Individual Differences in Language Performance after Cochlear Implantation at One to Three Years of Age: Child, Family, and Linguistic Factors

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Language skills were investigated in a multicultural sample of 13 prelingually deaf children (11 profoundly deaf from birth) who received cochlear implants between 14 and 38 months of age; average duration of implant use was 49 months. Individual postimplant language skills ranged from extremely delayed to age appropriate. On average, skills varied across domains: on vocabulary, several children functioned in the average range compared with hearing peers, but all were below that range on a test emphasizing syntax (CELF-P). Children with preimplant hearing experience had the highest scores on all language measures. Excluding these children, age of implantation (range 14 to 27 months) associated inversely and significantly with CELF-P scores, even when nonverbal IQ was controlled. Qualitative analyses indicated higher child language achievement associated with parents' reports of lengthy, in-depth processes to decide about cochlear implantation. Such reports may indicate high levels of ongoing parent involvement with child and programming.

Studies of both individuals and groups of profoundly deaf children have shown positive effects from the use of cochlear implants on speech perception (e.g., Blamey, Sarant, et al., 2001; Geers & Moog, 1994; Svirsky & Meyer, 1999), speech production (e.g., Blamey, Barry, et al., 2001; Osberger, Robbins, Todd, & Riley, 1994), and language development (e.g., Geers, Nicholas, & Sedey, 2003; Svirsky, Robbins, Kirk, Pisoni, & Miyamoto, 2000; Tomblin, Spencer, Flock, Tyler, & Gantz, 1999). Some research on effects of cochlear implants has documented a close association or intertwining of progress in the three abilities (Connor, Hieber, Arts, & Zwolen, 2000; Geers, Nicholas, et al., 2003; O'Donoghue, Nikolopoulos, Archbold, & Tait, 1999; L. Spencer, Tye-Murray, & Tomblin, 1998). In addition, there has been great interest in identification of factors that predict or at least are associated with rates of progress in spoken language development after implantation. This research focus has been motivated in part by the great variability reported in outcomes (e.g., Dowell, Blamey, & Clark, 1997; Osberger et al., 1994; Svirsky et al., 2000).

Differences in speech and spoken language development after cochlear implantation have been attributed to duration of use of the implant (Dowell et al., 1997; Tomblin et al., 1999), age at which an implant was first used (Barker et al., 2000; Cheng, Grant, & Niparko, 1999; Dowell et al., 1997; Kirk, Miyamoto, Lento, Ying-O'Neill, & Fears, 2002; Nikolopoulos, O'Donoghue, & Archbold, 1999; Tye-Murray, Spencer, & Woodworth, 1995), and interactions among these factors (Kirk, Miyamoto, Ying, Perdew, & Zuganelis, 2000). However, questions remain about whether age at implantation acts as a continuous variable (at least until middle childhood or early adolescence) and potential for effective use of the implant gradually decreases or whether implanta-
tion before some specific early age gives a clear advantage. There are reports of especially fast growth in listening and speech skills with implantation before 18 months or 2 years of age (i.e., Barker et al., 2000; Hammes, Novak, Rotz, Willis, & Edmondson, 2002). However, there is evidence that the auditory system remains capable of effective organization if stimulation is received by about 3.5 years of age. This last finding suggests that very early implantation, before 3 years of age, may not be necessary to support development of spoken language skills.

Cognitive abilities have also been implicated as influencing language development after cochlear implantation (i.e., Pyman, Blamey, Lacy, Clark, & Dowell, 2000), but this finding has not been universal (see, e.g., Knutson, Ehlers, Wald, & Tyler, 2000). It may be that cognition within the typical range for chronological age is not a critical factor, but having slower than typical development of cognitive skills limits the speed at which children profit from cochlear implantation. On the other hand, effects of “cognition” may be better identified when that general construct is further specified. For example, short-term sequential memory skills have been associated with the spoken language performance of children with cochlear implants (Pisoni, Cleary, Geers, & Tobey, 1999), and Quittner and colleagues (Quittner, Smith, Osberger, Mitchell, & Katz, 1994) reported growth in visual attention abilities subsequent to cochlear implantation. (But, see the 2002 work of Tharpe, Ashmead, and Rothpletz for a failure to replicate this finding.)

The language modalities used in children’s education programs have also been said to influence speech perception, speech production, and spoken language development after cochlear implantation, with the preponderance of evidence favoring children in auditory–oral or auditory–verbal educational settings (e.g., Geers, Brenner, & Davidson, 2003; Hodges, Ash, Balkany, Schloffman, & Butts, 1999; Osberger et al., 1994; Osberger, Fisher, Zimmerman-Phillips, Geier, & Barker, 1998). Strube (2003) reported, for example, that participation in an oral education program (instead of one that incorporated signing) contributed a statistically significant 11.7% to the prediction of speech perception skills after the contributions of other child, family, and implant characteristics had been controlled. However, not all reports regarding effects of language modality are in agreement. In contrast with the above reports, Connor et al. (2000) reported an advantage in spoken language vocabulary for children in programs using combined signs and speech compared to children in oral programs, but only when implantation occurred before 5 years of age. Kirk, Miyamoto, et al. (2000) failed to find any significant effect from communication mode on language development of a large group of children using cochlear implants when children’s habitual communication system (speech or speech plus signs) was used in the assessment.

Factors related to the intactness of the neurological system (Pyman et al., 2000), as well as equipment and surgical factors, are also recognized as influencing the functioning of individual children after cochlear implantation. Factors such as the depth of insertion of the electrode array and the number of channels that can be effectively programmed affect the subsequent development of speech perception and spoken language skills.

The variables mentioned above do not exhaust the list of factors reported to influence language development using cochlear implants. Tait, Lutman, and Robinson (2000) found that children with better expressive prelanguage skills, regardless of the modality through which they were expressed, predicted better language results after cochlear implantation. Prelinguistic communication skills, in addition to reflecting innate child characteristics such as social interest and cognitive abilities, are influenced by the early interaction experiences parents provide young children (P. Spencer, 2003). Other aspects of family functioning, such as teachers’ judgments of family support for children’s development and family involvement in children’s therapy and educational programs, have been reported to enhance benefits from cochlear implant use (e.g., Bertram & Pad, 1995; Geers & Brenner, 2003). (These factors have also have been reported to support development of deaf children with early identification, but not necessarily cochlear implant use [Moeller, 2000].) Although Strube (2003) reported that family socioeconomic status relates to parent involvement, there remains a need for more research investigating family characteristics that
predict the degree parents will become and remain involved with the education of their deaf children after cochlear implantation.

