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Educational factors contributing to cochlear implant benefit in children

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Abstract

Background: Factors contributing to auditory, speech, language and reading outcomes in children with prelingual deafness after 4 to 6 years of multichannel cochlear implant use were examined. The effects of child, family and implant characteristics were controlled to identify the educational factors most conducive to maximum implant benefit. *Methods*: One hundred eighty-one 8- and 9-year-old children from across North America who were implanted by age 5 were administered a comprehensive battery of outcome measures of speech perception, speech production, language and reading tests. A series of multiple regression analyses determined the amount of variance in each outcome accounted for first by child and family characteristics, then by implant characteristics and finally by educational variables, such as communication mode, amount of therapy and classroom placement. *Results*: Characteristics of the child (primarily nonverbal IQ) and the family accounted for approximately 20% of the variance in post-implant outcome. An additional 24% was accounted for by implant characteristics and 12% by educational variables, particularly oral communication mode. *Conclusions*: Providing the child with the most up-to-date processing strategy with a well-fitted map, and an emphasis on speech and auditory skill development in their educational program can make a significant difference in the overall benefit children obtain from cochlear implantation.
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1. Introduction

The advent of cochlear implants has had a dramatic effect on the achievements of young profoundly deaf children. Children who receive an implant early in life, followed by a period of appropriate rehabilitation, can achieve speech and language skills that exceed levels observed in profoundly deaf children with hearing aids. However, there continues to be considerable variability in the performance outcomes of individual children. The impact of educational choices on performance post-implant has yet to be conclusively determined.

In 1996, the Center for Applied Research in Childhood Deafness at Central Institute for the Deaf began a study, funded by the National Institutes of Health, entitled: "Cochlear Implants and Education of the Deaf Child" [1]. This study documents the effects of various educational and rehabilitation models on the deaf child's ability to understand, produce and read English while using a Nucleus 22-channel cochlear implant. This study was designed to reduce subject variability as much as possible through sample selection criteria and to include a sufficiently large number of children to control for extraneous variables that might impact the results. The goal is to provide information that allows parents and educators to make informed educational choices designed to maximize a child's post-implant hearing, speech and language development.

2. Methods

2.1. Participants

Implanted children were recruited, who were 8 or 9 years old, deaf before 3 years of age, implanted by age 5 with 4–6 years of experience with a multichannel cochlear implant. A total of 181 children who met these criteria and were also reported to exhibit normal intelligence and reside in an English-speaking home environment were recruited through cooperating implant centers across North America [2]. All children were tested under similar conditions with a consistent group of examiners on an identical battery of tests. The implanted children do not represent any single program or method, but rather come from the variety of educational settings across the United States and Canada, including both mainstream and special education classes, both public and private schools, and both oral and total communication methods.

2.2. Procedure

It was hypothesized that post-implant therapy and education factors might explain differences in performance on outcome measures once the impact of intervening variables associated with child, family and implant characteristics had been accounted for. Intervening variables and outcome measures were all obtained at one point in time at data collection camps when the children were 8 or 9 years old. Independent variables were assessed retrospectively and averaged across the years elapsed since the child received an implant.

2.3. Intervening variables

Family, implant and child characteristics were measured and controlled so that we would not mistakenly attribute the effects of these variables to rehabilitative causes. Child characteristics included age at onset of deafness, age at implant, duration of deafness before implantation and non-verbal intelligence. Family characteristics included family size, parents' education and income and involvement with the child. Implant characteristics included duration of implant use, duration of use of an updated speech processor strategy, number of active electrodes, the dynamic range between the processor threshold and maximum comfort levels and the highest frequency coded and loudness growth.

