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The Effectiveness of Cochlear Implants for Children With Prelingual Deafness

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No longer considered an experimental procedure, cochlear implantation in young children with profound hearing loss has become almost commonplace. This paper reviews the efficacy of cochlear implantation in children with prelingual deafness. First, a brief introduction to cochlear implants is provided. Second, research regarding the effects of cochlear implantation in children with prelingual deafness on speech perception, speech production, and language development is reviewed. Finally, implications for early childhood educators are discussed.

The development of cochlear implants is one of the most significant interdisciplinary biomedical achievements to date (Clark, Cowen, & Dowell, 1997). This therapeutic breakthrough has been the subject of widespread media attention in recent years as its effects have been increasingly reported in scientific journals (e.g., Balkany, 1993; Bonn, 1998; Osberger, Maso, & Sam, 1993). As technology continues to improve, public awareness increases, and the age of implantation lowers, young children with cochlear implants are becoming common in various types of early childhood educational settings.

This paper reviews the empirical evidence of the efficacy of cochlear implantation in children with prelingual deafness. We acknowledge that it is almost impossible to write a paper on this topic without addressing the controversy surrounding the use of cochlear implants for children. Cochlear implant professionals have met tremendous opposition from the Deaf community. Members of the Deaf community differentiate the term ''deaf'' that is used to describe a pathology, from the term ''Deaf,'' which denotes a culture and a sense of pride. Whereas many medical professionals view deafness as a condition to be diagnosed and treated, the Deaf community sees deafness as a difference, not a deficit. According to Lane and Bahan (1998), Deaf people have a language and are a cultural minority, and the world of deafness is distinctive, rewarding, and worth preserving.

Many deaf advocates consider cochlear implants as genocidal to the Deaf culture (Lane & Bahan, 1998). They argue that implantation of children conflicts with the right of the Deaf cultural minority to exist and flourish. Although these issues have been raised, this paper is written simply to evaluate the performance of children who have received cochlear implants. We do not wish to discredit the Deaf community or the potential value of manual communication. Instead, we recognize that there are parents of deaf children who desire that their child learn verbal communication. With this in mind, we have provided a critical review of the research literature, examining the effectiveness of cochlear implants on the development of verbal communication skills in children with prelingual deafness. In addition, we addressed issues that early childhood educators, who come in contact with children with cochlear implants, might face.

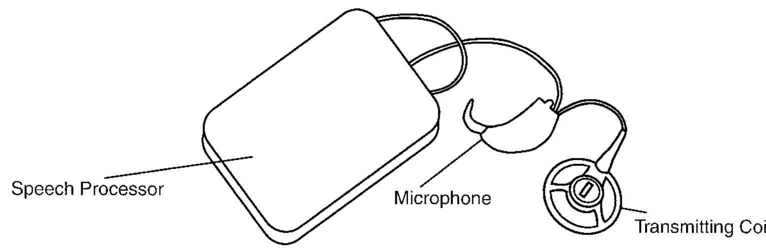

Figure 1.
Internal and external components as worn by the cochlear implant recipient.

A Primer on Cochlear Implants

A cochlear implant is an electronic device providing auditory information to individuals who have severe to profound sensorineural hearing loss in both ears and receive limited or no benefit from conventional hearing aids. Typically, these individuals have pure-tone thresholds of 100 dB HL or greater. The origin of profound deafness is usually damaged or diminished hair cells in the inner ear (Henderson, Salvi, Boettcher, & Clock, 1994). Because of the amount of hair cell damage, merely amplifying sound does not enable people with profound deafness to process sound. Unlike conventional hearing aids, which deliver amplified sound to the ear, a cochlear implant bypasses damaged hair cells and stimulates the auditory nerve directly with electrical current. Cochlear implants have been used in research trials with adult patients since the mid-1970s but did not receive Food and Drug Administration (FDA) approval for clinical use in children until 1989. Currently, children over the age of 18 months who have profound bilateral sensorineural hearing loss and demonstrate limited benefit from conventional hearing aids might be considered candidates for cochlear implants. More than 20,000 people around the world, half of them children, have received cochlear implants since the clinical introduction of the device (Bonn, 1998).

