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Beyond Early Intervention: Supporting Children With CIs Through Elementary School

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Background: The development of cochlear implants (CIs) and the broader availability of early intervention, made possible by newborn hearing screening, have raised prospects that deaf children can be mainstreamed at the start of elementary school and fare well with minimal support. This report examines the veracity of that perspective.
Methods: This report specifically: (1) reviews progress made by deaf children in spoken language acquisition over the past 25 years; (2) presents data collected from 104 children in the early elementary grades (49 with normal hearing (NH) and 55 with severe-to-profound hearing loss who use CIs); (3) describes language acquisition that typically occurs in elementary school; and (4) highlights intervention strategies for school-age deaf children with CIs.
Results: The spoken language skills of deaf children have improved thanks to CIs and early intervention, but remain below those of children with NH. The amount of deficit varies across the language construct examined, with the greatest deficit found for skills dependent upon phonological (speech-sound) sensitivity, and the mildest associated with morphosyntactic (grammatical) skills. There is substantial development in both phonological and morphosyntactic skills that typically occurs during the elementary school years.
Conclusion: Both the data and theoretical models of language acquisition indicate that even with the availability of CIs and early intervention, deaf children are behind their peers with NH when they enter school. And there is much language learning that lies ahead for them. Thus, there is a need for us to enhance our intervention with deaf children during the early elementary grades. **Key Words:** Children—Cochlear implants—Intervention—Language development—Pediatric.

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What does it mean for a child to acquire proficiency in language? In clinical settings, casual exchanges often serve as the bases for assessing the language skill of school-age deaf children who have received cochlear implants (CIs). Questions requiring short answers may be asked: How is your summer going? (*Fine, boring, okay*). What are you doing this summer? (*Going to camp; hanging out; playing with friends*). If children's responses reach basic criteria for intelligibility, it is concluded that their speech and language are developing typically. The attributes informally assessed can include voice quality, articulation, and grammaticality. At times, one may go further in such informal assessments of language proficiency by inquiring about school performance. If the child or her parents confirm that teachers' reports are favorable and grades are good, impressions of language proficiency and all that accompany that proficiency—such as academic well-being—will be bolstered.

But are those assessments adequate? What does it really mean for a child to have proficient language skills, and why are those skills essential for children as they progress through school? The sorts of casual exchanges described above require relatively little in the way of language facility. Much more is demanded of the child in a typical classroom setting, and those demands increase as the child advances through school. Children must master the technical vocabulary of science, geography, and other content areas. They must store and recall increasingly longer sequences of teacher instructions. They must comprehend complex syntactic structures, and be able to generate sentences with equally complex syntax. And of course children must be able to read increasingly difficult texts as they move through school. As the old adage goes, until fourth-grade children are learning to read and thereafter they are reading to learn. All these academic demands require ever-increasing language facility, and the child with CIs must be able to keep up as peers with normal hearing (NH) develop progressively better language and literacy.

The four main goals of this report are to: 1) review the progress that has been made in language performance by deaf children overall as a consequence of the availability

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of CIs and early intervention; 2) describe the current performance of deaf children who received CIs at early ages and received state-of-the-art early intervention; 3) describe the language development that typically occurs for children with NH over the course of elementary school; and 4) highlight intervention strategies that should be used during elementary school to help facilitate optimal language acquisition.

CI ADVANTAGE

It would be difficult to exaggerate the improvements in spoken language outcomes for children with severe-to-profound hearing loss (i.e., *deaf children*) brought about when CIs became available. Every aspect of these children's spoken language abilities was positively affected, but perhaps the single most noticeable improvement involved their speech intelligibility. Before CIs, problems with speech production severely diminished the intelligibility of the speech of deaf children. Much of the deficit in intelligibility could be traced to problems in voice quality, such as breathy voice, or problems in overall vocal-tract posture, such as deviant nasality. Other problems regarding speech production had to do with a failure to generate and coordinate the movements of the vocal tract appropriately, so omissions, insertions, and substitutions of speech sounds were frequently observed. Without question, the availability of CIs as a treatment option for deaf children has all but eliminated these problems (1). That improvement alone accounts for much of our collective impression that the spoken language skills of deaf children who receive CIs are similar to those of children with NH: deaf children just sound so close to normal now.

