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A Comparison of the Speech and Language Skills of Children With Cochlear Implants and Children With Normal Hearing

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This study explored the language skills of children with cochlear implants (CIs) compared to normal hearing (NH) peers. Standardized speech and language measures, including speech articulation, receptive and expressive vocabulary, syntax and morphology, and metalinguistics, were administered to 39 congenitally deaf children, ages 5 to 14, and a matched sample of NH children. Many CI children demonstrated age-appropriate scores on several language measures, yet their performance was significantly lower than NH peers. Results indicated that (a) *age at implant* predicted significant variance in receptive vocabulary and short-term auditory memory performance, and (b) *duration of CI use* predicted receptive syntax performance.

Keywords: *language; linguistics acquisition; development; technology; cochlear implants; hearing aids; elementary school age; exceptionalities; deaf; hard of hearing*

Changes in the identification of and intervention with children with hearing loss have been dramatic and rapid (Hall, 2000) and have reduced the average age of identification of hearing loss to between 12 and 25 months (American Speech-Language-Hearing Association [ASHA], 2004). Earlier identification, as well as a decrease in the minimum age of cochlear implantation to 12 months, has resulted in greater numbers of children receiving cochlear implants (CIs) at younger ages (ASHA, 2004). According to estimates, the number of children receiving CIs before 2 years of age has increased fortyfold from 1991 to 2002 (Drinkwater, 2004). In addition, improvements in CI technology have contributed to better speech perception and language outcomes for children with CIs (e.g., Geers, 2003; Parkinson, Parkinson, Lauder, & Gantz, 1998).

Earlier implantation and clinical advancements in CI habilitation enable deaf children to receive auditory stimulation during the critical period for the development of speech and language skills (Kirk, Miyamoto, Ying, Perdew, & Zuganelis, 2000; Pickett & Stark, 1987). Younger ages of implantation are generally associated with better outcomes in speech perception (Cheng, Grant, & Niparko, 1999; McConkey Robbins, Koch, Osberger, Zimmerman-Phillips, & Kishon-Rabin, 2004; Waltzman, Cohen, Green, & Roland, 2002; Zwolan et al., 2004), speech production (Tye-Murray, Spencer, & Woodworth, 1995), and receptive and expressive language skills (Kirk et al., 2000; Svirsky, Teoh, & Neuberger, 2004). Moreover, children with CIs demonstrate superior speech perception and language skills than children with hearing loss using hearing aids (Miyamoto, Svirsky, & Robbins, 1997; Tomblin, Spencer, Flock, Tyler, & Gantz, 1999).

Overview of Language Development of Children With CIs

Most deaf children demonstrate a delay in development of speech and language skills at the time of implantation, resulting from a lack of sensory input during a period critical to communication development. Children who are implanted at young ages generally acquire language at a similar rate to normal hearing (NH) peers, which mitigates a widening gap in language development after implantation (Kirk et al., 2002; Svirsky, Chute, Green, Bollard, & Miyamoto, 2000; Svirsky et al., 2004). However, significant variability exists in the speech and language skills of children with CIs. This variability is associated with a range of child, family, and environmental factors (Pisoni, Cleary, Geers, & Tobey, 1999). For example, variability in language skills has been associated with communication mode (Geers, 2003; Kirk et al., 2002), age at implantation, and duration of implant use (Hammes et al., 2002; Kirk et al., 2002; Svirsky, Teoh, & Neuburger, 2004), cognitive and information processing skills of the child (Pisoni et al., 1999), and a variety of family factors such as family size and parent education level (Geers, 2003; Geers & Brenner, 2003). Although these factors have been shown to play a role in predicting speech and language skills, research has not identified specific preimplant characteristics that reliably predict success with a CI. Pisoni et al. (1999), for example, used 6 years of longitudinal data to analyze the differences between a group of children, known as the "stars," with exceptional benefit from their CIs and a group with less optimal outcomes. Specifically, the stars attained significantly higher scores on measures of language comprehension, spoken word recognition, and speech intelligibility and scored in the top 20% on an open-set word recognition measure than the comparison group, which scored in the bottom 20% on the same measure. Yet the stars could not be significantly differentiated from the comparison group based on preimplant factors.

What the Language-Specific Research Tells Us

An increasing number of studies have examined a variety of aspects of speech and language development in children with CIs. Some have focused on the emergence of language skills in the first years of life (e.g., Svirsky et al., 2004). Others have investigated specific aspects of language development, such as morphology. Both Svirsky, Stallings, Lento, Ying, and Leonard (2002) and Szagun (2000) reported that the morphological development of children with CIs did not follow the typical developmental pattern but rather was influenced by the extent to which morphological forms were perceptually prominent. Still other investigators have focused on a range of language skills in small samples of children with CIs (Ertmer, 2001; Ertmer & Mellon, 2001). Young and Killen (2002), for example, found that after 5 years of implant use, their 7 participants demonstrated strengths in semantics, particularly expressive vocabulary with relative weaknesses in syntax and morphology.

Recent work has investigated the relationship between language and literacy in children with CIs. Spencer, Barker, and Tomblin (2003) examined the relationship between language and literacy skills in 16 children matched to an NH comparison group. The CI group used simultaneous communication with the assistance of sign language interpreters in regular education classrooms. Their language comprehension, reading comprehension, and writing accuracy skills were within 1 *SD* of those of the NH group. However, they performed poorer than their NH peers in expressive language use and had more difficulty with grammatical structures.

The most comprehensive language studies of children with CIs have been conducted by Geers, and colleagues (Geers & Brenner, 2003; Geers, Brenner, & Davidson, 2003; Geers, Nicholas, & Sedey, 2003; Geers et al., 2002; Niparko & Geers, 2004; Tobey, Geers, Brenner, Altuna, & Gabbert, 2003) who examined the effects of language, child, and family factors on language outcomes of one hundred eighty-one 8- and 9-year-old children with CIs. The participants were implanted by 5 years of age and used either oral or total communication. The test battery included measures of speech production, receptive and expressive semantics, syntax, morphology, and narrative discourse. As in other studies, the entire test battery was administered to each participant in his or her preferred communication mode (i.e., spoken English or total communication). Comparisons to children with NH were made on the basis of age-equivalent data provided by standardized tests.

Geers et al.'s (2003) results indicated that child and family factors accounted for 27% of the variance in the total language scores, with higher nonverbal intelligence, higher socioeconomic status (SES), smaller family size, and female gender associated with better language performance. Analysis of linguistic skills of these children revealed greater strengths in expressive vocabulary and narrative production, with relative weaknesses in expressive morphology and receptive morphology and syntax. Specifically, more than half of the participants scored in the average range on measures of utterance length, lexical diversity, and narrative production, whereas only 27% and 30% of participants scored in the average range on tasks assessing production of bound morphemes and syntactic comprehension, respectively. These results are consistent with previous findings that children with CIs demonstrate substantial gains in speech and language development and show variability in language skill across linguistic subsystems.

