based on the mean and standard deviation of the normal-hearing group. This figure reveals, that for the expressive subtest, "Formulated Sentences," the cochlear implant group scored 1.6 SD below the mean of the normal-hearing group (represented by an average score of 0). For the receptive subtest, "Concepts and Directions," the performance of the cochlear implant group was .69 SD below the mean of the normal-hearing group.

Reading Comprehension Measure

The results of the reading performance measured by the *Woodcock Reading Mastery Test* for each of the two groups are shown in Figure 2. This box plot shows that the normal-hearing group obtained a mean standard score of 99.5 (SD = 14.09), thus it suitably represents a group of normal readers. In contrast, the cochlear implant group obtained a mean score of 90.13 (SD = 11.18). A *t*-test revealed a significant difference between the mean standard score for the groups (t (30) = −2.09, $p < .05$). Although the cochlear implant group scored lower on the "Passage Comprehension" subtest than the normal-hearing group, the mean score of each group is within 10 points on the standard scale. In grade equivalency terms, the cochlear implant group obtained a mean grade equivalency of 3.3 (SD = .94), where as the normal-hearing group obtained a mean grade equivalency of 3.8 (SD = .68). The minimum standard scores for the cochlear implant group and the normal-hearing group were 71 and 71, respectively. The maximum standard scores for the cochlear implant group and the normal-hearing group were 118 and 120, respectively. Therefore the range of standard scores for both groups was similar.

Writing Measures

Productivity/Complexity—Writing productivity was indexed by the total words per sample and total number of T-units. Written utterance complexity was indexed by words per T-unit. A summary of the analyses is presented in Table 1. Unpaired *t*-tests revealed significant differences between the cochlear implant group and the normal-hearing group for two of the productivity variables: total words per sample ($t\ (30) = -3.69$, $p < .01$) and words per T-unit ($t\ (30) = -3.10$, $p < .05$). However, these two measures are not independent of each other. Given that the two groups did not differ significantly with regard to the number of T-units produced in their stories, it appears that much of the reduction in the total-word count of the cochlear implant group can be accounted for by their use of shorter, and possibly less complex, T-units. Because the total number of words produced was lower for the cochlear implant group, it is not surprising that in all cases the average use of each grammatical category was lower for the cochlear implant group. See the Appendix for an example story printed as written by a typical child from each participant group. Six of the 8 grammatical categories measured revealed significantly fewer instances of use by the cochlear implant group. These included pronouns, verbs, determiners, adverbs, conjunctions and prepositions. Note that the conjunction category facilitated production of complex sentences, thus resulting in longer T-units in the normal-hearing group.

Error Analysis—Because previous studies have reported that children with hearing impairments tend to produce more errors in written tasks than their hearing cohorts produce, the accuracy of written production was evaluated. For each narrative the total number of errors produced was recorded for each child. The errors included: deletion of obligatory word forms, incorrect verb forms and agreement errors involving subject-verb or modifier-noun agreement. The cochlear implant group averaged 4.25 total errors (SD = 2.52) and the normal-hearing group averaged 2.31 total errors (SD = 2.50) per narrative. Thus the narratives produced by the cochlear implant group contained significantly more grammatical errors ($t\ (30) = 2.19$, $p < .05$) than those of the normal-hearing group. In looking at the types of errors made, the use of incorrect verb forms was most prevalent for both groups, with a total of 31 errors made by the cochlear implant group as compared with 15 total verb errors made by the normal-hearing group. Mean number of errors committed by each group for the remaining categories was less than 1.0.

Profiling Spoken and Written Language

The separate analyses presented above show that the children with cochlear implants had language achievement levels below their age mates in all aspects of language usage. The reading and spoken language data were obtained using instruments that allowed normative comparison with hearing children and these data suggest that the effect size in the form of Cohen's *d* of these differences ranged from .74 (reading comprehension) to −1.85 (formulated sentences). Thus, it seems that the language skills of the cochlear implant children are variable. In order to examine this variability across language domains, all scores of the children with cochlear implants were standardized according to the performance of the normal-hearing group. This was done by dividing the difference between each cochlear implant child's score from the mean of the normal-hearing group and dividing by the standard deviation of the normal-hearing performance. These normalized scores are also presented in Figure 1.

The reading and writing data suggest that the normal-hearing group outperformed the cochlear implant group. Figure 1 shows that the literacy performance levels of the cochlear implant group were consistently between .58 and 1.2 SD below the mean score of the normal-hearing group, which is represented by an average score of 0. The reading score of the cochlear implant group on the receptive subtest “Passage Comprehension” was .79 SD lower than the normal-hearing group.

