Speech perception results in children with cochlear implants: Contributing factors

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Speech perception test results were obtained from a group of 40 pediatric cochlear implant users. Half of the children participated in oral-only habilitation programs, which included both traditional oral and auditory-verbal approaches, and half participated in programs that used a combination of oral and manual communication referred to as total communication (TC). Analysis of the scores showed that children enrolled in oral-only habilitation programs scored significantly higher on the speech perception measures than did children who were enrolled in total communication–based programs. These results were inconsistent with those of other reports, which suggested that communication methods had little effect on implant outcomes. To further examine the reasons for the differences in performance, we analyzed 7 additional factors, including length of implant use, age at surgery, device type, socioeconomic status, bilingualism, school setting, and participation in private therapy, which may affect implant performance. Multiple-regression analysis again showed communication mode to be the factor most highly correlated with speech perception abilities among this group of children. (Otolaryngol Head Neck Surg 1999;121:31-4.)

In an earlier work we described speech perception results obtained from 40 children treated at the University of Miami Ear Institute.[1] These 40 children had received cochlear implants during a period of 5 years. As the data were analyzed, it became evident that there were significant differences in performance among the children with implants. In the initial report on this group, results were analyzed on the basis of the type of communication method used with the children. That analysis revealed that children in oral programs (including both auditory-verbal and traditional oral approaches) performed significantly better on a battery of speech perception tests than did those children using total communication (TC). Caution was suggested in interpreting these results because many other factors could potentially contribute to individual performance. In this follow-up report, we have analyzed several additional characteristics to determine which appear to more strongly influence a child's performance with a cochlear implant. In addition to communication method, we have evaluated the contributions of age at implantation, length of implant use, socioeconomic status (SES), type of educational setting, bilingualism, type of device, and provision of outside therapy services.

METHODS

Subjects

Fifty-eight children between the ages of 2 and 17 years received cochlear implants at the University of Miami Ear Institute between 1990 and 1995. The children participating in the study included those from either English-speaking or bilingual homes who receive follow-up services at the Ear Institute. Nine children had moved and were being seen at other implant centers. Another 8 were from South America, and 1 child had become a nonuser. Sixteen subjects were male, and 24 were female. At the time of implantation the children ranged in age from 2 to 14 years (mean 6 years). Cochlear implant use ranged from 3 months to 5 years (mean 2.1 years). Twenty-seven children used Nucleus Spectra, 7 used Nucleus MSP, and 6 used the Clarion 1.2 device. Thirty-four children had congenital hearing loss, 2 were deafened prelinguistically, and 4 were deafened perilinguistically. Causes of hearing loss included cytomegalovirus, meningitis, Usher's syndrome, genetic causes, Mondini malformation, and unknown causes.

Commonly used guidelines for implantation of children include no open-set word-recognition abilities. Three children in this study did obtain scores on the Phonetically Balanced Kindergarten (PBK) word-recognition test. Two children in the oral group obtained scores of 2% each, and 1 perilinguistically deafened child in the TC group obtained a score of 8%. Mean preoperative pure-tone averages were 104.6 dB HL (±8.1 dB) for the oral group and 108.5 dB HL (±8.5 dB) for

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Presented at the Annual Meeting of the American Academy of Otolaryngology–Head and Neck Surgery, San Francisco, CA, September 7-10, 1997.

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0194-5998/99/$8.00 + 0 **23/1/92774**

Otolaryngology–
Head and Neck Surgery
July 1999

the TC group. These differences were not statistically significant ($P = 0.089$).

This subject population drew from the heavily Hispanic population of South Florida. As a result, bilingualism was not uncommon among the families of these children. Although both public and private educational settings suggest that parents speak only English with their hearing-impaired children, it is likely that a second language is often spoken in the home. Eleven children come from homes in which at least 1 parent's first language is not English.

Procedures

Data were collected from 3 different sources. First, all children were administered a battery of speech perception tests. These tests included the Early Speech Perception Test (ESP),[2] Northwestern University Children's Perception of Speech Test (NU-CHIPS),[3] Minimal Pairs,[4] and PBK word lists.[5] In addition, a chart review was conducted to obtain information on the child's educational and communication background. Finally, all parents completed a questionnaire of historic and demographic information.

All speech perception testing was done in the auditory-only condition. All implant devices were checked for proper function before testing, and all testing was done with a program that the child had been using for at least 1 month. All tests were administered live voice with the tester seated across a table from the child. A black mesh screen was placed in front of the tester's face to eliminate visual cues. Tests were administered and scored in accordance with instrument instructions.

Questionnaires were initially mailed to all parents. Those who did not return it were called, and the information was taken over the telephone by an audiologist on the implant team. Information obtained from the questionnaires was used to rank each child on SES based on the Hollingshead Four Factor Index of Social Status developed in the Department of Sociology at Yale University.[6] The 4 factors used in ranking social status by the Hollingshead are educational level, occupation, marital status, and sex of the head of the household.

A review of records was undertaken by members of the implant team to document other historic and demographic information. Data sheets were completed on each child containing information on communication strategy, type of schooling, age at surgery, device used, cause of hearing loss, and whether the child attends outside therapy.