The Present Study

Research has informed our understanding of the effects of CIs on the speech and language skills of children. The present study was undertaken as an effort to extend this knowledge in several specific ways. First, we included a control group of children with NH who were individually matched to children with CIs on the basis of age and gender. This design characteristic permitted a more direct and ecologically valid basis for CI–NH comparisons than the use of age-equivalent test norms. Such comparisons are essential, as children with CIs are increasingly receiving their education in mainstream instructional settings alongside NH peers. To fully benefit and succeed in general education settings, we need to determine whether these children are acquiring speech and language skills on par with their NH peers.

Second, all of the CI children in the present study used oral English as their primary mode of communication and demonstrated normal nonverbal IQs. These selection criteria enabled the examination of a relatively homogeneous group of children with respect to communication mode. Excluding children who relied on manual forms of communication allowed us to uniformly administer the test battery in the same communication mode (i.e., spoken English) to all participants. Third, we included children from 5 to 14 years of age, which enabled an examination of the speech and language development of children with CIs across a wider age spectrum than has previously been available. Fourth, we sought to obtain a comprehensive profile of the speech and language skills of our sample of children with CIs. To accomplish this, we examined the major subsystems of structural language: phonology, semantics, morphology, and syntax. In addition, we were interested in higher order language processing and included assessments of metaphonology and metasemantics, two areas that are not widely reported in the literature on children with CI. These two areas of metalinguistic skills were selected specifically because of their predictive connection to literacy development and academic achievement (Roth, Speece, & Cooper, 2002). Finally, we collected substantial information on the audiological history, educational experiences, and child and family characteristics of all participants. This background information facilitated the identification of a subsample of 39 children who were deaf from birth without potentially confounding effects of low IQ and deafness resulting from illness (i.e., meningitis). All of these steps yielded a small but relatively homogeneous group of children with CI. Nonetheless, certain variables remained uncontrolled such as type of CI device.

The following three research questions guided this study:

1. What are the similarities and differences in the speech articulation and language skills of children with CIs compared to children with NH?
2. To what extent do the family and child variables of IQ, SES, and gender (referred to as background factors) and speech perception predict variance in speech articulation and language skills?
3. Do implant-related variables such as age at implant or duration of implant use predict speech articulation and language performance of children with CI?

Method

Participants

Participants were obtained from multiple sources. Children with CI, ages 5 through 14 years, were recruited through advertisement to members of the Alexander Graham Bell Association for the Deaf and Hard of Hearing, educational programs for children with hearing loss, hospital-based CI programs, and speech-language pathologists and audiologists throughout the Mid-Atlantic United States. Professionals distributed study information to families, and parents of children with CIs who were interested in the study were asked to contact the Child Development Lab at the University of Maryland in College Park for further details.

A total of 56 children with CIs participated in the testing protocol that was administered during a 1-day visit to either the Child Development Lab or another location. The present sample of 39 children, ages 5 through 14 ($M = 9$ years), all met the following criteria: (a) were deaf from birth, (b) demonstrated no additional significant disability (such as blindness or autism), (c) used spoken English as their primary mode of communication at the time of testing based on parent report, (d) used spoken English as their native language, (e) had nonverbal IQ scores in the average or above range (a minimum score of 85 on the Matrices subtest of the *Kaufman Brief Intelligence Test* [K-BIT]; Kaufman & Kaufman, 1990), (f) had a minimum of 1 year of CI experience, and (g) had a general language proficiency level of 5 years—that is, they met the age cutoff on both the *Peabody Picture Vocabulary Test–Third Edition* (PPVT-III; Dunn & Dunn, 1997) and the age-appropriate Grammatic Understanding subtest of the *Test of Language Development–Primary, Third Edition* (TOLD-P:3; Newcomer & Hammill, 1997), the *Test of Language Development–Intermediate* (TOLD-I; Hammill

& Newcomer, 1997), or the *Test of Adolescent and Adult Language–Third Edition* (TOAL-3; Hammill, Brown, Larsen, & Wiederholt, 1994). There were 19 male and 20 female participants. Details of the 39 children are presented in Table 1.

The comparison group consisted of 37 children with NH and was recruited from a current database at the Child Development Lab at the University of Maryland, College Park. They were individually matched to children with CIs by gender and age (within 3 months of CI child's birth date). In two cases NH matches could not be obtained. There were 19 male and 18 female NH participants. All participants with NH had nonverbal IQ scores in the average or above range (a minimum score of 85 on the Matrices subtest of the K-BIT) and had no additional disabilities.

Materials

The materials for all participants consisted of three sets of measures: background factors, speech perception, and speech articulation and language.

Background factors. Three background factors were examined: gender, SES, and nonverbal intelligence. SES was determined using Hollingshead's (1979) four-factor index of social status. This scale is based on the educational level and current occupation of the child's father and mother and was administered to the parents of each participant. Nonverbal intelligence (IQ) was assessed with Matrices subtest of the K-BIT. The Matrices subtest measures fluid thinking—the ability to solve new problems through perceiving relationships and analogies. All test items contain pictures and abstract designs and require a pointing response so that cognitive ability can be assessed independently of oral language proficiency. Cognitive functioning information was used for two purposes: (a) to ensure that each participant's nonverbal intelligence was within the normal range and (b) to determine the relationship between nonverbal IQ and speech articulation and language skills for children with CI.

Speech perception. The ability of participants to understand spoken single words was assessed with the *Lexical Neighborhood Test* (LNT) and *Multisyllabic Lexical Neighborhood Test* (MLNT; Kirk, Pisoni, & Osberger, 1995). The LNT and MLNT measure speech perception through assessment of open-set word recognition. The LNT contains two 50-item lists of monosyllabic words, and the MLNT consists of two 24-item lists of two- and three-syllable words. In each test, half of the words are considered lexically "easy," meaning that they are common and have few phonologically similar words. Half are considered lexically "hard," meaning they are words that occur infrequently and have many phonologically similar words. This pair of tests was designed specifically for children with hearing loss who use CI. Good test–retest reliability ($\geq$ .83 for Lists 1 and 2, both easy and hard components) and interlist equivalency have been demonstrated (Kirk, Eisenberg, Martinez, & Hay-McCutcheon, 1999). Because normative data are unavailable for NH children, the percentage of correct words for the easy and hard word lists of both the LNT and MLNT were scored, and for simplification, an average of the four subtests was calculated.

Speech and language measures. The test battery included standardized norm-referenced measures of speech articulation and receptive and expressive language in three major areas of the structural linguistic system: semantics, morphology, and syntax. Furthermore, measures of higher order linguistic knowledge (metalinguistics) were administered in the domains of phonology and semantics. All of the measures in the battery have adequate reliability and validity characteristics and were developmentally appropriate for the age range of the participants.