A cochlear implant is comprised of internal and external components (see Figure 1). The internal components consist of electrodes, which are surgically placed in the cochlea (inner ear), and a receiver or stimulator, which lies beneath the skin behind the ear. The external components consist of a microphone, a speech processor, and a transmitter, which sends the signal to the internal components (see Figure 2). Cochlear implant surgery is usually a 2- to 3-hour procedure, performed by an otolaryngologist (ear, nose, and throat surgeon). The child typically spends 1 night in the hospital following cochlear implant surgery. Approximately 4 weeks following surgery, the child returns to the implant center for the initial stimulation of the device. This initial ‘‘tune-up’’ session usually takes 2 to 3 days depending on the child’s age and level of cooperation. An audiologist stimulates each of the implanted electrodes and determines the child’s threshold and comfort levels. Once threshold levels and comfort levels have been obtained for each of the electrodes, a map of these levels is created and programmed onto the child’s speech processor. Initially, the child will have to make frequent visits to the audiologist to fine-tune the map. After that, adjustments to the child’s map will be made periodically as perceptual performance changes.

Several modifications have been made to the cochlear implant device components and speech processing strategies as the technology has evolved. Currently, three cochlear implant devices have been cleared by the FDA for clinical use. The Cochlear Corporation received FDA approval for clinical use of the Nucleus 22 cochlear implant in children in 1989. This device was subsequently replaced by the Nucleus 24 cochlear implant in 1998. In 1997, the Advanced Bionics Corporation received FDA approval for the use of the Clarion cochlear implant in children. A fourth device, the COMBI 40+, manufactured by the

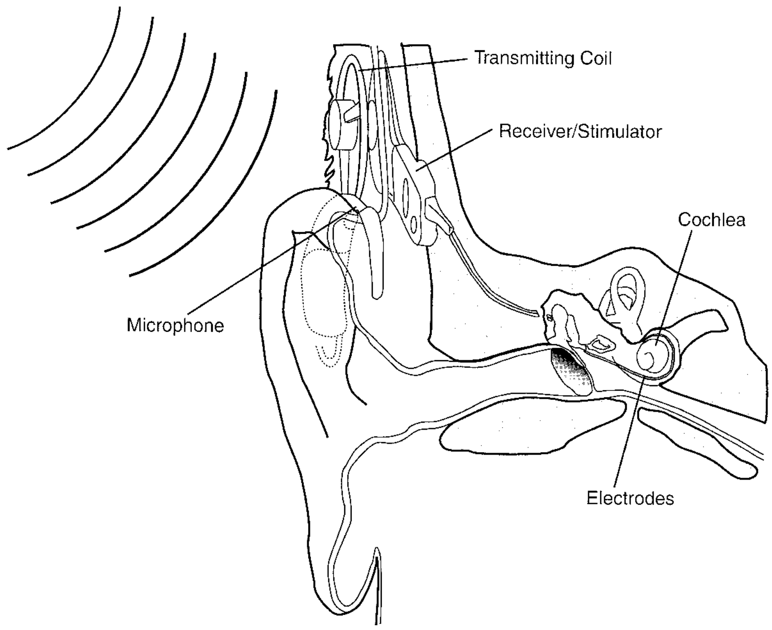

Figure 2.
Illustration of the external device of a cochlear implant.

Med. El. Cooperation, is currently undergoing clinical trials. The most significant advancement in cochlear implant technology has been in speech processing. Whereas the cochlear implant devices of the early 1990s encoded only specific features of speech, the current devices encode the entire speech signal.

In addition to device alterations, there have been changes in the demographic characteristics of children undergoing cochlear implant surgery. Specifically, children are receiving implants at a younger age because research has continued to suggest superior performance associated with early implantation (Miyamoto et al., 1994). In 1998, the FDA lowered the minimal age of pediatric implantation from two years to 18 months of age.