Existing research reports have tended to include measures of various aspects of language skills, usually development of a lexicon and of syntax skills (e.g., Blamey, Sarant, et al., 2001; Connor et al., 2000; Geers, Nicholas, et al., 2003). However, there has not been a direct focus on the issue of whether use of a cochlear implant is more critical for development of one more than other aspects of language. Descriptions of different syntactic structures for natural sign languages compared to spoken languages indicate that those structures “match” or are influenced by characteristics of visual versus auditory access to language (e.g., Emmorey, 2002). In addition, L. Spencer et al. (1998) reported that a group of children who participated in a program in which simultaneous communication (speech plus sign) was used tended to sign when speaking base words, but used voice only for grammatical markers (such as plurals and possessives). This finding suggests that access to auditory signals using a cochlear implant may have special influence on children’s use of English grammar.

In summary, despite the plethora of information available, many questions remain about factors that assist and/or predict the communication and language skills of children who receive cochlear implants at an early age. The study reported here was conducted to investigate variations in language skills of children who received cochlear implants by 3 years of age. Associations between language performance and differences in age at implantation across this early range were assessed. In addition, associations between language skills and a set of other variables, including nonverbal cognitive skills, communication modalities, and speech perception skills, were investigated. Parent interviews provided information about families’ experiences with early implantation and, for the purpose of the current analysis, indicators of parent involvement with their children’s development both before and after cochlear implantation. Language performance was sampled using three different tests that provided measures emphasizing vocabulary, syntax, and pragmatics. This allowed investigation of relations between cochlear implant use and development in each aspect of language.

Method

Design and Procedures

This study focused on a relatively small group of children and provides in-depth descriptions of their language skills as well as factors related to individual differences in those skills. A set of standardized, quantitative instruments was used to assess language and nonverbal cognitive abilities over two to three sessions with each child. Most children were tested at school on the two direct-test language instruments and the cognitive measure, but one child participated in some testing during a regular clinic visit, and two children had follow-up test sessions at home because of time constraints at school. Test sessions were videotaped to allow rechecking of scoring after the sessions. The third language assessment instrument was completed by parents and teachers of participating children. Parents also participated in in-depth qualitative interviews investigating their experiences with the identification of their child’s hearing loss, their resources and process in making the decision to obtain a cochlear implant, and their evaluation of their child’s progress since implantation.

Selection and Characteristics of Participants

Letters announcing the study were mailed to families whose children had received cochlear implants from a well-established surgical center in Australia. From those who responded, families were selected if their children had received a cochlear implant by the age of 3 years and were currently younger than 8 years old. This age range was chosen in part because it would allow use of established tests and assessment procedures. Children had to have used the implant for at least 1 year. An additional selection criterion was that families lived within the metropolitan area served by the center or no more than a 3-hour drive from that area. These criteria resulted in a sample of 13 children, 6 boys and 7 girls, who ranged in age at time of data collection from 3–11 to 7–11 (mean 70.5 months, median 67.0 months, SD 18.8 months). Their age at implantation ranged

Language Performance After Cochlear Implantation 397
from 13 to 38 months (mean 22.9 months, median 21.0 months, SD 7.16 months). The average duration of use of the cochlear implant across all participating children was 49.4 months (range 21–81 months). All of the children were using a Nucleus 22 or 24 cochlear implant. All of the children had hearing parents, and only 1 had a sibling with hearing loss.

One child had a congenital sensorineural hearing loss in the severe-to-profound range and was implanted at 38 months after having begun to acquire spoken language. Because this child had begun to develop spoken language skills before getting an implant, it is assumed that conventional aiding had been providing relatively consistent auditory experience. This child continued to use a hearing aid on the nonimplanted ear after cochlear implantation. Another child was born hearing, but became profoundly deaf after meningitis at 2 years. Therefore, this child (who received a cochlear implant at 32 months of age) had 2 years of typical auditory experience and had developed considerable spoken language prior to the hearing loss. The other 11 children had congenital bilateral profound sensorineural hearing losses, and all of these children were implanted by 27 months. For these 11 children, the average age at implantation was 20.7 months (range 13–27 months, SD 5.0 months).

Similar to the general deaf student population (Holden-Pitt & Diaz, 1998; Moores, 2001), a sizable proportion (n = 4 or about 30%) of the participating children had a documented secondary disability. The disabilities were generally mild in degree and included attention problems, behavior problems, and cognitive delay. During the course of data collection for the current study, an additional child was identified with probable cognitive and attention disabilities.

Families were of varied ethnic background (European, Asian, Middle Eastern), reflecting the multiethnic character of the population in the metropolitan area where participants lived. A second language was spoken in two of the homes, although the parents reported speaking only English to the children until they had gained some proficiency in spoken English. Educational levels of parents ranged from 10 years of school to completion of university degrees. Most had obtained specialized postsecondary vocational training. In three families, the mother was the sole parent in the home.

Children’s educational placements ranged from self-contained classrooms for deaf children to mainstreamed programs in which deaf children received special support but spent most of their academic day integrated with hearing students. At the time data were collected, seven of the children were in educational programs using an oral approach to language (without use of any signed language), and six of the children were in educational programs using some form of signed language. Five of these signing programs used Signed (Australian) English combined with spoken language; one child was in a classroom that was bilingual and provided models of both Australian Sign Language (without speech accompaniment) and simultaneous signed plus spoken English. This last classroom included a deaf and a hearing teacher; all other teachers were hearing. In addition to regular speech therapy from the school and/or follow-up visits to the clinic for monitoring of the implant and spoken language therapy, all of the children were exposed to spoken language during the school day and at home.