Speech articulation. Speech articulation was assessed with the Sounds-in-Words subtest of *Goldman-Fristoe Test of Articulation–Second Edition* (GFTA-2; Goldman & Fristoe, 2000), which requires the spontaneous production of 39 consonant sounds and consonant clusters in initial, medial, and final positions of single words.

Semantics. Receptive vocabulary was assessed with the PPVT-III, which assesses the comprehension of spoken words in standard English. Expressive vocabulary was assessed with the *Expressive Vocabulary Test* (EVT; Williams, 1997). Participants were asked to provide a label or synonym for pictured stimuli.

Morphology and syntax. Comprehension of English sentence types and morphological rules were assessed with one of three measures based on the chronological age of the children. For participants in the 5:0-7:11 age group, the Grammatic Understanding subtest of the TOLD-P:3 was administered in which participants pointed to one of four pictures in response to a verbal sentence stimulus. For participants in the 8:0-11:11 age group, the Grammatic Understanding subtest of the TOLD-I was administered. Participants were asked to listen to a series of sentences and identify them as correct or incorrect. Participants in the 12:0-14:11 age group were given the Listening/Grammar subtest of the TOAL-3, in which a series of

Table 1
Characteristics of the 39 Participants With Cochlear Implants

ID	Age	Age at Implant	Duration	Gender	Etiology
1	5:4	1:9	3:7	M	Unknown
2	5:8	1:8	4:0	M	Unknown
3	5:10	1:3	4:7	F	Genetic
4	6:3	1:4	4:11	M	CMV
5	6:5	1:6	4:11	F	Unknown
6	6:6	1:5	5:1	F	Unknown
7	6:7	1:4	5:3	F	Unknown
8	6:10	1:6	5:4	F	Unknown
9	7:0	3:2	3:10	M	Unknown
10	7:0	1:11	5:1	M	Unknown
11	7:4	2:9	4:7	M	Unknown
12	7:4	2:0	5:4	F	Unknown
13	7:5	2:0	5:5	M	Unknown
14	7:8	1:11	5:9	F	Unknown
15	7:11	2:6	5:5	F	Unknown
16	8:2	1:9	6:5	F	Unknown
17	8:3	3:7	4:8	F	Unknown
18	8:5	1:4	7:1	F	Unknown
19	8:10	2:6	6:4	M	Unknown
20	8:11	5:1	3:10	M	CMV
21	8:11	7:3	1:8	F	Unknown
22	9:5	3:0	6:5	M	Genetic
23	9:8	2:6	7:2	M	Unknown
24	9:8	1:4	8:4	F	Genetic (Connexin 26)
25	9:11	3:6	6:5	F	Unknown
26	9:11	2:4	7:7	M	Waardenburg Syndrome
27	10:3	2:1	8:2	F	Unknown
28	10:4	4:6	5:10	F	Unknown
29	10:4	3:10	6:6	F	Unknown
30	10:4	2:1	8:3	M	Unknown
31	10:5	7:6	2:11	F	Hyperbilirubinemia
32	10:10	4:4	6:6	M	Unknown
33	11:3	4:10	6:5	F	Unknown
34	11:10	3:1	8:9	F	Unknown
35	12:5	6:6	5:11	M	Unknown
36	13:0	8:2	4:10	F	Unknown
37	13:9	3:3	10:6	M	Unknown
38	14:2	2:6	11:8	M	Genetic (Connexin 26)
39	14:11	4:2	10:9	M	Genetic

Note: Overall age range = 5:4-14:11, 1:3-8:2, 1:8-11:8.

three sentences were presented and participants were asked to identify the two closest in meaning. A one-way ANOVA revealed that the standard scores among these three tests were not statistically significant, $F(2,73) = .217$, $p > .05$, and were entered as one variable in subsequent analyses.

Metalinguistics. Metalinguistic assessment focused on phonological processing and metasemantics. Three fundamental aspects of phonological processing as described by Torgesen and colleagues (Torgesen & Burgess, 1998; Torgesen, Wagner, & Rashotte, 1994) were assessed: phonological awareness, phonological memory, and rate of access of phonological information. Phonological awareness was measured with the Phonological Elision subtest of the *Comprehensive Test of Phonological Processing* (CTOPP; Wagner, Torgesen, & Rashotte, 1999) (also called *sound deletion*) in which participants were asked to repeat a word and then say what the word would be if a specified phoneme was deleted. For example, after repeating the word *bat*, participants were asked what would be left if the word was said without the sound /b/. Phonological memory was assessed with the Auditory Number Memory–Forward subtest of the *Test of Auditory Perceptual Skills–Revised* (TAPS-R; Gardner, 1996). This task assesses the ability to retain digits in short-term memory. The tester read a series of digits of increasing length, and participants were asked to repeat them. Rate of access for phonological information was assessed with age-appropriate Rapid Automatic Naming (RAN) subtests of the CTOPP. These tasks assess the ability to retrieve words from long-term memory. The Rapid Color Naming subtest and the Rapid Object Naming subtest were administered to participants in the 5:0-6:11 age group. Children were asked to name familiar colors and objects as quickly as possible. The Rapid Digit Naming subtest and Rapid Letter Naming subtest were used for participants in the 7:0-14:11 age group. Participants were asked to name familiar numbers and letters as quickly as possible. Again, the scores for each participant were summed and reported as one variable called RAN for the purposes of data analysis.

Two aspects of metasemantics were assessed: idiom knowledge and lexical ambiguity. The Figurative Language and Ambiguous Sentences subtests of the *Test of Language Competence–Expanded* (TLC-E; Wiig & Secord, 1989) were administered, which measured comprehension and production of idioms and lexical ambiguity, respectively. Each task requires an explanation of a given idiom or ambiguous word followed by the identification of a picture that best matches the nonliteral meaning of the item. There are two levels of this test: Level 1 was administered to participants in the 5:0-8:11 age group, and Level 2 was administered to participants in the 9:0-14:11 age group.

Procedure

Identified families were scheduled to participate in a 1-day assessment at the Child Development Lab or at another location. Informed consent was obtained from the accompanying parent before proceeding. The accompanying parent was asked to complete a questionnaire providing information on the child's audiological, educational, and family background. Experimenters from the Child Development Lab administered the LNT and MLNT tests and K-BIT to each participant individually. LNT and MLNT test word lists were presented using prerecorded speech stimuli at 75 dB SPL. Advanced graduate students in speech-language pathology administered the speech and language test battery to each participant individually in a quiet room. A certified speech-language pathologist supervised administration. Total testing time was approximately 2.5 hr, and breaks were offered between tests. The speech perception, IQ, and speech articulation and language tests were administered in variable order. However, within a test area, the order of testing was randomized and then administered uniformly for all participants.

The IQ, speech perception, speech articulation, and language tests were double-scored by an independent reviewer. Interrater reliability was then calculated on a randomly selected 15% of the test protocols in each area. Interrater reliability ranged from 90% and 95% for IQ, speech perception, and the speech articulation and language test battery. All discrepancies were discussed and resolved by the primary investigator.