Performance of Children With Cochlear Implants

Because children with profound sensorineural hearing loss constitute a very heterogeneous population, performance of children with cochlear implants varies greatly. Factors associated with the amount of benefit the child receives from a cochlear implant include age of onset of deafness, age of implantation, speech processor type, number of implanted electrodes, duration of deafness, communication mode, and duration of implant use (Miyamoto et al., 1994). In addition, it is possible that implant success is affected by the physiological functioning of the surviving neurons in the auditory nerve, the position of the electrodes in relation to excitable tissue, neural supply to the cochlea, the central processing abilities, and the child's cognitive and linguistic abilities. Furthermore, the quality of auditory training, parental motivation, and teacher expectations might also influence the amount of success a child achieves with a cochlear implant. Finally, the child's success is dependent on the parents' insistence and the child's compliance in wearing the external device full time.

When investigating the performance of children with cochlear implants, it is important to differentiate between children who became deaf prelingually and those who became deaf postlingually. Children with prelingual deafness might not demonstrate the immediate success seen in children with postlingual deafness. Children with postlingual deafness have had some language and auditory experiences prior to the onset of deafness and, therefore, might be expected to benefit from a cochlear implant at a faster rate than those with prelingual deafness do. The aim of this paper is to examine the effectiveness of cochlear implantation in children with prelingual deafness. Whereas a number of studies have included children who became deaf after the age of 3 years, we only describe studies that exclusively evaluated implant performance of children who became deaf prior to the age of 3 years.

Several studies are not included in this review because they did not meet our criteria of internal validity. To determine the benefit children receive from a cochlear implant, it is necessary to minimize extraneous variables, particularly maturation and education. Therefore, this paper only reviews longitudinal studies including a control group consisting of children without cochlear implants.

We recognize that some research in the area of cochlear implants is criticized for having selection bias. Because it is up to parents to decide whether or not their child undergoes cochlear implantation, random assignment to treatment groups is impossible. It is conceivable that there are characteristics inherent in children who receive cochlear implants that differ from those in children who do not receive cochlear implants. Particularly, it might be argued that children with cochlear implants come from families who have a stronger desire for their child to develop verbal language skills, than the families of children without cochlear implants. Although this potential source of bias might have a slight influence on these studies, it is unlikely that it accounts for the notable effect.

The majority of research on the performance of children with cochlear implants has been in the area of speech perception. The number of studies examining speech production and language skills has been more limited. Because the perception of speech is a necessary requisite to speech production and the acquisition of an oral language, we will first describe current research findings regarding the speech perception performance of children with cochlear implants.

Speech Perception

Speech perception skills progress developmentally, beginning with speech detection, then discrimination, recognition, and finally comprehension. Speech perception abilities are typically evaluated using closed-set tests, which measure speech discrimination, or open-set tests, which measure speech recognition. In closed-set tests, a small set of answers is provided from which the child must choose the correct response. In open-set tests, the examiner presents a word or phrase and the child must respond by repeating or signing the word. Open-set measures of speech perception are considered more difficult than closed-set tests because the possible responses are not provided to the child.

Speech perception performance of cochlear implant versus hearing aid users. When cochlear implantation was first recognized as a possible habilitative component for deaf children, the evaluation of speech perception abilities of children who receive cochlear implants versus those who used conventional hearing aids or tactile aids became the focus of several researchers.

A few studies compared the performance of children who received cochlear implants to the performance of children who used multichannel tactile aids. Miyamoto, Robbins, Osberger, Riley, and Kirk (1995) compared the speech perception performance of children in the predevice condition and at a post-device interval after an average of 1.5 years of device use. The results demonstrated statistically significant improvement in closed-set and open-set word recognition between the predevice and postdevice condition for the children who received cochlear implants, but not for the children who used the tactile devices. In addition, the scores of the cochlear implant group were statistically significantly higher than the scores of the tactile group on all measures after 18 months of device use.

Geers and Tobey (1995) assessed the speech perception abilities of children with cochlear implants and children who wore tactile devices. After 12 months of device use, the auditory speech perception scores of children with cochlear implants exceeded those of children with a similar hearing loss who wore tactile devices. In addition, statistically significant improvements in lip-reading abilities were documented in the cochlear implant group but not in the tactile aid group. Similar findings were reported by Carney et al. (1993) who found that children with multi-channel cochlear implants statistically significantly outperformed children using tactile aids on a change/no change speech discrimination procedure.