Relationship between Language and Literacy Skills

The data in Figure 3 display the association between language and reading skills for the cochlear implant group and the normal-hearing group. The correlation between language and reading for the cochlear implant group was found to be a strong and significant one ($r = .8$, $p = .001$). The correlation for the normal-hearing group was a moderate one ($r = .52$, $p < .05$). Figure 4 shows the relationship between language and writing productivity for the cochlear implant and normal-hearing groups. In this instance, however, only the cochlear implant group had a strong and significant correlation ($r = .70$, $p < .01$)

Discussion

A review of the literature reveals that since the inception of standardized reading testing, children who are deaf have consistently achieved lower scores than their hearing peers (e.g., Allen, 1986; DiFrancesca, 1972; Furth, 1966; Goetzinger & Rousey, 1959; Kroese, et al., 1986; Musselman, 2000; Traxler, 2000; Trybus & Kachmer, 1977; Wrightstone, Aronow, & Moskowitz, 1963). Again, progress from year to year is reported to be slow, and studies report that average yearly improvement is at a rate of 1 to 6 mo (for every 12 mo of education). Children with profound hearing loss may fall behind early in their educational careers. One study by Yoshinaga-Itano and Downey (1996) tested reading comprehension skills of 33 children with profound, bilateral hearing loss and no additional disabilities using the *Woodcock-Johnson Psychoeducational Battery*. Using the norms provided by the test, these researchers found that by the time children with profound hearing loss were between the ages of 10 and 12 yr (120 to 144 mo) they were already three grade levels below their hearing peers. This lag in reading development appears to widen, in that adolescents who are deaf typically complete high school with reading levels 7 to 8 grade levels below age expectations (Furth, 1966; Kroese et al., 1986).

The current reading data obtained from the cochlear implant group are contrary to these aforementioned data of deaf children. To begin with, although the participants in the current study were younger (mean age = 118 mo) than the children in previous studies, they were reading at grade levels comparable to their normal-hearing peers. Recall, that the average reading grade level of the normal-hearing group was 3.8 while the average reading grade level of the cochlear implant group was 3.3. It remains to be seen what the reading achievement level of the cochlear implant group will ultimately be; follow-up studies are warranted.

These data suggest that the cochlear implant users have attained the first critical stage of reading (Chall's level 3), and that the often-cited lag in achievement that deaf children tend to exhibit, is not present in this sample. The range of standard scores for both groups was the same, and the mean standard scores between the groups were within 8 points of each other. Although the mean score of the cochlear implant group was 9 standard points below average on the “Passage Comprehension” subtest, the scores essentially fell within the normal range. Therefore it can be concluded that the pediatric cochlear implant users should be able to meet ordinary classroom expectations. Ten of the 16 children in the cochlear implant group achieved a standard score that was within 1 SD of the average standard score of 100. Only two of the children in the cochlear implant group attained standard scores that were 1.5 SD below the average standard score of 100. Indeed, only 2 children in this group would qualify for reading recovery services according to the state of Iowa's guidelines, which typically require that children be more than 1.5 SD below the mean in order to receive such services. Finally these data demonstrate that advancement in the literacy proficiency of pediatric cochlear implant users appear to be associated with gains in English language competence afforded by the cochlear implant as illustrated by the high correlation between the cochlear implant users' language and reading skills.

The present study was particularly concerned with documenting and comparing the literacy skills of prelingually deaf, cochlear implant users with that of children who have normal hearing and are of a similar age. Paul (1998) concluded that deaf children had greater problems with writing than they did with reading. These final data provide evidence that this does not seem to be the case with pediatric cochlear implant users; their performance on outcome measures evaluating writing productivity, utterance complexity and usage errors was similar to their performance on reading comprehension measures. When compared with the normal-hearing group, the cochlear implant group's writing skills were immature. This immaturity was evidenced in the cochlear implant group's use of shorter, less complex sentences and more usage errors. However, as shown in Figure 1, the written productivity and written error rates (plus the reading standard scores) were less than 1 SD away from the scores of the normal-hearing group. As was previously stated with regard to reading skills, the writing skills of the pediatric cochlear implant users should also allow them to perform at a level commensurate with their hearing peers in a regular classroom setting. This parallel in the reading and writing performance patterns is not surprising and, when combined with the documented gain in spoken language, highlights the interdependence of these systems. These data support the hypothesis that the language skills of children with cochlear implant experience are related to and correlated with the development of literacy skills. This is demonstrated by the positive correlations between reading standard scores and composite language scores, as well as the total words produced in writing samples and composite language scores.