Results

Table 2 reports the descriptive statistics for all measures. In the table, the mean scores and their corresponding standard deviations are compared to the normal range of scores. In addition, the table includes means adjusted for the covariates nonverbal intelligence and SES. As one can see, the CI and NH groups are closer on the covariate-adjusted means than on the nonadjusted means. Because standard scores account for age differences, CI and NH group status constituted the two independent variables for all further analyses, regardless of age.

Results of a one-way ANOVA indicated a significant main effect for group for both SES and nonverbal IQ. The NH group received higher ratings of SES, $F(1, 70) = 5.446$, $p = .022$, and higher scores on the K-BIT Matrices subtest, $F(1, 73) = 9.589$, $p = .003$. Comparison of performance by gender using a one-way ANOVA revealed no significant differences in speech articulation and language scores based on gender (all ps $> .05$). Because SES and IQ are known to be associated with speech and language skills (e.g., Leonard, 1998; Snow, Tabors, & Dickinson, 2001) and we found significant differences in SES and IQ between the groups, these two variables were entered as covariates for all subsequent analyses. Because no gender differences were found, this variable was eliminated. Although some previous research has reported associations between gender and language performance, we preferred to focus on the background factors that significantly differentiated the CI and NH groups in our sample.

Two data analysis approaches were implemented to answer our primary research questions. First, ANCOVAs were conducted to compare the speech articulation and

Table 2
Descriptive Statistics for All Measures Compared to the Normal Range of Scores

	Group						
	Cochlear Implant[a]			Normal Hearing[b]			
Measure	*M*	Adj. *M**	*SD*	*M*	Adj. *M**	*SD*	Normal Range of Scores
Background variable							
Nonverbal intelligence (K-BIT Matrices)	111.13	—	11.86	120.08	—	13.18	85-115
SES (Hollingshead household status)	56.38	—	9.49	60.94	—	6.66	c
Speech articulation							
GFTA	93.54	95.20	18.94	103.03	101.19	5.92	85-115
Semantics							
Receptive vocabulary (PPVT-III)	87.33	91.39	17.81	111.57	107.11	12.63	85-115
Expressive vocabulary (EVT)	90.82	93.88	16.52	105.68	102.33	10.84	85-115
Morphology and syntax							
Syntax (TOLD-P, TOLD-I, or TOAL)[1]	8.44	9.13	2.53	12.86	12.10	3.66	8-12
Metalinguistics							
Elision (CTOPP)	8.72	9.39	3.50	12.35	11.62	2.82	8-12
TAPS-R	82.23	84.90	12.34	101.78	98.85	13.36	90-110
Rapid naming (CTOPP)	9.22	9.65	2.47	11.58	11.11	2.26	8-12
Ambiguous sentences (TLC-E)	4.97	5.77	3.56	9.89	9.01	3.75	7-13
Figurative sentences (TLC-E)	4.58	5.23	3.25	10.89	10.18	3.30	7-13
Speech perception							
Composite of LNT and MLNT scores	69.85	72.31	10.55	96.25	93.55	2.16	d

Note: K-BIT Matrices = Matrices subtest of Kaufman Brief Intelligence Test; SES = socioeconomic status; GFTA = Goldman-Fristoe Test of Articulation; PPVT-III = Peabody Picture Vocabulary Test–Third Edition; EVT = Expressive Vocabulary Test; TOLD-P = Test of Language Development–Primary; TOLD-I = Test of Language Development–Intermediate; TOAL = Test of Adolescent and Adult Language; CTOPP = Comprehensive Test of Phonological Processing; TAPS-R = Test of Auditory Perceptual Skills–Revised; TLC-E = Test of Language Competence–Expanded; LNT = Lexical Neighborhood Test; MLNT = Multisyllabic Lexical Neighborhood Test.
a. $n = 39$.
b. $n = 37$.
c. Means are adjusted for nonverbal intelligence and SES. This does not affect the standard deviation.
d. Scores are unavailable for these measures.

language performance of the CI and NH groups. Regression analyses also were used to determine the extent to which the background factors (i.e., IQ and SES) and speech perception predicted variance in speech articulation and language skills. Then, regression analyses were used to determine whether age at implant and duration of CI use predicted speech articulation or language skills.

For the ANCOVAs, we exceeded the estimate of 30 participants per cell needed to detect a medium to large effect (80% power; Cohen, 1988). Using the PEPI 4.0 software program (Abramson & Gahlinger, 2001), we determined the statistical power needed to detect differences in predictor variables for the regression analyses. For example, for the outcome variable PPVT, we were able to detect a statistically significant ($p < .05$) difference between the groups (difference score = 14.9, $SD = 5.6$) with a power of 72%. This power would be reduced with the addition of other confounders. On the other hand, there is justification (see, e.g., Grissom & Kim, 2005; Lipsey, 1990) for using more relaxed criteria in judging meaningful effects in studies such as ours where the results are both clinically and educationally important.

Comparison of Speech Articulation and Language Performance of Children With CIs and Children With NH

Table 3 presents the number of participants with CIs and participants with NH who scored within the normal limits on the speech articulation and language tests, as well as the total percentage of participants who scored within the average range for each test. There were several

Table 3
Percentage and Number of Cochlear Implant and Normal Hearing Participants Who Obtained Scores Within the Average Range

	Group			
	Cochlear Implant[a]		Normal Hearing[b]	
Test	%	*n*	%	*n*
Speech articulation				
GFTA	85	33/39	100	37/37
Tests of structural language				
Semantics				
Receptive vocabulary (PPVT-III)	51	20/39	97	36/37
Expressive vocabulary (EVT)	66	25/38	100	36/37
Morphology and syntax				
Syntax (TOLD-P, TOLD-I, or TOAL)[1]	59	23/39	94	35/37
Performance within average range for Tests 2, 3, and 4	36	14/38	92	34/37
Metalinguistic measures				
Phonological processing measures				
Elision (CTOPP)	89	33/39	86	32/37
TAPS-R	26	10/39	84	31/37
Rapid naming (CTOPP)	78	28/36	94	32/36
Performance within average range for Tests 5, 6, and 7	26	10/36	75	27/36
Metasemantic measures				
Ambiguous sentences (TLC-E)	33	12/38	83	29/35
Figurative sentences (TLC-E)	29	11/38	94	33/35
Performance within average range for Tests 8 and 9	13	5/38	80	28/35

Note: GFTA = *Goldman-Fristoe Test of Articulation*; PPVT-III = *Peabody Picture Vocabulary Test–Third Edition*; EVT = *Expressive Vocabulary Test*; TOLD-P = *Test of Language Development–Primary*; TOLD-I = *Test of Language Development–Intermediate*; TOAL = *Test of Adolescent and Adult Language*; CTOPP = *Comprehensive Test of Phonological Processing*; TAPS-R = *Test of Auditory Perceptual Skills–Revised*; TLC-E = *Test of Language Competence–Expanded*.
a. $n = 39$.
b. $n = 37$.

missing data points (because of testing error or participants' failure to complete testing protocol); therefore, total numbers of participants scoring in the average range are reported with the total sample size for that test in Table 3.