Vermeulen, Beijk, Brokx, van den Borne, and van den Broek (1995) compared the speech perception of children with cochlear implants to the speech perception of children with an equivalent hearing loss who used conventional hearing aids. After 12 months of device use, the children with cochlear implants performed statistically significantly better on every measure than the children who wore hearing aids did. Whereas the cochlear implant group achieved 61% on a discrimination task of segmental aspects of speech, the hearing aid group scored 23%.

Five studies have compared the speech perception performance of children with cochlear implants to the performance of children with varying amounts of residual hearing who wore conventional hearing aids (Geers, 1997; Geers & Moog, 1994; Miyamoto, Kirk, Todd, Robbins, & Osberger, 1995; Myer, Svirsky, Kirk, & Miyamoto, 1998; Svirsky & Myer, 1999). Collectively, these studies assessed open-set and closed-set speech phoneme, word, and sentence perception abilities. Results of all five studies demonstrated that after an average of 2 to 3 years of device use, children with cochlear implants outperformed children with hearing aids who had pure tone hearing thresholds greater than 100 dB HL, and performed comparably to children with hearing aids whose hearing thresholds were between 90 and 100 dB HL.

Speech perception and early versus late cochlear implantation. There is a world-wide trend towards giving cochlear implants to deaf children at increasingly younger ages. Early implantation allows deaf children access to auditory information during the preschool years, which might positively impact the development of speech and language. Miyamoto, Kirk, Svirsky, and Sehgal (1999) selected children with prelingual deafness, who received a cochlear implant prior to 5 years of age and examined their speech perception performance as a function of age at implantation. These children were administered speech perception tests prior to receiving their implant, and then at 6-month intervals following implantation. For each subject, data were analyzed until the child's chronological age was closest to 4 years and 6 months. Results demonstrated that, on average, the children who received their cochlear implant prior to 3 years of age achieved higher speech perception scores than children who received their cochlear implants after that time did. As acknowledged by the authors, however, this study was confounded by the fact that the children who received their implants at younger ages also had more years of experience with their device than the children who received cochlear implants after the age of 3 years. It is not clear if the speech perception abilities of children who received their cochlear implants at older ages will ultimately plateau at the same level.

To date, no studies have been published that exclusively compared the speech perception abilities of children who received cochlear implants beyond the age of 5 years, to age-matched children who continued to use conventional amplification. However, using a repeated measure design, Osberger, Fisher, Zimmerman-Phillips, Geier, and Barker (1998) compared preoperative performance with hearing aids to postoperative performance with cochlear implants after 3 and 6 months of device use in children who received their cochlear implants after the age of 5 years. Their findings demonstrated statistically significant improvement in both closed-set and open-set speech perception abilities over time following cochlear implantation, particularly in children who were educated through an oral modality. Although unlikely, it cannot be ruled out that the children in this study might have achieved similar gains in speech perception had they continued to use their conventional hearing aids. Nevertheless, the child's age is an important consideration for cochlear implant candidacy if the child has prelingual deafness. The expectations of parents and professionals might need to be readjusted for older children undergoing cochlear implantation.

Speech Production

The acquisition of intelligible speech is often the goal of parents and teachers of children with cochlear implants. The acoustic benefits provided by a cochlear implant might contribute to articulation of precise speech. Speech production, however, typically does not change as quickly as speech perception. Although there might be slow progress during the first 2 years following implantation, it has been suggested that speech production will improve as long as the child is trained and challenged in an oral modality (Nevins & Chute, 1996).

Research has demonstrated that speech intelligibility of children with cochlear implants increases gradually over time. A study by Miyamoto et al. (1997) demonstrated that speech intelligibility of prelingually deaf children improved from 0% prior to implantation, to 40% after 4.5 to 7.5 years of device use. In addition, after 2 years of device use, the speech intelligibility of children with cochlear implants surpassed the speech intelligibility of hearing aid users whose pure-tone auditory thresholds averaged 100–110 dB HL. Robbins, Kirk, Osberger, and Ertmer (1995) reported similar findings.

Ertmer, Kirk, Sehgal, Riley, and Osberger (1997) compared vowel production by children with cochlear implants to that of children with multi-channel tactile aids, and demonstrated better performance of children with cochlear implants than children with tactile aids. Specifically, they found that after an average of 20 months of device use, children with cochlear implants showed a statistically significant improved production of diphthongs and most vowel categories, whereas the children with tactile aids demonstrated statistically significant improvement only in the production of diphthongs.