It is interesting to note the discrepancy between the normal-hearing and cochlear implant groups when looking at the correlations between writing productivity and composite language scores (see Fig. 4). The normal-hearing group generated a negative correlation, but the cochlear implant group demonstrated a positive correlation between writing productivity and composite language. One possible explanation for these opposing results may be that early in development there is a tight coupling between oral language skills and writing skills that eventually becomes disjoined with maturation. In other words children's written productions initially mirrors their spoken language. As their writing matures they begin to use a more sophisticated writing style when they gain more cognitive control over the written form. As this control develops children are more able to detach their written output from their spoken output and to “access non-default, less productive marked options” (Ravid & Tolchinsky, 2002). The data from the current study suggest that the normal-hearing group has begun to undergo this “detachment” while the cochlear implant group has not, thus they continue to use their spoken language scripts for writing. Further research is warranted in order to explore this relationship in both children with normal hearing and in children with cochlear implants.

When the performance levels of the children with cochlear implants were compared across language usage domains, the data revealed the greatest deficits in two areas: formulated sentences, which is an expressive spoken language task, and the measures of written language complexity. Thus, it appears that expressive language performance is more challenging to children with cochlear implants than receptive language, regardless of modality. One can only speculate as to the basis of this pattern, however, as children acquire language skills, they usually acquire competency receptively before they show expressive competence. It is likely that use of language skills in the expressive mode are more demanding and require greater levels of mastery than receptive performance. This pattern of poorer performance in the expressive modes of speaking and writing may be an additional reflection that language competence is emerging in the children with cochlear implants, thus they are more vulnerable to demanding language usage tasks.

Implications for remedial programming could first include decreasing the receptive/ productive gap within an individual child and targeting structured production work. This might include targeting formulation skills by having the child produce sentences using target words taken from a child's school vocabulary lesson, spelling lists or curriculum based materials. Other ideas might include encouraging the child to formulate sentences to caption illustrations or working on sentence generation during functional tasks such as writing letters. The primary difference in written narratives between the cochlear implant group and the normal-hearing group was that the former group produced shorter sentences with fewer conjunctions. Accordingly specific work on sentence generation tasks that target conjunction use would be appropriate.

The majority of the children in the cochlear implant group received their cochlear implants in their preschool years (average age of implantation was 44 mo). When they entered kindergarten they had slightly over 24 mo of implant experience. Recently there has been a substantial shift in the typical age of implantation in the United States and Europe. As a result, it is very common for children to receive an implant prior to the age of 24 mo. A previous examination of the reading skills of children with cochlear implants demonstrated a relationship between age at implant and reading performance, with children implanted at an earlier age having better reading performance (Tomblin & Spencer, Reference Note 2). It is predicted that the generation of children implanted at earlier ages should enter school with greater language proficiency than the pediatric cochlear implant users focused on in this study, because they will enter kindergarten with 48 to 60 mo of language experience while using a cochlear implant. Cummins (1979) proposed that academic tasks require children to have a language proficiency that coincides with an age level of 48 or 60 mo. Given this information it is predicted that future research comparing the reading and writing performance of pediatric cochlear implant users with their hearing peers is likely to reveal a narrowing of the performance gap between children with normal hearing and children with cochlear implants.

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Appendix

Written Language Samples

120-Mo-Old Normal-Hearing Child (Version as Written)

Once upon a time there was two great horses. They were so great because the were 5 times champ hurderlures. They were Mom and son. Their names were Susei and Black Jack. They hated their next door neighbor. He was a mean bull. The Bull loved his apples. He has been taking very good care of them. Jack thought he might play a trick on him and steel his apples. He was on the bulls side of the fence when he saw the bull. He said what are you doing here." In a deep voice. Jack said steeling your apples. Bull said why oughta.. Jack said got to jet. So they were chasing each other around the whole field when Jack saw his mom and the fence and jumped. It was the farthest he'd ever jumped and made it. He ran straight to his mom and handed her the apples. She gave the apples to grun and they lived happily ever after.

120-Mo-Old Cochlear Implant User (Version as Written)

The white horse told the little black horse. The white horse said, "Would you please get those apples from the old meany bull?" Then the little black horse said, "Sure." Then he went to get the apples and the old meany bully saw him and caught him and said, "What are you doing here?" The black horse said "To get some of apple." The bull said, "for who, for your girlfriend?" He said, "No, for me." Then the horse ran off.

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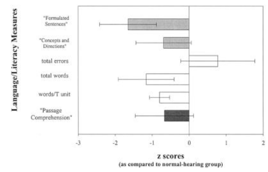

Figure 1.

Comparison of the cochlear implant group's standard scores to the scores of the normal-hearing group, as calculated for the language (light gray bars), writing (white bars) and reading (dark gray bars) measures.