An overall examination of the standard scores on the speech articulation and language tests indicated that the mean scores of the CI group were within 1 *SD* of the reported mean for the NH sample on the following measures: GFTA, PPVT-III, EVT, TOLD-P/TOLD-I/TOAL, CTOPP Elision subtest, and CTOPP RAN subtest. Their scores on the TAPS-R Auditory Number Memory–Forward subtest and TLC-E Ambiguous Sentences and Figurative Language subtests placed their performance below age-level expectations. The NH group obtained scores within normal limits on all measures in the speech articulation and language test battery.

A series of ANCOVAs were then conducted to determine whether significant differences existed between the CI and NH groups on each measure of speech and language administered.

Speech articulation. No main effect for group was found on the GFTA-2, $F(1, 66) = 3.460$, $p > .05$, indicating that the CI and NH groups attained comparable word-level articulation scores. Significant group effects were found for all language and metalinguistic measures.

Language measures. A main effect for group was found on both the PPVT-III, $F(1,67) = 27.44$, $p < .001$, and EVT, $F(1,65) = 6.93$, $p = .011$, revealing significantly lower scores for CI participants in their comprehension and production of vocabulary. Results showed a main effect for group on the TOLD-P, TOLD-I, or TOAL Grammatical Understanding subtest, $F(1, 67) = 20.93$, $p <. 001$, indicating that the children with CIs scored significantly lower on the receptive measures of morphology and syntax. To further describe the structural language performance of these youngsters, we calculated the proportion of CI and NH participants who obtained age-appropriate standard scores on all three structural linguistic measures (PPVT-III, EVT, and TOLD-P/TOLD-I/TOAL). Results indicated that 36% of the CI group ($n = 14$) and 92% of the NH group ($n = 34$) demonstrated age-appropriate performance on this set of measures. We were then interested in determining whether the disparity between CI and NH groups was attributable to a single domain of structural language. On the PPVT-III, EVT, and TOLD-P/TOLD-I/TOAL, the proportions of participants with CIs who received age-appropriate scores were approximately 51%, 66%, and 59%, respectively. In contrast, most NH participants (97%, 100%, and 94%, respectively) received age-appropriate standard scores on each of these language measures.

Phonological processing. There was a significant main effect for group on the CTOPP Elision subtest, $F(1, 67) = 11.67$, $p = .001$; TAPS-R Auditory Number Memory–Forward, $F(1, 61) = 22.14$, $p < .001$; and CTOPP RAN task, $F(1, 61) = 9.19$, $p = .004$, indicating that the CI participants obtained significantly lower scores on all three measures of phonological processing than the NH participants. To further describe the phonological processing performance of these youngsters, we calculated the proportion of CI and NH participants who obtained age-appropriate standard scores on all three measures. Results indicated that 26% of the CI group ($n = 10$) and 75% of the NH group ($n = 27$) demonstrated age-appropriate performance on this set of measures.

Metasemantic measures. Finally, a significant main effect for group was found for the Figurative Language, $F(1, 60) = 46.55$, $p < .001$, and Ambiguous Sentences, $F(1, 62) = 24.17$, $p = .001$, subtests of the TLC-E, indicating that the CI participants received significantly lower scores on these receptive and expressive metasemantic tasks.

Effects of Background Factors and Speech Perception

To determine the effects of background factors and speech perception on speech articulation and language performance, regressions were conducted for CI and NH groups for each measure with IQ, SES, and speech perception as predictor variables in the equation. This analysis strategy permitted examination of the independent contributions of each variable on language performance. Table 4 presents the resulting models for the CI group. In each model, the three variables were entered in the following order: IQ, SES, and speech perception.

Different patterns emerged for the CI and NH groups for each of the background factors examined. IQ did not predict performance differences on any of the speech and language measures for the CI group. For the NH group, IQ was a significant predictor of three language measures: PPVT-III, $R^2 = .318$, $F(1, 31) = 15.936$, $p < .01$; EVT, $R^2 = .259$, $F(1, 30) = 11.826$, $p < .01$; and TAPS-R, $R^2 = .144$, $F(1, 29) = 6.046$, $p < .05$, accounting for approximately 34%, 28%, and 17% unique variance, respectively.

An opposite pattern emerged for SES. In the CI group, SES was a significant predictor of performance on the PPVT-III, $R^2 = .083$, $F(1, 34) = 5.084$, $p < .05$; EVT, $R^2 = .113$, $F(1, 33) = 4.576$, $p < .05$; TOLD-P/TOLD-I/TOAL, $R^2 = .235$, $F(1, 34) = 10.769$, $p < .01$; CTOPP Elision subtest, $R^2 = .140$, $F(1, 34) = 6.174$, $p < .05$; and TAPS-R Auditory Number Memory–Forward subtest, $R^2 = .098$, $F(1, 30) = 5.459$, $p < .05$, accounting for approximately 1%, 11%, 23%, 15%, and 15% of unique variance, respectively. In contrast, SES did not predict performance on any measure of speech, structural language, or metalinguistics for the NH group.

Speech perception scores on the LNT and MLNT explained 14% of unique variance on PPVT-III performance for the CI group, $R^2 = .206$, $F(1, 33) = 6.307$, $p < .05$, indicating that children with better speech perception obtained higher scores on this measure of single-word receptive vocabulary. Speech perception did not predict performance on any of other speech articulation and language measures for the CI group. For the NH group, speech perception scores predicted unique variance for only one measure, TAPS-R Auditory Number Memory–Forward subtest, $R^2 = .248$, $F(1, 27) = 5.127$, $p < .05$, explaining approximately 13% of the variance.