During data collection, it became evident that several children had recently changed from classrooms using one kind of language system to another. One had transferred from a Signed English classroom to an oral classroom during the school year. Another had transferred from an oral classroom to one using Signed English. Another had moved recently from a Signed English classroom to the bilingual classroom. In addition, it was found that two of the families used signs at home even though their children were exposed to only spoken language at school. Simple comparisons of language achievements based on current language mode were therefore deemed inappropriate. Looking ahead, such an analysis would also have been complicated by the fact that the average measured level of nonverbal cognition was higher for children who were currently in oral programs than for those in signing programs. Three of the four children who had a documented secondary disability had been placed in signing programs.

Instruments and Measures

Language Assessments. Children’s language performance was assessed using two direct test instruments,
the *Peabody Picture Vocabulary Test, Third Edition* (PPVT; Dunn & Dunn, 1997) and the *Clinical Evaluation of Language Functioning—Preschool* (CELF; Wiig, Secord, & Semel, 1992), and one parent report instrument, the Language Proficiency Profile (LPP; Bebko & McKinnon, 1993, 1998). The first two instruments are normed for hearing children, but have been used in previous studies of deaf children (e.g., Blamey, Sarant, et al., 2001). Specialists in schools in which sign language was used served as interpreters and assisted in administering the direct test instruments when appropriate. The third instrument was developed specifically for assessment of children who are deaf (Bebko & McKinnon, 1993, 1998). Parents and teachers responded to this instrument by rating children’s skill levels across various areas of language use.

The direct test instruments (CELF, PPVT) emphasize different aspects of language functioning: syntactic knowledge versus semantic. The CELF emphasizes English syntax knowledge and skills. It assesses processing of utterances containing varied amounts of information, understanding and producing basic sentence structures, understanding and producing bound and unbound English grammatical morphemes (e.g., markers for verb tense, plurals, possessive; prepositions; articles), as well as conceptual receptive and expressive vocabulary (e.g., “many,” “slow,” “full”). This instrument was administered in the language mode(s) used in the children’s current classrooms. For children in signing programs, English bound morphemes and grammatical words were signed using the conventions of each child’s school. Because several children were slightly older than the oldest norm group for the CELF, standard scores could not always be legitimately computed. Therefore, a “percent-of-age” score was calculated. This was obtained by calculating an age-equivalent score for each child based on instrument norms, dividing this score by the child’s chronological age, and multiplying by 100.

The PPVT assesses receptive vocabulary. Children in classrooms using spoken language only were tested orally; children in classrooms using signs were tested once orally and then again using bimodal communication (sign plus spoken word). Because there is no one-to-one match between sign and spoken word for some items on the PPVT past the 6- to 7-year levels, those words had to be fingerspelled instead of signed during the speech-plus-sign administration. This might result in the word’s representation being more difficult for children who were relying on signs; however, very few words required this approach at the functional levels attained by this group of children. Teachers at the participating schools reviewed the list of words on the PPVT before it was administered to ensure the signs used were appropriate. Standard scores were obtained for the PPVT and used in analyses.

The parent and teacher report language instrument, the LPP (Bebko & McKinnon, 1993, 1998), includes a number of subscales that tap child pragmatic or conversational ability as well as more formal aspects of language. The subscales cover form, content, reference, cohesion, and use of language in communicative settings. The instrument was designed to be a “global” measure of language functioning of deaf children and to provide an assessment that was not dependent on language modality (Bebko & McKinnon, 1998); therefore, it does not necessarily provide an assessment of functioning in English or using spoken means. Normative data were still being collected on this test at the time of its use; however, scores could be calculated on each subscale. Points were assigned according to Bebko and McKinnon’s (1993) instructions, with two points given for an activity already accomplished and one point given when the activity was judged as emerging. A total score was calculated. Because the various subscales have different numbers of items, a “percentage passed” score was also determined for each subscale (number of points for “past this level,” “yes,” or “emerging” divided by the total possible subscale score possible) to allow comparison of relative strengths and weaknesses across subscales.

**Cognitive Assessment.** Nonverbal cognitive performance was assessed using the *Leiter International Performance Scale—Revised* (Leiter-R) (Reid & Miller, 1997). This test is conducted without the use of any language by the examiner, who must rely on gesture and demonstrations specified in the test manual. Although the norming sample for this test is comprised primarily of typically developing hearing children,
a small \( n = 69 \) sample of children with “severe hearing impairment” (Roid & Miller, 1997, p. 151) was considered during the development of the test to identify and eliminate problematic items or test procedures. The Leiter-R and its predecessors the Leiter and the Arthur Adaptation of the Leiter have been used frequently with deaf children (e.g., Boyd & Shapiro, 1986; Lindsay, Shapiro, Musselman, & Wilson, 1988; Ulissi & Gibbons, 1984). The Brief I.Q. form of the test was used because of time restrictions. The Brief I.Q. is calculated on four subscales: Figure Ground, Form Completion, Repeated Patterns, and Sequential Order. The first two of these subscales represent a Visualization factor; the last two represent a Reasoning factor (Roid & Miller, 1997, p. 7).

**Speech Perception Assessment.** Open set speech perception for phonemes was assessed during regularly scheduled clinic visits using either the Consonant–Nucleus–Consonant Word Test (CNC) (Peterson & Lehiste, 1962) or Bench–Kowal–Bamford (BKB) words and sentences tests (Bench & Bamford, 1979; Bench, Doyle, & Greenwood, 1987). With one exception, stimuli were presented by live voice. Scores on open set speech perception, obtained within 6 months of the date of language testing, were available for nine of the children. Two children could not be tested using open set procedures. Records for the two other children were not available.

**Parent Interviews.** Parents were interviewed at a location of their choice. Most interviews were conducted in families’ homes, but several occurred in a private room in children’s schools; one mother was interviewed at the cochlear implant clinic, and one was interviewed by phone. Except for the phone interview, during which the researcher made extensive notes, all interviews were tape recorded. Both parents participated in the interview in families with two parents in the home; one grandmother was present during the interview of a single mother.

The interviews were qualitative and were conducted in as “conversational” a manner as possible. The specific topics to be covered were listed and referred to by the researcher during each interview; however, specific wording and order of the questions varied. The topics in the interview included description of the child’s hearing loss and how the parent found out about it, child’s educational and related experiences before getting the cochlear implant, parents’ process of making the decision about the cochlear implant, description of the process of implant surgery, experiences after surgery and at initial “turning on” of the implant, parents’ evaluation of child’s progress with the implant, and advice for other parents and for professionals.