2.4. Independent variables

Independent variables included measures of educational methodology, individual therapy and educational setting. Each of these rehabilitation variables was measured over five rating periods: pre-implant, 1st year post, 2nd year post, 3rd year post and current year. Methodology was assessed with a rating scale that was intended to reflect the amount of emphasis on speech and auditory skill development provided in the child's classroom. A rank between 1 and 6 was assigned to each instructional mode for each year. Ratings between 1 and 3 were assigned to total communication programs. In *mostly sign* programs, sign-only was used for communication during some of each day. In speech *and sign* programs, speech almost always occurred simultaneously with each signed word and sign-only or speech-only were rarely used. In *speech emphasis* programs, speech-only was used for communication during some of each day. Ratings between 4 and 6 were applied to oral communication programs. In cued *speech* programs, a formal system of manual cues was used to facilitate lipreading. In *auditory–oral* programs, the child was encouraged throughout the day to both lipread and listen to the talker. In *auditory–verbal* programs, the child was taught to rely on listening alone to understand speech. Methodology scores were averaged across 5 years. Ninety-two children had average scores of four or higher and had spent most of their years using an oral communication mode. Eighty-nine children had average mode scores below four and had been using a total communication mode.

Therapy variables included hours of therapy each year, the therapist's experience with implanted children and parent participation in the child's therapy. Parents reported their child's educational setting each year as none, public, private or both public and private. Classroom placement was reported by parents as none, special education, partial mainstreaming or full mainstream placement. The percentage of children enrolled in full time special education classes decreased from about 60% before implant to about 20% at the time of the study. By the time of the study, over half of the children were fully mainstreamed.

2.5. Outcome measures

The speech perception battery covered a range of skills including phoneme discrimination, closed-set word identification, open-set speech recognition, lipreading enhancement and listening skills in everyday situations. Two open-set measures were administered in which the child was required to imitate a recorded stimulus: the Lexical Neighborhood Test [3] and the BKB Sentences [4]. Almost all children understood some words within the BKB sentence context and half of them understood 50% or more of the keywords. Oral children understood significantly more words (62%) than TC children (32%). In addition to words in sentences, the children also recognized words presented in isolation. The average percent correct score on the Lexical Neighborhood Test was 40%. Half of the children understood 20 or more words from the 50 presented out of context. Again, there was a significant advantage for orally educated children, who averaged 88% correct, while the children educated in total communication averaged 34% correct word recognition.

Speech production measures included listener judgments of sentence intelligibility, phonemes imitated correctly from a spoken model, time spent repairing communication breakdowns in an oral conversation and parental report of the child's intelligibility in everyday communication situations. A set of 36 sentences [5] that varied in length and degree of contextual support was digitally recorded of each child and played to naive listeners. Listeners understood an average of 77% of key words spoken by orally educated children as opposed to 49% of words spoken by children from total communication settings. The histogram in Fig. 1 displays scores obtained by all 181 children in the sample in ascending order. Examples of children's speech at representative levels of intelligibility are demonstrated and may be accessed by clicking on the corresponding loudspeaker icons.

Language competence was measured separately in speech-only and speech and sign contexts. Two language samples were elicited. Speech-only measures were all derived from an oral language sample. Speech and sign measures were derived from a total