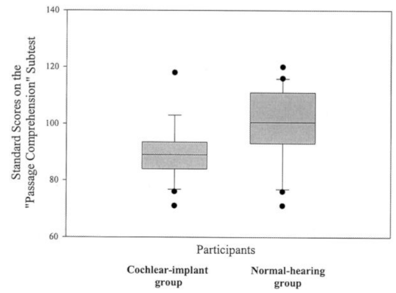

Figure 2.

Reading comprehension, as measured by the *Woodcock Reading Mastery Tests Revised Form* (Woodcock, 1987), for the cochlear implant and normal-hearing groups.

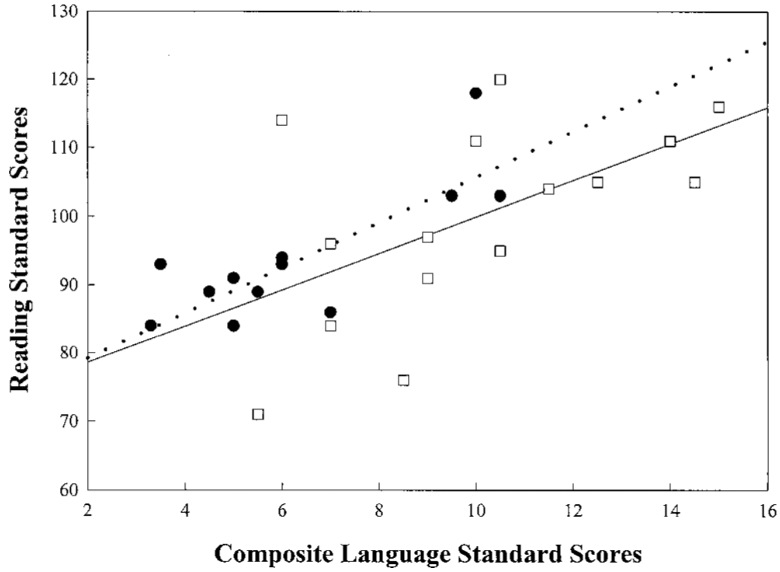

Figure 3.
This figure illustrates the relationship between reading standard scores and composite language standard scores for the cochlear implant and normal-hearing groups. The solid circles represent the scores from the cochlear implant group, and the squares represent the scores from the normal-hearing group. The regression line for the cochlear implant group is represented by the dotted line (r = .80, p = .001), and the regression line for the normal-hearing group is represented by the solid line (r = .52, p = .02).

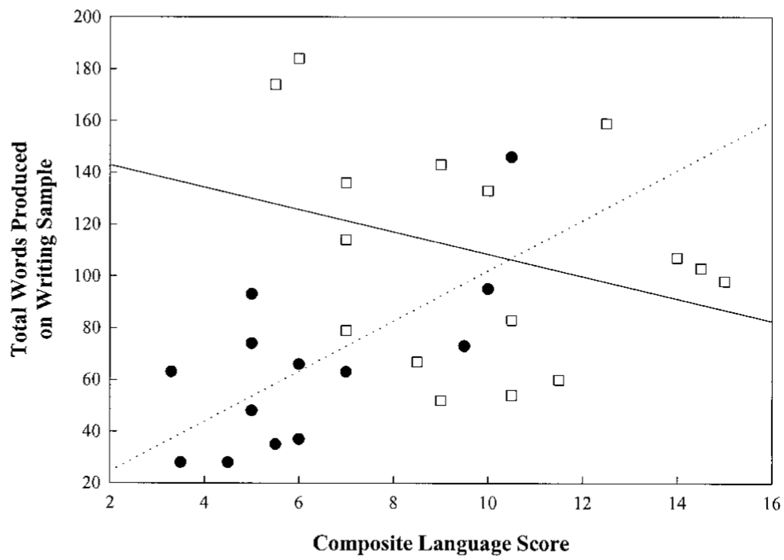

Figure 4.
This figure illustrates the relationship between writing productivity and composite language standard scores for the cochlear implant and normal-hearing group. The solid circles represent the scores from the cochlear implant group, and the squares represent the scores from the normal-hearing group. The regression line for the cochlear implant group is represented by the dotted line ($r = .70$, $p = .008$), and the regression line for the normal-hearing group is represented by the solid line.

TABLE 1

Writing productivity

	Mean Produced by Group		
	CI	**NH**	**t**
Total words	60.06 (32.03)	109.13 (42.44)	-3.69^{**}
T-units/story	8.16 (3.71)	11.30 (5.40)	-1.91
Words/T-unit	7.22 (1.09)	10.42 (3.98)	-3.10^{*}

Values enclosed in parentheses represent standard deviations.

CI = cochlear implant group; n = 16. NH = normal-hearing group, n = 16.

* $p < 0.05$

** $p < 0.01$.