**Data Analysis**

Descriptive statistics, including means and standard deviations, medians, skewness, and range measures, were calculated for all variables. Characteristics of data distribution as well as number of scores available for a given measure were considered when selecting parametric or nonparametric statistical tests. In most cases, correlations were computed between pairs of variables, with partial correlations used if appropriate to control effects of shared variance.

Comparisons between expressive and receptive scores on the CELF were made using guidelines provided in the test manual and by dependent-measures tests. One-way nonparametric analysis of variance and nonparametric tests of differences between pairs of means were used to investigate differences among LPP subscale scores.

Parent interviews were transcribed from audi-tapes, and transcripts were checked by a second listener. The researcher and both transcribers then discussed the content of the tapes as they referred to the topic questions that had guided the interviews. A constant comparative method was used to code and group ideas expressed by the parents. These codes were further combined to determine major “themes” occurring in the interviews. This article focuses on themes of “active engagement in decision” and “active engagement in parenting supportive of child development,” both of which are thought to provide insight into the degree of involvement of parent(s) with the child. Trustworthiness of coding and analysis was supported by extensive review and revision of the coding system, peer review of coding definitions and
examples, and triangulation with information from direct child assessments, observations of parents during assessment of the child, and (in most cases) observation of the child in the classroom and at home during the interviews.

Results

Performance on Quantitative Measures of Child Functioning

Initial exploration of the data revealed that the quantitative measures were distributed normally, with no evidence of significant skew or kurtosis. Table 1 shows the mean, standard deviation, median, and range for each measure.

<table>
<thead>
<tr>
<th>Measure</th>
<th>N</th>
<th>Mean (SD)</th>
<th>Median (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at test (mo)</td>
<td>13</td>
<td>70.46 (18.84)</td>
<td>67.00 (41–94)</td>
</tr>
<tr>
<td>Age at implant (mo)</td>
<td>13</td>
<td>22.92 (7.16)</td>
<td>21.92 (13–38)</td>
</tr>
<tr>
<td>Duration of use (mo)</td>
<td>13</td>
<td>49.38 (19.24)</td>
<td>49.00 (21–81)</td>
</tr>
<tr>
<td>CELF-P percent of age</td>
<td>12</td>
<td>50.33 (12.96)</td>
<td>46.00 (35–75)</td>
</tr>
<tr>
<td>PPVT (speech) standard score</td>
<td>13</td>
<td>59.69 (25.53)</td>
<td>62.00 (0–96)</td>
</tr>
<tr>
<td>PPVT (sign plus speech) standard score</td>
<td>13</td>
<td>71.00 (17.09)</td>
<td>74.00 (40–96)</td>
</tr>
<tr>
<td>LPP total (% achieved)</td>
<td>8</td>
<td>59.00 (19.77)</td>
<td>62.50 (35–61)</td>
</tr>
<tr>
<td>LPP—Form %</td>
<td>8</td>
<td>74.00 (23.90)</td>
<td>83.00 (44–100)</td>
</tr>
<tr>
<td>LPP—Content %</td>
<td>8</td>
<td>66.25 (19.00)</td>
<td>69.00 (38–96)</td>
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<tr>
<td>LPP—Reference %</td>
<td>8</td>
<td>64.37 (13.33)</td>
<td>66.00 (46–86)</td>
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<tr>
<td>LPP—Cohesion %</td>
<td>8</td>
<td>40.25 (24.17)</td>
<td>31.50 (18–82)</td>
</tr>
<tr>
<td>LPP—Use %</td>
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<td>51.13 (28.11)</td>
<td>54.50 (15–89)</td>
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<tr>
<td>Perception—Phonemes %</td>
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<td>69.38 (20.21)</td>
<td>75.00 (54.00)</td>
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<td>Perception—Words %</td>
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<td>42.88 (26.33)</td>
<td>49.00 (67.00)</td>
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<tr>
<td>Perception—Sentence %</td>
<td>9</td>
<td>46.00 (34.27)</td>
<td>54.50 (83.00)</td>
</tr>
</tbody>
</table>

*This mean includes two children with some auditory experience prior to obtaining the cochlear implant. Excluding these two children, mean 20.73 (SD 5.02), median 21.00, range 13–27 months.

*Excluding two children with some auditory experience prior to obtaining cochlear implant, mean 45.90 (SD 8.54), median 42.50, range 35%–61%.

*Excluding two children with some auditory experience prior to obtaining cochlear implants, mean 53.63 (SD 22.77), median 57.00, range 0–83.

*Excluding two children with some auditory experience prior to obtaining cochlear implant, mean 67.00 (SD 15.3), median 74.00, range 40–85.

Table 1 Central tendency and variability for language, cognition, and related measures

Children generally showed strengths on the CELF in the areas of use and understanding of word order in sentences and basic concept vocabulary. Consistent weaknesses were found in understanding and production of grammatical morphemes, especially pronouns, possessive markers, and verb tense. No significant difference was found between children’s performance on the receptive subscales and on the expressive subscales of this test using either the guidelines in the test manual or a t test for repeated measures.

Figure 2 illustrates the distribution of scale scores for the PPVT when it was administered in the language system used in each child’s classroom. That is, these scores represent performance on the sign-plus-speech administration for children in programs using signs.
and the speech-only administration for children in oral programs. (Individual scores are displayed in Figure 2 in the same order as shown in Figure 1. The child farthest to the left had the lowest CELF performance; the child farthest to the right had the highest CELF performance.) As Figure 2 illustrates, two of the children attained scale scores at or above 90 on the PPVT, that is, within the average range for age compared with the hearing normative group. Both of these children were in oral programs: one was the child who was deafened by meningitis and the other was the child who had a less-than-profound congenital loss. The third highest scorer was the congenitally deaf child who had been in a classroom using signs plus speech until the current year in school, when the child moved to an oral classroom. The lowest-scoring child was also in an oral program; most children in the middle of the distribution were in programs using signs. Overall, there was much variability among the children, and the mean score of 71 for the group was below the expected range for age for hearing children.