Where grammar is concerned, it can be difficult to construct a description of how the skills of deaf children compared to those of children with NH before the advent of CIs. The language of deaf children was so poor in those earlier times that it was hard even to use tests designed for children with NH. The methods and materials incorporated into language assessment tools for young children were below the cognitive and interest levels of the older deaf children who would be tested with those materials. Nonetheless, the few investigators who attempted to compare the grammatical abilities of deaf children to those of children with NH in a valid manner painted a picture of severe impairment. For example, Geers and Moog (2) assessed both the spontaneous and imitated language of deaf children between 4 and 15 years of age using two tools developed to test the language of children with NH: Developmental Sentence Analysis (3) and the Carrow Elicited Language Inventory (4). In both cases, it was observed that half of the 52 deaf children who were tested scored below means for 3-year-olds with NH. That outcome matched what Watson et al. (5) reported when they assessed 25 school-age deaf children with standardized language measures designed for children with NH. When error types were analyzed, it was found that deaf children had greater difficulty with unstressed grammatical elements than with more salient grammatical structures (6). Thus, word order was relatively well learned, but elements such as tense markers, morphological inflections, and relative pronouns were usually found to be more seriously impaired (7).

Even compared with grammatical abilities, it is more difficult to construct a picture of how deaf children were faring in their awareness of and ability to manipulate phonological structure in that pre-CI era. The importance of this level of structure to other language and cognitive functions such as reading and working memory was only being uncovered by psycholinguists around the time that CIs were being developed (7–11). As a result, phonological awareness was not routinely assessed in the years before CIs became available. Nonetheless, we are able to garner insight into the phonological sensitivities of deaf children in those earlier times by considering their reading abilities, because those abilities are strongly dependent on having sensitivity to phonological—especially phonemic—structure (12–14). In 1977, Trybus and Karchmer (15) reported that 12-year-old deaf students had an average reading level of third grade, and that reading level only rose to fourth grade by 20 years of age. This finding supports suspicion that phonological awareness was not very strong for deaf children before CIs, and it is reasonable to propose on theoretical grounds that deaf children would have had difficulty in recognizing phonemic structure in the acoustic speech signal. In addition to the raised auditory thresholds that accompany sensorineural hearing loss, there is also a loss of frequency resolution, which would constrain access to the kind of spectral detail underlying phonemic categories.

Status of Deaf Children Receiving CIs at Early Ages

The data reported below provide a picture of how deaf children who receive CIs early in life and obtain intensive language intervention are presently faring in the early elementary grades. Although these data are from just one study, outcomes are in agreement with those from other investigators (16–19).

The specific language measures reported here can be grouped into three categories on the basis of the type of language skill they assessed. In total, results for 12 measures are reported. Five measures were related to children's sensitivity to phonemic structure, and their abilities to use that structure for related language and cognitive functions. Phonemic structure refers to the sequences of consonants and vowels found in a language; it is a component of the broader, more common term *phonological* structure. The ability to recognize individual phonemes in the signal is fundamental to other language processes because those units serve as codes for those other processes. Four measures were morphosyntactic in nature, meaning they tapped into children's abilities to generate morphological units, and concatenate those units to create syntactically correct sentences. The final three measures assessed children's abilities to understand and attach meaning to language structures.

METHODS

Participants

Data were collected from 104 children during the summer after they completed second grade: 49 of the children had NH and served as a control group; 55 of the children had pure-tone average thresholds in their better ear of greater than 60 dB hearing level before receiving a CI, and wore CIs at the time of testing. Median ages of specific treatment milestones for these children with CIs were all quite young: age at identification of hearing loss = 4 months; age at start of early intervention = 6 months; age of first CI = 15 months. Children in both groups were well matched on socioeconomic status, and most children had at least one parent who received a 4-year college degree. All children had nonverbal cognitive abilities within the normal range, as measured by the Leiter International Performance Scales (20). None had any disability (other than hearing loss for those in the CI group) that would put them at risk of language delay or deficit. More details regarding these samples are available in other reports arising from this study (21–23).