Effects of Implant-Related Variables: Age at Implant and Duration of Implant Use

A series of linear regression procedures were applied to determine whether the age at implant or duration of CI use predicted performance on each of the speech articulation and language tests in the battery. In each regression analysis, IQ and SES were entered as independent variables in the first step of the procedure to determine the combined contributions of the background variables. IQ and SES were entered as a block and were followed by age at implant or duration of implant use. Based on

Table 4
Regression Analysis Results for Prediction of Speech Articulation and Language Performance as a Function of IQ, Socioeconomic Status (SES), and Speech Perception (SP) for Children With Cochlear Implant (CI) and Children With Normal Hearing (NH)

		Adj. R^2 (overall)		Std. β		*t* Ratio		Unique R^2	
Dependent Variable	Measure	CI	NH	CI	NH	CI	NH	CI	NH
Speech articulation									
GFTA	IQ	–.029	–.032	.024	–.027	0.142	–0.148	.001	.001
	SES	.030	.042	.295	.325	1.770	1.835	.087	.101
	SP	.002	.009	–.007	.025	–0.041	0.140	.000	.001
Semantics									
Receptive vocabulary (PPVT-III)	IQ	–.025	.318	.063	.583	0.372	3.992	.004	.340**
	SES	.083	.296	.361	.030	2.225	0.199	.010*	.001
	SP	.206	.346	.383	.267	2.511	1.810	.139*	.067
Expressive vocabulary (EVT)	IQ	.020	.259	.219	.532	1.308	3.439	.048	.283**
	SES	.113	.241	.342	.084	2.139	0.531	.116*	.007
	SP	.097	.217	.107	.054	0.650	0.329	.011	.003
Morphology and syntax									
Syntax (TOLD-P, TOLD-I, or TOAL)[1]	IQ	.021	.062	.220	.302	1.337	1.763	.049	.091
	SES	.235	.057	.480	–.161	3.282	–0.918	.229**	.025
	SP	.220	.026	.089	–.038	0.588	–0.213	.007	.001
Metalinguistics									
Elision (CTOPP)	IQ	.012	.066	.200	.309	1.206	1.808	.040	.095
	SES	.140	.037	.386	–.040	2.485	–0.225	.148*	.002
	SP	.114	.023	–.029	–.138	–0.180	–0.767	.001	.018
TAPS-R	IQ	–.032	.144	.027	.415	0.148	2.459	.001	.173*
	SES	.098	.137	.392	–.151	2.336	–0.881	.154*	.022
	SP	.107	.248	.195	–.369	1.139	–2.264	.036	.128*
Rapid naming (CTOPP)	IQ	.017	.065	.216	.312	1.249	1.735	.047	.097
	SES	.064	.049	.274	–.136	1.619	–0.739	.074	.018
	SP	.105	.025	.264	–.109	1.550	–0.575	.065	.011
Ambiguous sentences (TLC-E)	IQ	–.018	.114	.115	.379	0.656	2.204	.013	.143*
	SES	–.041	.292	.093	.453	0.521	2.883	.009	.196**
	SP	.006	.294	.281	.165	1.574	1.040	.075	.025
Figurative sentences (TLC-E)	IQ	–.028	–.019	.070	.124	0.386	0.672	.005	.015
	SES	.045	–.040	.320	–.121	1.819	–0.635	.102	.014
	SP	.055	–.054	.206	.154	1.14	0.791	.404	.022

Note: GFTA = *Goldman-Fristoe Test of Articulation*; PPVT-III = *Peabody Picture Vocabulary Test–Third Edition*; EVT = *Expressive Vocabulary Test*; TOLD-P = *Test of Language Development–Primary*; TOLD-I = *Test of Language Development–Intermediate*; TOAL = *Test of Adolescent and Adult Language*; CTOPP = *Comprehensive Test of Phonological Processing*; TAPS-R = *Test of Auditory Perceptual Skills–Revised*; TLC-E = *Test of Language Competence–Expanded*.
*$p < .05$. **$p < .01$.

R^2 values, age at implant was a significant predictor of performance on PPVT-III, $R^2 = .246$, $F(1, 34) = 8.207$, $p < .01$, and TAPS-R, $R^2 = .193$, $F(1, 34) = 6.048$, $p < .05$ (see Table 5), accounting for 17% and 13% of unique variance, respectively. Duration of implant use (see Table 6) was a significant predictor of morphological and syntactic processing as measured by the TOLD-P/TOLD-I/TOAL, accounting for 10% of unique variance, $R^2 = .334$, $F(1, 34) = 5.730$, $p < .01$.

Because of null findings for most of the regression analyses involving the implant-related variables, a power analysis was conducted to determine whether there was sufficient power in the research design to permit detection of a true effect. For the regression analyses involving age at implant as the dependent variable, the effect size correlations were large ($d > .80$) with the exception of the analyses of the TLC-E subtests, in which the effect size correlations were in the medium range ($d > .40$). For the regression analyses involving duration of implant use as the dependent variable, the effect size correlations were large ($d > .80$) with the exception of the analyses for the TLC-E subtests, in which the effect size correlations were medium ($d > .50$). These power analyses indicate that findings pertaining to

Table 5
Regression Analysis Results for Prediction of Speech Articulation and Language Performance as a Function of Age at Implant (Controlling for IQ and SES)

Dependent Variable	Adj. R^2 (overall)	Std. β	*t* Ratio	Unique R^2
Speech articulation (GFTA)	.023	–.049	–0.301	.002
Semantics				
Receptive vocabulary (PPVT-III)	.246	–.410	–2.865	.170**
Expressive vocabulary (EVT)	.170	–.292	–1.920	0.085
Morphology and syntax				
Syntax (TOLD-P, TOLD-I, or TOAL)[1]	.280	–.233	–1.663	0.054
Metalinguistics				
Elision (CTOPP)	.146	–.162	–1.066	.026
TAPS-R	.193	–.364	–2.459	.132*
Rapid naming (CTOPP)	.042	.071	0.416	.005
Ambiguous sentences (TLC-E)	–.006	–.235	–1.400	.055
Figurative sentences (TLC-E)	–.002	–.027	–0.160	.001

Note: SES = socioeconomic status; GFTA = *Goldman-Fristoe Test of Articulation*; PPVT-III = *Peabody Picture Vocabulary Test–Third Edition*; EVT = *Expressive Vocabulary Test*; TOLD-P = *Test of Language Development–Primary*; TOLD-I = *Test of Language Development–Intermediate*; TOAL = *Test of Adolescent and Adult Language*; CTOPP = *Comprehensive Test of Phonological Processing*; TAPS-R = *Test of Auditory Perceptual Skills–Revised*; TLC-E = *Test of Language Competence–Expanded*.
*$p < .05$. **$p < .01$.

Table 6
Regression Analysis Results for Prediction of Speech Articulation and Language Performance as a Function of Duration of Implant Use (controlling for IQ and SES)

Dependent Variable	Adj. R^2 (overall)	Std. β	*t* Ratio	Unique R^2
Speech articulation (GFTA)	.032	.130	0.787	.017
Semantics				
Receptive vocabulary (PPVT-III)	.088	–.152	–0.958	.023
Expressive vocabulary (EVT)	.087	–.093	–0.578	.008
Morphology and syntax				
Syntax (TOLD-P, TOLD-I, or TOAL)[1]	.334	–.324	–2.394	.103*
Metalinguistics				
Elision (CTOPP)	.170	–.222	–1.469	.048
TAPS-R	.148	–.289	–1.766	.080
Rapid naming (CTOPP)	.039	.037	0.219	.001
Ambiguous sentences (TLC-E)	–.011	–.229	–1.317	.052
Figurative sentences (TLC-E)	–.024	–.098	–0.543	.009

Note: SES = socioeconomic status; GFTA = *Goldman-Fristoe Test of Articulation*; PPVT-III = *Peabody Picture Vocabulary Test–Third Edition*; EVT = *Expressive Vocabulary Test*; TOLD-P = *Test of Language Development–Primary*; TOLD-I = *Test of Language Development–Intermediate*; TOAL = *Test of Adolescent and Adult Language*; CTOPP = *Comprehensive Test of Phonological Processing*; TAPS-R = *Test of Auditory Perceptual Skills–Revised*; TLC-E = *Test of Language Competence–Expanded*.
*$p < .05$. **$p < .01$.

the relationship found in this sample of children between CI variables, on the one hand, and speech articulation and language measures, on the other, although not achieving 80% power, could in fact be meaningful. It is also possible that a power analysis using more relaxed criteria (see, e.g., Grissom & Kim, 2005; Lipsey, 1990) might reveal other meaningful differences in the data that we did not find because of the small sample size.