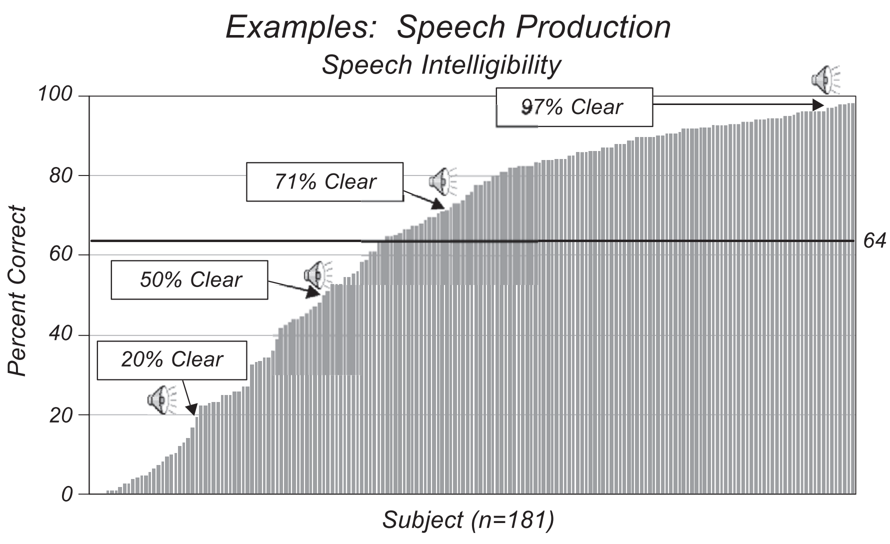

Fig. 1. Average percentage of key words produced by 181 cochlear implant users in 36 sentences as understood by naive listeners are plotted in ascending order. A horizontal line is drawn at the average group intelligibility (64%). Audio examples of children at four levels of intelligibility are provided.

communication language sample. The oral group produced more different words in both the oral-only and the total communication language sample. Oral children also obtained significantly higher linguistic scores on the syntax complexity measure, the IPSyn [6] and produced significantly longer sentences.

Reading was assessed with the Word Attack subtest of the Woodcock Reading Mastery Test [7], and Word Recognition and Reading Comprehension from the Peabody Individual Achievement Test [8]. The average reading grade equivalent scores at the mid-second grade level were only a few months behind their expected reading level compared to hearing children. Over half of the sample (52%) scored within the average range compared to hearing children. There was a significant advantage for the oral group in their word attack and word recognition skills, but no group differences in reading comprehension.

3. Results

Multiple regression techniques were used to examine the effects of independent variables (communication method, classroom type, amount of therapy) on outcome measures (speech perception, speech production, language and reading) after controlling for intervening variables associated with the child, the family and the implant device. Child and family characteristics accounted for 22% of explained variance in speech perception and speech production scores, 23% in spoken language, 27% in spoken and signed language and 25% in reading. Performance IQ accounted for significant variance in all outcomes. Children from smaller families achieved significantly higher scores in all areas but reading. All areas but speech perception were affected by gender (girls scored higher than boys) and family socioeconomic status, a combination of parents' education and income. Children with later onset of deafness tended to have better language skills, when both speech and sign were considered together and better reading scores. Reading scores were, of course, better for 9-year-olds than 8-year-olds. None of the categories was significantly affected by the age at which the child was implanted.

Next, we examined the contribution of implant characteristics to outcomes once the variance due to child and family characteristics had been removed. Each of the implant variables contributed significant variance to all outcomes except for reading, where the number of active electrodes and loudness growth was not significant. These variables together accounted for 22% of added variance in speech perception, 20% in speech production, 15% in spoken language, 14% in spoken and signed language and 12% in reading.

Finally, we determined the amount of variance accounted for by educational variables after variance due to family, child and implant characteristics had been removed. These variables accounted for 12% of the variance in speech perception, 11% in speech production, 9% in spoken language and 3% in spoken and signed language, and 6% in reading. Use of an oral communication mode contributed significant variance for all outcomes, except for reading. Greater educational emphasis on speech and auditory skill development was associated with significantly better outcomes. Amount of time spent in a mainstream class was a significant predictor of speech production and reading outcomes.

4. Conclusion

A variety of factors influences a child's ability to obtain benefit from a cochlear implant. Amount of benefit is a product of what the child brings to the learning environment, what is provided by the implant itself and what is provided by the child's rehabilitation program. Our ability to influence intrinsic factors, such as the child's intelligence, the family environment or the number of active electrodes is limited. However, we can insure that each child gets the most up-to-date processing strategy with a well-fitted map that permits maximum dynamic range and loudness growth, and we can provide each child with an emphasis on speech and auditory skill development in their educational program. Results of this study indicate that attention to these factors can make a significant difference in the overall benefit children obtain from cochlear implantation.

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