Procedures

All procedures were approved by the Institutional Review Board of the Ohio State University. Children traveled to the Ohio State University for 2 days of testing. They were tested in sessions lasting no longer than 1 hour, and had at least 1-hour breaks between sessions. Again, more details regarding these procedures as well as reliability metrics can be found in other reports.

Five measures of children's awareness of phonemic structure and their abilities to manipulate and use that structure were obtained. Two measures were explicitly of awareness of phonemic structure: Initial Consonant Choice (ICC) and Final Consonant Choice (FCC). A third measure assessed children's abilities to manipulate phonemic structure: Phoneme Deletion (PD). All three of these tasks consisted of 48 items, and were presented in an audiovisual format. In the ICC and FCC tasks, a target word was presented that the child needed to repeat correctly. Then three word choices were presented, and the child had to indicate which word started or ended with the same sound. In the PD task, the child repeated a target nonword, and then was instructed to say the nonword without one of its segments. The correct answer resulted in a real word. Percent correct answers served as dependent measures for all three tasks. Two measures were obtained of children's abilities to use phonemic structure to facilitate literacy and cognitive functioning. First, a measure of word reading ability was derived from the Qualitative Reading Inventory (24). For this task, the child read each of 3 passages, and 10 comprehension questions were asked after each. The total number of words read correctly across the passages served as the measure of word reading. Second, a measure was obtained of working memory, largely a cognitive function. In this task, children heard the same 6 consonant–vowel–consonant (CVC) nouns, presented 10 times in different orders. After each presentation of the six words, children recalled word order by touching pictures of the six words on a monitor. Percent correct recall (out of 60 ordered words across the 10 presentations) served as the dependent measure.

Four measures of morphosyntactic abilities were obtained from transcriptions of 100 utterances taken from 20-minute language samples. Mean length of utterance in morphemes (MLU) and number of conjunctions (excluding *and*) were obtained to index children's abilities to create syntactically correct and complex sentences. The number of different words used in the 100-utterance sample and number of personal pronouns used correctly indexed children's morphological skills.

Three measures of children's abilities to derive and attach meaning to language structures are reported here. They include reading comprehension, which was the number of questions answered correctly in the reading task; auditory comprehension, which was a standard score derived from the paragraph comprehension subtest of the Comprehensive Assessment of Spoken Language (25); and expressive vocabulary, which also was a standard score, in this case derived from the Expressive One-Word Picture Vocabulary Test (26).

RESULTS

Table 1 shows results of the 12 separate measures, along with outcomes of *t* tests and effect sizes given as Cohen's *d*s. Every measure shows a statistically significant difference in mean performance between children with CIs and those with NH. However, effect sizes vary across the types of language functions being examined. Children with CIs performed more poorly, relative to children with CIs, on tasks involving phonemic sensitivity or tasks requiring that children attach meaning to language. Children with CIs fared best on their abilities to generate language with appropriate morphosyntactic structures.

Next, principal components analysis was performed using these 12 measures. Although the presumption was made that these 12 measures could be grouped according to underlying constructs as shown in Table 1, a principal components analysis assessed whether these groupings had validity. Outcomes are shown in Table 2. It can be observed that these observed measures loaded on the principal components as predicted.

Three latent scores were then derived for each child, based on the outcomes of that principal components analysis: one each for phonemic sensitivity, morphosyntactic abilities, and understanding of meaning in language. Children with NH served as the selection group, so their scores on all three latent measures had means of 0 and standard deviations of 1. Mean scores for the children with CIs are shown in Figure 1, where the latent constructs are labeled as phonological, morphosyntactic, and meaningfulness. Here the trends observed in Table 1 come into focus: the phonological sensitivities and skills of children with CIs are almost two standard deviations below those of children with NH, and their abilities to attach meaning to language are roughly one and a half standard deviations below. Their morphosyntactic skills are not as significantly impaired, at just about a half standard deviation below the mean of children with NH. These outcomes reveal another shortcoming in our customary procedures for assessing the degree of language delay in deaf children: most standardized language measures are heavily weighted toward morphosyntactic abilities. Consequently, when formal testing is done, it can underestimate the extent of the delay by not measuring phonological (especially phonemic)

TABLE 1. *Mean scores and SDs for dependent measures, along with outcomes of t tests and Cohen's ds*