Discussion

The present study had three main objectives. First, it sought to compare the speech articulation and language skills of children with CIs and those with NH. Second, it examined the extent to which background factors such as nonverbal IQ, SES, and gender predicted variance in speech articulation and language skills in children with

CI. Finally, it explored whether age at implant, duration of implant use, or speech perception scores influenced speech articulation and language performance in this group of children with CIs.

Comparison of Speech Articulation and Language Skills of Children With CIs and Children With NH

Speech articulation, as measured by the Sounds-in-Words subtest of the GFTA-2, was the one area that did not differentiate the groups. This was a somewhat surprising finding because articulation skills of deaf children have historically been a primary area of difficulty for this population (Marschark, Lang, & Albertini, 2002). The relative homogeneity of our sample with respect to communication mode may explain this finding. All of our CI participants used spoken communication and had histories of early and intensive speech intervention. Possibly, this combination of educational experiences increases the likelihood that children with significant auditory deficits can acquire levels of articulation accuracy comparable to NH peers, at least at the isolated single-word level.

Structural language. As a group, children with CIs obtained significantly lower scores on each measure of structural language than children with NH. Further inspection of the data revealed that 36% ($n = 14$) of children with CIs achieved age-appropriate scores on all three structural language tests (PPVT-III, EVT, TOLD-P/TOLD-I/TOAL) in contrast to 92% ($n = 34$) of children with NH. A larger percentage of children with CIs scored within the normative range on individual tests in the battery (PPVT-III: 51%; EVT: 65%; TOLD-P/TOLD-I/TOA: 59%). These results indicate that the linguistic proficiency levels of CI children were significantly lower than those of children with NH in lexical semantics, morphology, and syntax, despite the fact that one third of the children with CIs scored in the age-appropriate range on these measures.

This finding is of interest for at least two reasons. First, it was anticipated that this sample would demonstrate relatively advanced structural language skills because all of the children were orally educated, used oral English as their primary language, had normal or above nonverbal IQs, and demonstrated no frank comorbid disabilities. We further required that all participants meet a minimum standard of general language proficiency based on performance on the PPVT-III, EVT, and the Grammatical Understanding subtest of the TOLD-P/TOLD-I/TOAL. Second, the structural language abilities demonstrated by our sample supports the value of a research design that includes a comparison group of hearing peers (Robbins, 2000). This methodology may add a dimension to our understanding of the language abilities of children with CIs relative to hearing peers. The use of age-equivalent norms provided by standardized tests as a "surrogate" comparison or control group, while certainly informative, may overestimate the actual abilities of children with CIs compared to children with NH.

Research has clearly shown that children who receive CIs demonstrate language growth trajectories that are similar to their hearing peers, stemming an otherwise widening gap between the language skills of deaf children and NH children (Bollard, Chute, Popp, & Parisier, 1998; Robbins, Syirsky, & Kirk, 1997). The present results show that significant language differences exist even in a high-functioning group of CI children such as our sample. Of course, these findings are based on a relatively small sample of children at a single time point. Longitudinal work with larger groups is required to more fully understand the language development patterns and outcomes of children with CIs.

Unlike some previous work (e.g., Robbins, 2000; Szagun, 2000; Young & Killen, 2002), the present sample with CIs exhibited a fairly even pattern of strengths and weaknesses in structural language. Research has shown that deaf children who use spoken communication have significant difficulty acquiring the morpho-syntactic aspects of spoken language (e.g., Bishop, 1983; Bochner & Albertini, 1988; Mogford, 1993; Tur-Kaspa & Dromi, 2001). We did not find a specific deficit in syntactic performance in this CI sample. The disparate findings may be a reflection of a combination of factors including effective language intervention efforts for children with CI, communication experience with NH partners who encourage and reinforce syntactic accuracy, and improved CI technology and processing strategies.

Metalinguistics. In addition to basic speech articulation and language skills, the present study assessed higher order linguistic abilities, in particular, aspects of metaphonological processing (i.e., phonemic awareness: elision; auditory memory: digit span; and rate of access to phonological information: RAN) and metasemantic processing (comprehension and production of idioms and lexical ambiguity). With respect to metaphonology, the CI group scored significantly more poorly than their NH peers on all three measures. When compared to test norms, however, the CI children achieved age-appropriate scores on the elision and RAN tasks and obtained below-average scores on the digit span task. Thus, the present group of CI children demonstrated similar difficulties in auditory working memory as those reported by previous researchers (Geers, 2003; Pisoni & Cleary, 2003; Pisoni et al., 1999). We also calculated the percentage of children in each group who scored in the age-appropriate range on all three phonological processing measures. Only 26% (*n* = 10) of the CI group met this criterion as opposed to 73% of the NH group (*n* = 27). However, the digit span task seemed to be much more difficult for the CI group than the elision and RAN tasks. The pattern of phonological processing demonstrated by the CI group may be understood in light of the specific demands of each task and the knowledge base required for performance. To successfully execute a phonemic awareness task, such as elision, children can rely on their letter knowledge and reading word recognition skills; similarly, a RAN task provides visual cues that facilitate naming as well as reliance on lexical knowledge. However, the digit span task is a purely auditory task that requires maintenance of grammatically unrelated words in short-term memory for their subsequent accurate retrieval without benefit from background knowledge or contextual supports. Still, the overall performance of CI children on the phonological processing tasks was relatively strong and bodes well for the acquisition of literacy skills, an area that historically has been exceedingly challenging for deaf children. National data indicate that, on average, deaf individuals do not progress beyond a third- or fourth-grade level of reading ability, regardless of the amount or quality of intervention (Gallaudet Research Institute, 1996; Holt, Traxler, & Allen, 1997). The results of the present study suggest that some children with CIs are able to develop phonological processing skills that are critical to the acquisition of reading.