Finally, 8 factors, which were judged by the implant team to potentially affect implant outcomes, were selected for analysis. These factors included length of implant use, age at surgery, type of device, family SES rank, bilingualism in the home, type of school setting, participation of the child in private therapy, and communication mode. A multiple-regression analysis was run to assess the contribution of each of these factors in the child's abilities on speech perception measures.

RESULTS

Speech Perception Tests

Scores on the ESP Pattern Perception ranged from 0% to 100% (mean 74.1%). Scores on the Spondee Identification subtest also ranged from 0% to 100% (mean 61.3%). The final subtest, Monosyllabic Word Identification, also showed a range of scores from 0% to 100% (mean 61.9%).

Scores on the Minimal Pairs test ranged from 35% to 96%. Chance score for this measure is 50%. The average score obtained by this group of children was 75%. NU-CHIPS scores ranged from 25% to 100%. The mean score was 67% compared with a chance score of 25%. The only open-set measure included was the PBK Monosyllabic Word Test. Scores ranged from 0% to 88% (mean 28.3%, median 20%).

Record Review

The chart review provided information on the children's medical histories and communication and educational backgrounds. Of the 40 children studied, 21 used TC and 19 used oral communication. Among the oral communication users 12 received services from certified auditory-verbal therapists, and 7 were in traditional oral settings. Educational settings included public school (n = 31), private school (n = 6), home schooling (n = 1), and none yet (n = 2). Sixteen children received no therapy in addition to that provided at school, whereas 24 received private therapy services outside of the educational setting. Communication development may also be influenced for 11 of the children for whom 1 or both parents were not native English speakers.

Questionnaires

For the purpose of analysis, the 5 social status groups described by the Hollingshead were assigned numeric identifiers. Category 1 was assigned to the lowest social strata described as unskilled laborers and menial service workers. Category 2 corresponds to those described as semiskilled workers. Category 3 was assigned to the group consisting of skilled craftsmen, clerical, and sales workers. Category 4 represented those that the Hollingshead describes as medium business, minor professional, and technical workers. Finally, category 5 was assigned to the highest social strata including major business executives and professionals. The children in the study group came from families that covered a wide range of SES. Table 1 shows the breakdown of study subjects on the Social Status Index. The mean of all subjects was 3.7.

In the initial report subject scores on the speech perception measures were compared on the basis of communication mode. Table 2 shows a comparison of the

Table 1. Comparison of SES among subject groups based on the Hollingshead index

Group	SES 1	SES 2	SES 3	SES 4	SES 5
Oral	n = 0	5% (n = 1)	5% (n = 1)	42% (n = 8)	42% (n = 8)
TC	n = 0	10% (n = 2)	50% (n = 10)	40% (n = 8)	—

Table 2. Mean scores on speech perception measures for subjects grouped by communication method

	Mean score (%)	
Test measure	Oral	TC
ESP Pattern*	96	37
ESP Spondee*	91	33
ESP Monosyllable*	86.5	35
NU-CHIPS†	81.5	51
Minimal Pairs‡	79	67
PBK Words*	46.5	11

All differences in scores between the oral and TC users were statistically significant.
*$P < 0.0001$.
†$P < 0.01$.
‡$P < 0.05$.

mean scores obtained by children who use only oral communication with those of children who use TC. It was found that the children in this group of subjects who use oral communication score better on speech perception measures than do those using TC.

The first step in analysis of the data was to compare PBK scores to the other speech measures to determine whether scores on the open-set measures were correlated to those on closed-set measures. Regression analysis showed a strong positive relationship between performance on PBK and the other speech measures. Those children who scored higher on PBK words also scored higher on each of the other measures. Table 3 shows the *r* value representing the correlation between each of the other tests and the PBK score. On the basis of the established relationship between the open- and closed-set measures, the PBK score was used as the independent variable in the multiple regression. Data were coded numerically for use in the analysis. Table 4 presents the results of the analysis, which shows the relationship among the 8 selected variables and the PBK word score. The results show that communication mode with an *r* value of 0.67 ($P < 0.0001$) is the most highly predictive factor of speech perception performance. School setting ($r = 0.49$, $P < 0.002$), SES rank ($r = 0.41$, $P < 0.008$), and participation in private therapy ($r = 0.41$, $P < 0.008$) also exhibited strong positive relationships with performance on speech perception measures.

Table 3. *r* Values for all closed-set measures compared with the PBK open-set format

Measure	*r*	*P*
NU-CHIPS	0.8	<0.0001
Minimal Pairs	0.6	<0.0001
ESP Pattern	0.7	<0.0001
ESP Spondee	0.6	<0.0001
ESP Monosyllable	0.7	<0.0001

Analysis shows that scores on all closed-set measures have strong positive relationships to the open-set test.