	NH		CI				
	Mean	SD	Mean	SD	t	p	Cohen's d
Phonological							
Initial consonant choice	87.4	*13.2*	63.1	*25.9*	5.92	<0.001	1.18
Final consonant choice	69.8	*17.9*	35.8	*25.6*	7.73	<0.001	1.54
Phoneme deletion	71.5	*21.5*	47.5	*32.6*	4.35	<0.001	0.87
Word reading	200.3	*5.3*	190.5	*14.7*	4.39	<0.001	0.88
Working memory	56.1	*16.5*	43.3	*15.4*	4.06	<0.001	0.80
Morphosyntactic							
Mean length of utterance	6.3	*1.5*	5.5	*1.4*	2.67	0.009	0.53
Conjunctions	30.2	*14.9*	23.2	*10.8*	2.75	0.007	0.54
Number of different words	199.2	*32.5*	178.9	*37.8*	2.92	0.004	0.58
Pronouns	122.2	*32.0*	102.7	*30.7*	3.17	0.002	0.62
Meaningfulness							
Expressive vocabulary	110.0	*13.7*	94.4	*18.1*	4.92	<0.001	0.97
Auditory comprehension	111.6	*11.9*	99.4	*19.5*	3.77	<0.001	0.75
Reading comprehension	20.8	*3.0*	16.6	*6.0*	4.39	<0.001	0.88

awareness and processing skills or children's abilities to associate meaning with language.

The goals of this study were stated as examining language performance specifically for children who were implanted early, and many clinicians are especially concerned with how age of implantation affects language outcomes. Accordingly, Pearson product–moment correlation coefficients were computed between age of receiving a first CI and each of the three latent scores for children with CIs. None of these coefficients was significant, indicating that age of receiving a first CI did not influence these scores significantly. As a further check, t tests were performed on means between children who received their first CIs on or before 15 months of age (N = 28) and those who received their first CIs on or after 16 months of age (N = 27). None of these t tests reached significance ($p > 0.10$ in all cases), even though there was a trend toward lower scores for the later implanted children, compared with the earlier implanted children, for two of the three latent scores: morphosyntactic abilities (−0.75 versus −0.46) and meaningfulness (−1.71 versus −1.23). Phonological latent scores for the later and earlier implanted children were quite similar (−1.96 versus −1.91).

Typical Language Growth During School Age

Support for early intervention programs is often derived from a critical periods' hypothesis, which suggests that specific environmental factors need to be in place at specific times in the development of an organism, in order for certain developmental events to unfold. Accordingly, language input needs to be available early in a child's life if language acquisition is to have an appropriately timed start. This account receives support from the very population of children of interest here: studies involving samples of deaf children with broader ranges in the ages of identification and implantation than the children in the study reported above have shown that language performance varies inversely with the age of initiation of intervention for children with hearing loss (27), and with the age of first cochlear implantation (19). Other studies have demonstrated

TABLE 2. *Loadings of observed scores on principal components*

	Component		
	Phonological	Morphosyntactic	Meaningfulness
Initial consonant choice	**0.753**	0.075	0.450
Final consonant choice	**0.793**	0.113	0.180
Phoneme deletion	**0.765**	0.073	0.400
Word reading	**0.710**	0.090	0.347
Working memory	**0.701**	0.142	0.077
Mean length of utterance	0.058	**0.951**	0.190
Conjunctions	0.174	**0.857**	0.042
Number of different words	0.102	**0.861**	0.331
Pronouns	0.098	**0.923**	0.077
Expressive vocabulary	0.438	0.044	**0.767**
Auditory comprehension	0.285	0.303	**0.803**
Reading comprehension	0.333	0.275	**0.796**

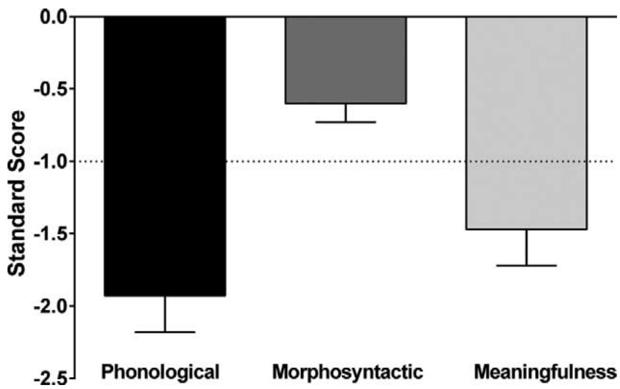

FIG. 1. Mean scores and standard errors of children with cochlear implants for latent measures, standardized on scores from children with normal hearing.