The average scale score for the speech-only administration of the PPVT was lower, falling to 59.7, because scores fell for all of the children in total communication programs. The gap between the children’s speech-only and speech-plus-sign performance varied, however, with the score of one child (Child 6) decreasing only slightly when signs were withdrawn; another child (Child 5) could not respond to any items when only spoken language was provided.

Percentage scores for the total LPP and for each subscale can be found in Table 2. Scores were available for eight of the children. For seven children, the scores are based on teachers’ reports. The eighth child (the child who had meningitis at age 2 years) was in a completely mainstreamed situation, and it was decided that parent report would provide a more accurate measure. Calderon, Bebko, and Bargones (1999) found parent reports on the LPP were generally more favorable than those from teachers; therefore, this child’s scores may be inflated related to those of the other children. Overall scores on this instrument, on
which hearing children typically reach a ceiling after age 4 years, ranged from 37 to 101, which is from 33% to 90% of the total score possible. Friedman’s test revealed significant differences among the subscales on the LPP $\chi^2 = 18.84$ ($df = 4$), $p = .001$, and follow-up with paired Mann–Whitney U tests showed that the percentage scores on the Cohesion subscale of the LPP were significantly below those of the subscales assessing form, content, and reference. The Cohesion subscale asks questions about the degree to which a child maintains the flow and topic of a conversation. Doing so requires both mastery of basic syntax and the cognitive ability to understand the perspective of a conversational partner; thus, both linguistic and cognitive skills are involved in this skill, which is generally representative of the pragmatic aspect of language. Although the Cohesion scale received the lowest percentage scores for all the subscales for each of the children, the score for the subscale representing “use” was also low for most of the children. Items assessing language use require a high level of integration across linguistic and social skills.

Nonverbal IQ scores ranged from 70 to 115 (mean 91.6, median 91.0, SD 15.9). Four of the children (two with total IQ scores in the 70s and two with overall IQ scores of 91 and 103) showed a pattern of relatively high performance on the “visual” parts of the test, but low scores on the “reasoning” parts of the test. These reasoning subscales share an emphasis on sequencing and identifying patterns. Performance differences shown in this pattern of scores are similar to those identified for some hearing children with learning disabilities and may indicate the presence of such disabilities in children who are deaf. The results of earlier studies (e.g., Pisoni et al., 1999; P. Spencer & Delk, 1989) have also indicated that deaf children find sequencing activities are especially challenging. It is not clear whether this association results from or is a cause of some of the difficulties so often seen for syntactic skills in this population.

Open Set Auditory Perception Scores

The average percentages correct were 69% for open set perception of phonemes (range 35% to 89%) and 43% for perception of words (range 4% to 71%). Only six of the children could participate in and obtain a score on the assessment of open set sentence perception, and their scores ranged from 26% to 83% correct. Phoneme and word perception scores were available for nine of the children. These scores correlated so strongly ($r_s = .984, p < .001$) that only one of these measures (perception of words) was selected for use in subsequent analyses. Perception of sentences correlated with perception of phonemes ($r_s = .643, p < .05$) and with words ($r_s = .620, p < .05$). Because data on sentence perception were available for only six children, this measure was not used in subsequent analyses.

Relations among Child Quantitative Measures

Correlations among scores on the language, cognitive, and speech perception measures are shown in Table 3. The CELF percent-of-age score showed significant and moderately to strongly positive correlations with open set perception for words, with the vocabulary score (whether administered with signs or without signs for children in signing programs) ($r = .72, p = .004$; $r = .65, p = .008$, respectively) and with nonverbal IQ score ($r = .65, p = .012$). This pattern of correlations

Figure 2 Standard scores on PPVT (Vocabulary) from administration using language modalities used in child’s school program. Children’s scores are displayed in same order as in Figure 1, based on lowest to highest scores on CELF.
was the same whether parametric or nonparametric correlation coefficients were computed.

Except for the correlation with CELF scores, PPVT Vocabulary scale scores on the test administered in the school language system (that is, with signs added for children in signing programs) failed to correlate significantly with any of the other measures. However, scores obtained in the speech-only administration of the PPVT correlated moderately, although not significantly, with scores for open set perception of phonemes and words.

Children’s total ratings on the LPP correlated significantly with nonverbal IQ scores ($r_s = .74$, $p = .02$), but only moderately with vocabulary ($r_s = .57$, $p = .07$) and CELF scores ($r_s = .49$, $p = .11$). Accomplishing items on the LPP does not require use of any specific modality or language system, and the emphasis in several scales is on pragmatics and the ability to sustain conversational turn taking. Cognitive abilities may provide important support for such skills, especially in the context of delayed language.

Open set speech perception, in this case measured as the ability to repeat CNC or BKB words, correlated significantly with CELF percent-of-age scores ($r_s = .766$, $p < .05$) and marginally with both the PPVT speech-only administration scores ($r_s = .571$, $p = .10$) and the total LPP score ($r_s = .643$, $p = .06$). Speech perception also correlated significantly with nonverbal cognition ($r_s = .611$, $p < .05$). These associations should be interpreted with two cautions. First, as is always the case for correlational analyses, no causal relationship should be assumed. Second, as Blamey and colleagues (Blamey, 2003; Blamey, Sarant, et al., 2001) have indicated, task requirements for at least one of the CELF subscales are highly similar to those in open set speech perception; therefore, the association may result because the two procedures actually test the same ability. On the other hand, the association between speech perception and CELF scores may indicate direct benefits from auditory experience on the kind of syntactic abilities tested on that instrument. The association between speech perception and nonverbal cognitive skills also lends itself to more than one explanation. Although it may simply be an artifact of this particular sample of children, it is also possible that strengths in cognitive skills assist children in making sense of the imperfect auditory information obtained through use of a cochlear implant. Finally, the specific kinds of sequencing and patterning skills tested in the Leiter Brief IQ scale, even though in visual modality, may be analogous to skills inherent in auditory processing, and the correlation may reflect this underlying similarity in process.