The higher order language area of metasemantics was most challenging for both CI and NH groups. The CI children performed significantly more poorly than their NH peers on both measures of metasemantics (i.e., idioms, and lexical ambiguity). Moreover, the magnitude of disparity between the CI and NH groups was greatest in this language domain. Only 13% (*n* = 5) of CI children achieved scores that fell into the age-appropriate range on this set of tests. In contrast, the 76% (*n* = 28) of the NH group met test norm criteria for expected performance on both subtests. These results are not surprising given that metasemantic knowledge is a late-emerging and advanced aspect of language learning, which requires conscious awareness of and the ability to manipulate the meaning aspect of language.

We examined metasemantic performance, in part because it represents an important language skill for advancing literacy acquisition, including reading comprehension and written composition (Nippold, 1998; Simmons & Kame'enui, 1998; Singer & Bashir, 2004). Idiom knowledge requires the ability to assign a figurative language meaning to a series of words with an already given literal meaning (e.g., "over the hill"), whereas lexical ambiguity necessitates knowledge of multiple word meanings (e.g., the words "bat" or "block"). Facility with these language uses necessitate going beyond the literal or grammatical meaning to appreciate the figurative, nonliteral interpretations of these linguistic forms. As children progress through elementary school, their textbooks, reading literature, and writing genres increasingly demand such metasemantic knowledge (Nippold, 1990).

Further examination of the data indicated that the metasemantic performance of neither the CI nor NH groups was correlated with factors such as age, IQ, or SES. However, unlike their NH peers, metasemantic performance of the CI group was highly correlated with structural language scores. Each of the 5 CI children who obtained age-appropriate scores on the metasemantic tasks also scored at age-expected levels on all three measures of structural language. This pattern of performance seems to indicate that development of higher order semantic skills in CI children is bolstered by a better grasp of basic linguistic skills.

Association Among Background Factors, Speech Perception, and Language Performance

Three background variables (i.e., gender, IQ, and SES) and speech perception were examined in this study. Nonverbal IQ was a significant predictor of language performance in the NH group (PPVT-III, EVT, TAPS-R), but not in the CI group. These findings contrast with those of Geers (2003), who reported that performance IQ accounted for 20% of the variance in oral language scores of the CI group. A comparison of the two samples indicates that all of the CI children in the present study scored at or above the average range (> 85) on the measure of nonverbal intelligence (i.e., K-BIT Matrices). Geers's sample included CI children with a wider range of IQ scores. Perhaps this intersample IQ variability may, at least in part, account for the differing relationships between IQ and language ability across the two studies.

The background variable of SES-predicted CI group performance on several language measures (PPVT-III, EVT, TOLD-P/TOLD-I/TOAL, Elision, TAPS-R), whereas SES was not associated with the language performance of children with NH. It is possible that this difference is attributable to lower SES ratings of the CI group. On the other hand, both of our groups scored well within the upper-middle class range of parental education and occupation.

Furthermore, Geers (2003) found a similar relationship between SES and language outcomes for children in the same SES range. Perhaps SES reflects access to therapeutic intervention, and it is the quality and quantity of therapy that actually influences language performance.

Speech perception had virtually no effect on the speech articulation and language performance of the NH group. It also did not appear to be a decisive factor in the speech articulation and language performance of the CI group. For the CI group, speech perception was not associated with speech articulation skills, and it predicted performance on only one language measure (i.e., receptive vocabulary). It is important to acknowledge that the present sample of CI children demonstrated relatively strong speech perception skills (in the present study, approximately 70% correct on LNT/MLNT vs. 44.2% to 51.5% correct reported in Geers, Brenner, et al., 2003) and had normal or above nonverbal IQs. These factors either alone or in combination may reduce the influence of speech perception on speech articulation and language skills in a manner similar to the relationship among these factors in children with NH.

Connection Between Implant-Related Variables and Language Performance

We found that age at implant predicted performance on PPVT-III and TAPS-R measures, indicating that the children who received their CIs at earlier ages showed better performance on assessments of receptive vocabulary and phonological memory. This variable did not predict performance for many of the speech articulation and language measures, consistent with Geers's (2002) findings, despite wider variability of actual age at implant in the present study (our sample received implants between 1:8 and 8:3 years; Geers's sample all received implants before age 5). Many studies, however, report an age-at-implant effect on language development. It is interesting that most of these studies examined younger children who were in the early stages of the language acquisition process. For example, Svirsky et al. (2004), studying 2-, 3-, and 4-year-olds, found that implantation before 2 years of age resulted in better scores on speech perception and language measures than later implantation. Similarly, Kirk et al. (2000) found that children implanted before 3 years of age demonstrated faster rates of linguistic growth than children who received their implants after this age.

It is possible that age at implant is most critical when examining children's growth of language during the most dramatic language spurt stage (i.e., between 2 and 5 years of age). The influence of age at implant may become less obvious in older children, especially when language skills are measured by currently available standardized tests that are not sensitive to subtle differences in linguistic knowledge. Again, this is a hypothesis that requires testing as both Svirsky et al. (2004) and Kirk et al. (2000) used longitudinal designs, and our study was cross-sectional in nature.

Finally, duration of CI use did not significantly predict performance on most of the speech articulation and language measures. The mean duration of CI use for the current sample was 70 months (*SD* = 23 months), a relatively long period for children ages 5 to 14 years. Possibly after a certain period, large differences in language performance are not clearly associated with the duration of implant use in children as old as the participants in the present study. Our analyses indicated that duration of CI use predicted performance on only one language variable (i.e., syntax). This finding suggests that receptive syntax improves the longer children have the benefit of auditory input with a CI.

Limitations and Conclusions

Limitations of the present study must be acknowledged. Our study examined speech articulation and language performance of a relatively small sample of CI and NH children at only one measurement point. Further work using prospective longitudinal designs is needed to examine the developmental course and sequence of spoken communication acquisition by these children. In addition, this study did not measure an important aspect of communication, pragmatics including discourse ability. Moreover, differences attributable to CI device and processor strategy were not controlled.

In conclusion, a large proportion of the CI group demonstrated age-appropriate language abilities in some areas. At the same time, many of their language and metalanguage skills were significantly poorer than those of their NH peers. The results also showed that the children with CIs exhibited age-appropriate single-word speech articulation skills. Although encouraging, this finding does not provide information regarding the overall speech intelligibility of these children. Furthermore, the factors that are unique to CI users, such as age at implant, duration of implant use, and speech perception, did not seem to be the major impetuses driving speech articulation and language performance of these children. Finally, the purpose of the present study was to document similarities and differences in speech articulation and language skills of children with CIs and children with NH. One of our next steps is an in-depth examination of the linguistic patterns across the linguistic subsystems studied.

Given the advancements in technology, earlier implantation, and the increased expectations for successful outcomes for children with CIs, the profiles of these children and their habilitation needs are rapidly changing (Cheng et al., 1999). Continued study of their language skills is critical for accurately charting the developmental course of their language acquisition patterns, including specification of relative strengths and weaknesses at different points in development.

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