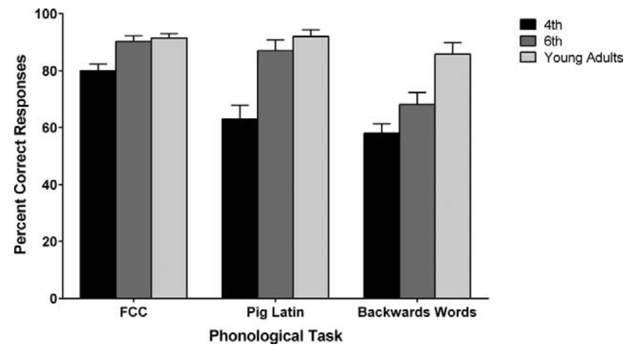

FIG. 2. Mean scores and standard errors on three measures of phonological sensitivity and processing for participants with normal hearing in three age groups.

similar benefits to early intervention and implantation using methods that involved grouping children depending on age of implementation of one or the other of these factors (19,28,29). All these results demonstrate the importance of providing appropriate environmental support for early language learning.

But not all language skills emerge early in life. In particular, sensitivity to phonemic structure emerges only after the start of school (30). Initially, lexical units are thought to be stored as holistic acoustic structures (31); later children discover the phonemic structure comprising those words by learning to attend to the acoustic details that define phonemic categories. For example, Walley, Smith, and Jusczyk (32) found that kindergarten children were poor at discriminating CVCV nonwords that differed by only one or two segments; by second grade they were sensitive to such differences. This sharpening of phonemic sensitivity is thought to continue until roughly puberty, and results from this laboratory support that suggestion.

Figure 2 shows percent correct responses from the 49 children with NH for whom data are reported above, when they reached fourth grade. Data are also shown for 12 sixth-grade children and 12 adults between 18 and 40 years of age. These data come from three measures of phonemic awareness and processing: the FCC task already described, a traditional Pig Latin task, and a Backwards Words task in which participants were asked to say the words they heard with the order of segments reversed (e.g., *spin* becomes *nips*). As can be observed, children with NH are honing their sensitivity to this kind of phonemic structure through elementary school.

Although somewhat more subtle, continued development through elementary school has been described for morphosyntactic abilities, as well. For example, Chomsky (33) showed that children between the ages of 5 and 10 years were still learning to comprehend sentences with embedded clauses or with meanings that were not apparent from surface syntactic structure.

When the evidence of continued language acquisition through elementary school is put in the context of a critical periods' hypothesis, the suggestion can be made that strong environmental support must be in place for deaf children who receive CIs through elementary school, even if those CIs are obtained at early ages and appropriate early intervention is provided. There are simply some language skills that are not expected to begin emerging until after children start school. The same quality and quantity of environmental support required for the acquisition of early language skills is needed for these children to accomplish the language learning that typically occurs during the elementary school years.

At the same time, some urgency exists in our efforts to support language acquisition by deaf children who receive CIs. Studies of second language acquisition have revealed that the ability to learn a language to the level of first-language proficiency declines precipitously around the age of puberty. Specifically where phonemic categories are concerned, it is apparent that individuals can develop native phonemic categories up to the age of puberty, but not after (34). Thus, it is not the case that children with CIs will merely have delayed language acquisition. It is reasonable to propose that any language deficit present around the time of puberty will have lifelong consequences.