Associations of Language Measures with Duration of Use and Age at Implantation

Duration of use of the cochlear implant did not correlate significantly with the language performance measures for either the whole group or the subgroup of 11 who were congenitally profoundly deaf. In addition, initial analyses including all 13 children showed no significant relation between age at implantation and language scores. Correlations between these sets of measures were computed again, however, omitting the 2 children with significant auditory experience before implantation. (The age at implantation for these 2 children was older than that for the congenitally profoundly deaf children precisely because of their auditory experience.) As Table 4 shows, CELF scores
for the subgroup of 11 congenitally deaf children correlated negatively and significantly with age at implantation. Thus, children who received the implant earlier performed better on the measure that emphasized syntax, even though they had all received cochlear implants by 27 months of age. No significant associations were found between age at implantation and the vocabulary measure or the LPP.

Because both nonverbal IQ and age at implantation correlated significantly with performance on the syntax-focused measure for the congenitally profoundly deaf children, a partial correlation was computed between age at implantation and the CELF percent-of-age scores with IQ controlled. The result was a significant and moderately strong negative age–CELF relation (r = −.68, p = .023). Therefore, age at implantation contributed significant unique variance to the prediction of CELF scores over and above the contribution of nonverbal cognitive scores. In contrast, the correlation was not significant when the computation was changed, so that the relation between the CELF and the IQ measure was investigated with age at implantation controlled.

Despite the significant association between age at implantation and CELF scores for the 11 children who were congenitally profoundly deaf, it should be recalled that the 2 children who scored highest on the language test were those with previous auditory experience. These children provide examples of the importance of a history of auditory experience, even if only through amplification, for the ability to benefit from increased access to auditory information provided by a cochlear implant.

Children with Multiple Disabilities

The children with multiple disabilities presented such varied profiles that they are discussed individually. Of the four children initially identified with multiple disabilities, one had a significant neurological anomaly, below-average cognitive skills, and behavioral difficulties. This child (who was in a total communication program that used speech plus signs) scored in the lower half of the group on both vocabulary and syntax tests and was the child who could not respond to any items on the vocabulary test in the speech-only administration. In contrast, another child with diagnosed neurological dysfunction and below-average scores on the cognitive test appeared to use the cochlear implant to support acquisition of spoken language skills in conjunction with primary use of signed language. This child’s linguistic skills, in fact, were consistent with the nonverbal cognitive quotient.

A third child, in a total communication program, gave evidence of a short attention span and behavior problems and had a below-average cognitive score. This child’s scores were low on all language tests, regardless of the language modalities used, despite

| Table 3 | Bivariate correlations between measures of language, cognition, and speech perception |
|----------------|-------------------------------------|---------------------------------|----------------|----------------|-----------------|
| Total*         | CELF-P (Word)*                      | PPVT (speech only)              | PPVT (sign + speech) | Nonverbal IQ  | LPP             | Perception |
| CEF-P          | —                                  | .700** (n = 12)                 | .717** (n = 12)     | .646** (n = 12)| .491 (n = 8)    | .766*      |
| PPVT (speech)  | —                                  | —                               | .748** (n = 13)     | .246 (n = 13)  | .180 (n = 9)    | .571+      |
| PPVT (sign + speech) | —                                  | —                               | —                | .406+ (n = 13) | .572+ (n = 9)   | .467       |
| Nonverbal IQ   | —                                  | —                               | —                | —              | .735* (n = 8)   | .611*      |
| LPP total      | —                                  | —                               | —                | —              | —               | .643+      |
| Perception (Word) | —                                  | —                               | —                | —              | —               | —          |

*Nonparametric Spearman rank correlations r, used for measures with n < 10. Pearson r used for other measures.

†p ≤ .10

**p ≤ .05

***p ≤ .01
having received a cochlear implant before the age of 2.5 years. Deaf children with this constellation of disabilities have traditionally faced special challenges acquiring language and other skills. Neither use of a cochlear implant nor access to signed language seemed to be sufficient in this case to alleviate the learning difficulties.

A fourth child, who had a cochlear implant before 2 years of age and had always been in oral programming, was reported to have slow motor skill development and at the time data collection occurred was being evaluated for placement in a school for children with multiple disabilities. This was the child who was unable to reach a basal-level score on the CELF. In fact, the child barely established a basal score on the PPVT, and virtually no expressive language skills (in any mode) were observed during testing or the home visit.

In addition to the four children initially known to have multiple disabilities, a fifth was indicated as a result of this testing. The fifth child, whose averaged score on the nonverbal cognitive test was below 80, had in fact scored slightly above average on the visual (Figure Ground, Figure Completion) subscales of the test, but significantly below average on the subscales requiring sequencing and identification of patterns (reasoning tasks). In addition to this split in cognitive abilities, the child gave evidence of significant attention problems, an observation that was supported by reports from parents and teachers. The child had only recently moved from an oral to a total communication program, and language test scores (vocabulary as well as syntax) were low whether or not signs were used. Although it is not surprising to find low language skills associated with this child’s profile of cognitive and behavioral characteristics, it is not clear whether there is any causal relation between the language and nonlanguage abilities.

### Qualitative Analysis of Parent Interviews: Indications and Implications of Parental Involvement

Indications of parents’ involvement with their deaf child were identified in responses across the array of questions. One of the first things noted was that parents differed in their descriptions of the resources and processes they used in deciding to obtain a cochlear implant for their child. These differences can be interpreted as indicating the degree to which the parents became personally involved in and took personal responsibility for making that decision.

Some parents reported little research, and no angst, in making the decision. For example, one mother reported that, after her child’s hearing loss was identified, the audiologist referred her to the cochlear implant center and, on finding out that the child was a viable candidate, she ‘‘signed . . . up without a second thought.’’ Another reported that she immediately thought ‘‘Well, why not?’’ and, as soon as payment for the procedure was assured, did what the doctors ‘‘told me to do.’’ This last explanation was curious in that most of the parents reported, some of them with much frustration, that the physicians and staff at the implant center steadfastly refused to make their decision for them. In the words of one parent, ‘‘They leave you all alone to make your own decision, you know.’’