Table 4. Summary of the regression analyses assessing the relationship among 8 selected variables and the PBK open-set word score

Measure	*r*	*P*
Length of implant use	0.03	0.05
Age at surgery	0.04	0.81
Device	0.12	0.45
SES rank	0.41	0.008
Bilingualism	0.25	0.11
Communication mode	0.67	<0.0001
School setting	0.49	0.0018
Private therapy	0.41	0.008

DISCUSSION

The 40 children included in this study represented a broad spectrum of characteristics. The children had been using their implants for periods of 3 months to 5 years. They were implanted at ages ranging from 2 to 14 years. They used 3 different implant systems and represented all except the lowest social strata. They overwhelmingly attended public school, although a significant number attended private school and some were home schooled. Some children received private therapy services; others received therapy only at school. Because of the unique makeup of the South Florida population, a quarter of the children came from bilingual homes. Finally, this group of subjects included children who used TC, some who used a traditional oral communication approach, and some who used an auditorially based oral approach (auditory-verbal). All of these characteristics combined to affect each child's performance with his or her cochlear implant.

The data collected in this study show that among this particular group of children, those who used some form of oral communication scored significantly higher on a battery of both closed- and open-set speech perception tests. Because of the diversity represented in the group, it was suspected that other factors may contribute to these results, and the analysis performed confirmed that several variables were found to be significantly correlated to speech perception scores. The strongest relationship did prove to be communication mode, with an r value of 0.67 ($P < 0.0001$). In addition, school placement, SES, and provision of private therapy are factors found to contribute significantly to speech perception abilities. These factors show that children in higher socioeconomic groups, those who attend private schools, and those who receive private therapy also score higher on speech perception measures. Not surprisingly children from higher SESs also are more likely to attend private schools, receive private therapy services, and use oral communication modes. On the basis of these findings, the variables that had the least influence on test results were age at surgery, device type, and bilingualism in the home.

At first glance these data seem to suggest that to have higher scores on speech perception measures, children must come from higher SES groups and attend private schools. It is more likely that those from middle and lower SES groups are dependent on the public schools for all educational services, and most public school programs represented by this group used a TC approach. Only 2 children among this group attended oral programs in public schools. Both of these children scored above the TC group mean on all speech measures. On the other hand, the 1 oral child who fell into SES category 2 scored not only above the mean of the TC group but also well above the mean of the oral group. Comparison of the scores of all children who fell into SES group 4, the largest group for both TC and oral communication users, shows that the mean score obtained by the oral children (38.4%) was significantly higher than the mean score obtained by the TC users (9.1%). These findings are consistent with those of an earlier report by Hodges et al[7] in which the performances of implanted children from differing SES groups, but who attended the same educational setting, were compared. These results showed no differences in speech perception abilities based on SES alone.

Miyamoto et al[8] described the speech perception results of 19 prelinguistically deafened children and found that communication mode did not play a significant role in speech perception abilities among this group. In 1994 Magmata et al[9] reported results from a study similar to the University of Miami work. They reported that length of implant use accounted for the greatest variance in performance among a group of 61 children with implants, a factor that was found to have little effect in the current work. It is interesting to note that in a group of 227 profoundly deaf hearing aid users, Geers and Moog[10] found that those in oral settings demonstrated better speech and auditory skills than those in TC settings. Obviously the variation in speech perception performance among implanted children cannot be explained by 1 or even several factors. Other more difficult to quantify factors such as family motivation, the child's own communication characteristics, different teacher and therapist effects, and learning styles probably contribute significantly as well.

This article discusses only scores on measures of speech perception and includes no evaluation of language abilities. It is possible that oral children are simply more likely to reproduce what they hear even if they do not have the language to support their speech production. The next step in this study will be to collect data on the language abilities among this group to assess the potential relationship of these factors on language development among children who use cochlear implants.

REFERENCES

1. Dolan-Ash MM, Hodges AV, Balkany TJ, et al. Speech perception abilities in pediatric cochlear implant recipients receiving TC, oral and auditory-verbal communication. Presented at the VIth International Conference on Cochlear Implants. New York (NY), May 1997.
2. Moog JS, Geers AE. Early Speech Perception Battery. St. Louis, Central Institute for the Deaf, 1990.
3. Elliott LL, Katz DR. Northwestern University Children's Perception of Speech (NU-Chips), St. Louis: Auditec, 1980.
4. Robbins AM, Renshaw J Magmata RT, et al. Minimal pairs test. Indianapolis (IN): Indiana Univ School of Medicine; 1988.
5. Haskins HA. A phonetically balanced test of speech discrimination for children [master's thesis]. Chicago: Northwestern Univ; 1949.
6. Hollingshead AB. Four factor index of social status [thesis]. New Haven (CT): Department of Sociology, Yale Univ; 1975.
7. Hodges AV, Eilers R, Coco-Lewis A, et al. The effects of socioeconomic status on pediatric cochlear implant users. Presented at the International Cochlear Implant Symposium, Melbourne, Australia, October 1994.
8. Magmata RT, Osberger MJ, Robbins AM, et al. Prelingually deafened children's performance with the Nucleus multichannel cochlear implant. Am J Otol 1993;14:437-45.
9. Magmata RT, Osberger MJ, Todd SL, et al. Variables affecting implant performance in children. Laryngoscope 1994;104:1120-4.
10. Geers AE, Moog JS. Speech perception and production skills of students with impaired hearing from oral and total communication settings. J Speech Hear Res 1992;35:1384-93.