Designing Intervention for School-Age Children With CIs

A quandary immediately presents itself when an attempt is made to use the findings above to design intervention programs for children with CIs in elementary school. The greatest deficit these children face rests with their abilities to recognize phonemic structure in the acoustic speech signal, a problem undoubtedly arising because of the degraded spectral representation available through CIs. Although continued research is clearly needed regarding the most effective ways to facilitate the acquisition of phonological sensitivity in these children, attempts to train it should be proceeding nonetheless. At the same time, enhanced training in other areas of language function should be provided. Morphosyntactic structure is the most available level of structure for deaf children with CIs. It should be strengthened as much as possible to support communication functions when detailed representations are not available. In such cases, strong knowledge of morphosyntactic structure helps constrain the possibilities of allowable phonemic sequences, through top-down processes. Below are some principles that should help shape intervention programs.

Direct language instruction. Largely because of the diminished opportunity to access high-quality sensory input, children with CIs have decreased opportunity for the kinds of language experiences most children have that allow them to discover naturally the phonological and morphosyntactic patterns of their native language. Children with hearing loss, including those who use CIs, are affected to a greater extent than other children by background noise, room reverberation, and simple distance. The term, *direct language instruction*, is often invoked to refer to instructional methods used with students who are second-language learners of English, but the motive and principles are the same where children with CIs are concerned. Essentially, the term indicates that phonological, lexical, and morphosyntactic structure needs to be introduced explicitly to the student. General educational approaches have moved away from this practice, placing an emphasis instead on naturalistic learning of language. That approach is appropriate and sufficient for typically developing children without sensory deficits, precisely because language acquisition is such a natural process for them. However, children with hearing loss need direct instruction in order for them to learn linguistic patterns.

Use sufficiently long signal stretches. Children acquire sensitivity to all levels of language structure simultaneously. It is not the case that they learn smaller units such as individual phonemes or words, and subsequently discover how to combine those small units to construct larger ones. Accordingly, complete syntactic structures should be used in clinical and educational settings. Intervention to correct errors at the segmental level should be implemented only after a child demonstrates a desire to communicate with spoken language, and is producing—or attempting to produce—speech to express needs, feelings, and wishes. According to this approach, intervention to improve production of smaller units serves to polish what the child is already attempting to produce. Thus, an appropriate conceptualization of the therapy process might be one of *progressive refinement*, indicating that children's attention should first be directed to global structure, with gradual redirection to increasingly detailed structure.

Use speech signals to teach language. Acoustic signals are perceptually organized differently depending on whether listener expectations are that they are part of speech or nonspeech signals (35). Consequently, only speech should be used in language learning experiences with children with CIs; anything else is unrelated to children's development of spoken language.

Aids to perceptual organization. Speech recognition does not proceed by listeners harvesting small bits of the acoustic signal that directly and unequivocally signal individual phonemic segments. Instead, listeners skillfully attend to relevant structure, and organize that structure appropriately to recover linguistic elements. Nonetheless, the more complete the signal reaching the listener, the more reliably phonemic segments can be recovered. And where language learning is concerned, complete signals—robust sensory information—facilitate that process best. Consequently, efforts should be made to provide the clearest signal possible to children with CIs, and several methods exist for doing so. When possible, it may be helpful to supplement the electric stimulation of the CI with amplified signals through hearing aids. Application of noise reduction systems, including FM transmitters, can be useful. And care should be taken in selecting seating in the classroom to ensure that the child with a CI is far from sources of noise, but close to the teacher. As stated above, spoken language is the product of people speaking. Listeners use all the sensory information available to them to make sense of their environment. Where speech is concerned, information gathered from lipreading is indistinguishable from that gathered from the auditory system for purposes of speech recognition. Deaf children should always be permitted to see the talker.

CONCLUSIONS

The spoken language of deaf children has improved remarkably as a result of the development of CIs. In particular, the quality of deaf children's speech is now very close to normal, if they received CIs early and received appropriate intervention. Nonetheless, deficits remain. Children with CIs lag behind children with NH on all language functions, but especially so on tasks requiring sensitivity to phonemic structure: the average deaf child who received CIs early, along with appropriate intervention is almost two standard deviations behind the average child with NH. That places that average deaf child with CIs at the second percentile in terms of performance by children of the same age. This poor sensitivity puts these children at a severe disadvantage for many aspects of learning that must occur in elementary school, especially reading. Thus, a strong argument can be made for suggesting that language intervention needs to continue for children with CIs through elementary school. This intervention needs to be tailored to meet the needs of these children.

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