About half of the parents reported a much more complicated process of deciding about cochlear implantation. One mother reported: ‘‘I read and read and read. Everything I could find.’’ Another mother described the process as ‘‘a very big learning curve.’’ She spoke of using a basically ‘‘social’’ process to make the decision; that is, she met and talked with other parents and with service providers to collect information about the pros and cons. Her husband, in contrast, relied more on scientific reports and the Internet to collect data, which he evaluated and tried
to relate to their child and their family’s situation. Fortunately, they came to the same conclusion through their different routes. Another mother indicated that she and her husband had “researched it for more than a year” and had decided to get a cochlear implant for their child only after newer, more promising technology had been developed.

The mother of a 5-year-old said that the early intervention program had provided her with reading materials, contacts with other parents, and videotapes: “They showed both sides—for and against.” This mother reported that she had shared these materials with other family members, who also read, watched, and shared their opinions. She said, “It was a hard decision, you know. Looking back, it was so hard.” Her decision making extended over almost a calendar year. A few parents reported that they had initially been disinclined toward the cochlear implant, but that as their children matured and began to show delayed acquisition of spoken language, they changed their minds.

It was striking that parents of the children who were performing at the highest levels on the most difficult language measure, the CELF, consistently reported having taken much time debating (sometimes with others, sometimes just with themselves) whether getting the cochlear implant was the best decision. They showed creativity and persistence in seeking out sometimes conflicting information and applying it to their own situation as they went through the decision-making process. It is important to note that this group of parents did not share similar educational levels or backgrounds. And, their choice of information sources varied considerably. At first, the association between this more extended and extensive decision-making style and the children’s language performance was perplexing. However, a hypothesis emerged that this style was, in fact, only one example of parents’ general tendency to be actively involved in their children’s educational and developmental issues. To follow up, the transcripts were then checked for other indications of involvement, specifically those related to activities that can be expected to relate to educational programming and achievement.

None of the questions used in the interview specifically asked parents to describe special things they did to support their children’s development. However, the transcripts of the interviews are full of spontaneously given examples of such efforts. The mother of a child with one of the highest language levels reported that she had learned sign language to use with her child by intently studying a sign language dictionary and taking every opportunity to sign to her child. Two other mothers described careful decisions about and advocating for a specific language mode to be used with their child. One persisted in demanding that signs be used and even taught her child signs to demonstrate to school personnel how effectively the child could learn them. Another just as strongly advocated for an oral program for her child, despite having been told that her child “is so deaf that [the child] will never be able to learn to speak.” This mother, reporting that she based her opinion on having noted the child’s attention to faces and early attempts to speak while using traditional amplification, insisted that the child was able to learn effectively using an oral approach—and that turned out to be the case. It was evident that both of these mothers went to great lengths to make a case for their chosen language modality and then worked consistently to provide language experience in that mode.

Another set of parents described the amount of time and effort that they took to get their child to the cochlear implant clinic for follow-up sessions. Because they lived a long distance from the city, this required a 2-day trip and many arrangements to handle care for the other children in the family. These parents showed strong awareness of their child’s difficulty interacting in group situations in school and other places, and they went into detail explaining the steps they were taking to ensure the child had easier access to communication in these settings. This mother expressed concern that “I think I should do more” to support her child’s language development. However, she went on to note that they “read together—three or four stories a day.” Another mother reported driving up to 4 hours a day to get her child to what she considered to be the best educational program. Another family took a strong advocacy role to convince school administrators to provide transportation to school for other children as well as their own.

None of the children whose parents were inter-
viewed were neglected, and love between parent and child was clearly evident in all cases. However, parents who reported being highly involved in learning activities at home and in advocacy roles with educational programs had also reported extended and intense involvement in making the decision about getting the cochlear implant. Data from these interviews, therefore, suggest that an extended decision-making process related to obtaining a cochlear implant and active searches for information predict parents’ degree of involvement with children’s development using a cochlear implant. As expected, the level of parent involvement was associated with children’s rate of progress.

Discussion

Although children in this study received a cochlear implant by 38 months of age, language outcomes showed much variability. Several factors were associated with language scores, especially those obtained on the measure that emphasized syntax skills. Development of relatively higher level English syntax was associated with better speech perception skills and with auditory experience prior to receiving the implant. For those children whose hearing loss was profound and congenital, younger age at implantation also was associated with better performance on the syntax measure. Nonverbal cognitive skill related positively with the syntax measure and the measure that emphasized pragmatics. The presence of multiple disabilities was associated with slower progress using a cochlear implant. Parent involvement was positively associated with children’s language skills, and indicators of parents’ process for deciding to get a cochlear implant gave indications of their postimplant level of involvement with the child’s development.

Auditory experience before using a cochlear implant, even the imperfect experience provided by amplification, appeared to provide very significant benefits. The two children who had the most such experience, one who had normal hearing before becoming deaf at age 2 years and one with less-than-profound hearing loss, were high performers on all three language measures as well as the speech perception measures. In addition, parents of another two children with high language levels as measured by the CELF attested to production of spoken language prior to getting the cochlear implant. One mother, for example, reported that her child had spoken single words while signing short sentences when using conventional amplification before getting the cochlear implant.

The fact that children who appeared to process auditory information before receiving the cochlear implant performed at high levels compared to the rest of the group when using the implant is consistent with findings from other studies (e.g., Eisenberg, Martinez, Sennaroghi, & Osberger, 2000). Apparent benefits from preimplant auditory experience support a policy of early and careful amplification of hearing for children who expect to use cochlear implants later. The apparent impact of early hearing experience also has implications for research on outcomes of cochlear implantation. Inclusion in analyses of children who were not born profoundly deaf—even though they lost hearing during what is typically considered to be the “prelinguistic” period—can complicate interpretation of influences on outcomes.

For the children who were born with profound hearing loss, younger age at implantation was associated with attaining higher levels of language development as measured by the CELF, the instrument that had the strongest focus on English syntax, after implantation. This association is particularly striking because of the relatively restricted range of age at implantation, from 13 to 27 months. Furthermore, the pattern of scores suggests a gradual decrease in rate of language progress with later ages of implantation. No such effect of age at implantation was found on the receptive vocabulary measure, whether the PPVT was administered in speech-only form or speech plus signs for those children whose classroom used signed communication. A specific association between audition and syntax development appears also to be supported by the significant correlation between scores on the CELF and measures of auditory perception. In contrast, PPVT scores, which were associated only moderately with CELF scores, were not correlated significantly with any of the auditory perception measures. The difference in patterns of association of
the CELF and PPVT with other factors may indicate that that auditory experience is especially important for the acquisition of syntax of a language such as English that has developed through auditory–oral communication. Thus, use of a cochlear implant may specifically support this aspect of language.

Scores on the syntax-oriented CELF were also significantly associated with nonverbal cognitive quotients. In addition, children who showed a particular profile of skills on the cognitive measures, with a gap between abilities in more purely visual tasks (Figure Ground and Form Completion) and those referred to as visual reasoning tasks (Repeated Patterns and Sequential Order), scored lower on the syntax measure than those without such a gap. It is possible that the sequential nature of both of the reasoning nonverbal tasks is analogous to the strongly sequential nature of spoken English syntax, and that a deeper ability to utilize sequential information is being assessed in both the linguistic and nonlinguistic tasks. Given that the analyses in this study utilized correlations, it is not possible to conclude that one task is a foundation or precursor for the other. The current findings are supportive, however, of those by other researchers (Geers, Brenner, et al., 2003; Pisoni et al., 1999), who have reported a strong association between selected cognitive skills and spoken language skills of children using cochlear implants. Although vocabulary scores also were positively associated with the nonverbal cognitive scores obtained in the current study, this association was not statistically significant. This is further suggestion that, despite the shared variance between the syntax-focused measure and the vocabulary measure, processes that underlie these two aspects of language may be differentially sensitive to early auditory experience.

Not surprisingly, children with multiple disabilities tended to perform less well on the language tasks than children without such complications. However, it is notable that one child who had moderately lower cognitive skills as well as some associated disabilities scored on the vocabulary measure at a level consistent with the nonverbal cognitive quotient. This child, who was using some spoken language as well as signed language, appears to have benefited from a cochlear implant, at least in achieving access to basic spoken communication. This child’s syntax development, however, was much slower than vocabulary development, and the gap between the two types of language skills was larger than for other participating children.

It is equally important that at least two of the children with multiple disabilities gave little evidence of having developed any significant level of auditory–oral skills. One of these children remained in oral programming for a number of years and had extreme difficulties in any communicative setting. It is important to acknowledge that special challenges faced by deaf children with multiple disabilities can negatively impact use of cochlear implants. These children often require specialized programming based on frequent assessment of progress and integration of knowledge. They benefit, as well, from educational approaches developed by educators who specialize in supporting learning of children with cognitive, attention, or behavioral disabilities. Although a cochlear implant may provide benefits to such children, their other educational and developmental needs cannot be forgotten. The relatively poor performance of the two such children in this study suggests that access to a visual language system may be a critical “safety net” for children who show early signs of slowed or atypical general development.

Confounding factors in this small group of participants precluded any valid comparison of outcomes based on language modalities. However, in this group of participants, both the highest- and the lowest-performing children as measured by the CELF were in oral programs. A similar trend was evident in PPVT scores. Children in programs that used signs plus spoken language tended to score in the midrange on these measures. They all performed at a somewhat higher level on the vocabulary measure when signs were used. This indicates that they were gaining information from the visual representation.

The fact that some children were moved to and from classrooms using one approach or the other in an apparently well-thought-out manner suggests that, in many cases, families and educators were making decisions about programming based on performance as well as expectations for the children. One example is the child who was the highest scorer on the CELF of the congenitally profoundly deaf participants. This
child’s language experience, at home and at school, began as “total” (signed plus spoken) communication. The child received a cochlear implant at the early age of 13 months. By age 5 years, the child had made sufficient progress in spoken as well as signed language to be moved to an oral-only classroom. The child was also beginning to acquire a second spoken language that was used in the home. An individualized and flexible approach, based on careful assessments of progress, was successfully supporting the child’s language development in spoken as well as signed modalities.

Qualitative analyses revealed an apparent association among child progress, parent involvement, and parents’ process for making a decision about getting a cochlear implant for their children. The fact that a more intensive, information-seeking approach to decision making associated with later parent involvement with the child’s learning may provide an indicator of that later characteristic. Because the characteristic of “involvement” appeared to be consistent over time, interventionists should be alert for signs of parents’ involvement before cochlear implantation, and additional supports should be provided for those who do not demonstrate high levels of this characteristic.

Cochlear implants were supporting spoken language development of most of the children who participated in this study considerably beyond that which might typically be expected, especially for the children born profoundly deaf. Moreover, the data presented in this article fail to capture the most striking aspect of the outcome of these children’s early use of a cochlear implant: Many had the ability to converse with a stranger using spoken language—a feat rarely accomplished by deaf children at these relatively young ages, if at all. When only the congenitally profoundly deaf children are considered, the data reported here provide support for the idea that earlier ages of implantation provide more benefits, even among children who received cochlear implants during the first 2 or 3 years of life.

However, early experience with cochlear implants had not yet resulted in language skills that were solidly within the range expected for hearing children. Only two children had scores in the “average” range for age for receptive vocabulary skills, and both of these children had a significant amount of auditory experience prior to using the cochlear implant. On the syntax-focused measure, not even the highest scores reached the average range for hearing children of the same age. Results of teacher reports on the LPP also indicated that, unlike typical hearing children of the same age, most of the children had not yet accomplished the ability to sustain communicative topics in conversation as measured by the Cohesion subscale. Higher level integrative skills such as maintaining cohesion across conversational utterances may be slow to develop when effort is still required to manage other aspects of communicating. Development of pragmatic abilities such as cohesion by children using cochlear implants is worthy of further investigation to determine whether additional programming support is needed.

This study included a small group of participants, and results cannot be generalized to the entire population of children who receive cochlear implants during their first years of life. Continuing delays in language skills for most of the children in this study, as well as great variability in outcome, however, mitigate strongly against complacency and overreliance on use of cochlear implants to remediate the difficulties in language development that continue to face many children who are deaf. The performance of most of these children indicates a need for continued research and development of specialized intervention methods to support development of language skills of children who are deaf, even when cochlear implants are provided during the children’s early years.

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Received January 26, 2004; revisions received March 9, 2004; accepted March 11, 2004.