Spencer, Tye-Murray, and Tomblin (1998) reported that children with cochlear implants comprehend more and use more bound morphemes in their spontaneous speech than children who use conventional hearing aids do. Finally, findings from Tye-Murray, Spencer, and Woodworth (1995) indicated that children with prelingual deafness who receive cochlear implants prior to the age of 5 receive greater benefit from their cochlear implant in terms of speech production than children who receive a cochlear implant after the age of 5 years do.

Language Development

Although improved speech intelligibility is typically the focus of parents and teachers of deaf children, speech skills do not directly reflect language competence. Speech refers to oral production, whereas language refers to the abstract knowledge basis of symbolic communication. The ultimate goal for children with prelingual deafness who have cochlear implants is to integrate auditory information provided by their devices into their developing language system (Hasenstab & Tobey, 1991).

The Sensory Aid Study conducted at the Central Institute for the Deaf (Geers, 1997; Geers & Moog, 1994), longitudinally compared language acquisition of children with cochlear implants and children with other sensory aids (i.e., conventional hearing aids and tactile aids). The children ranged from 2 to 12 years of age at the beginning of the study. Participants' language performance was evaluated based on spontaneous language samples, receptive and expressive vocabulary tests, and a battery of language tests normed on children with a hearing impairment. Results demonstrated statistically significant improvement in all sensory aid groups on all measures. After 3 years, the performance of children with cochlear implants was superior to all other groups of children who had pure-tone thresholds of 100+ dB HL (essentially no residual hearing) and similar to the hearing aid users who had pure-tone thresholds of 90–100 dB HL (a limited amount of residual hearing). In addition, results indicated that the deaf children using hearing aids progressed in their vocabulary development at a slower rate than normally hearing children did, whereas the vocabulary development of children with cochlear implants progressed at the same rate as that of normally hearing children.

Miyamoto, Svirsky, and Robbins (1997) also examined the efficacy of cochlear implants in children with prelingual deafness on language acquisition. In this study, cross-sectional data from 89 children with prelingual deafness who had not received cochlear implants were used to obtain a regression slope, which the authors referred to as the ''deaf slope.'' The deaf slope was then used to obtain a predicted score for the children with cochlear implants. Longitudinal data were then collected on 23 children with cochlear implants and compared to the predicted deaf slope. Children were tested between 0 and 3 months before implantation and at 6 and 12 months postimplantation. Results indicated that profoundly deaf children without implants, on average, could be expected to make only 5 months of language growth in 1 year. The language growth of children with cochlear implants exceeded the predicted growth by 7.1 and 6.9 months for expressive and receptive language, respectively. In addition, the authors reported that during the 1st year following implantation, the rate of language development was the same for deaf children with cochlear implants as for normally hearing children. Consequently, the gap in language scores between children with implants and children with normal hearing did not increase, but remained constant during the 1st year. The authors suggested that these findings support early implantation because there is a smaller language gap between a deaf child and his or her hearing peers at a younger versus an older age.

Tomblin, Spencer, Flock, Tyler, and Gantz (1999) also conducted a study comparing the language achievement of children with and without cochlear implants. These researchers compared the English language development of 29 children with prelingual deafness and who had cochlear implants to the language development of 29 children with prelingual deafness who wore conventional hearing aids. Children received cochlear implants between the ages of 2 and 13 years. Samples of expressive language were obtained from all children using story recall. These samples were analyzed using the Index of Productive Syntax scoring system (Scarborough, 1990). In addition, the children with cochlear implants were administered the Rhode Island Test of Language Structure (Engen & Engen, 1983) to assess sentence comprehension. The norms provided by the test were used to represent performance by deaf children without cochlear implants. Results indicated superior language achievement by children with cochlear implants compared to their peers without implants. Performance on the Index of Productive Syntax indicated that children with cochlear implants scored higher on all subscales, than did the control group of children without implants. In addition, scores on the Rhode Island Test of Language Structure demonstrated a mean percentile rank of 95% for children with cochlear implants, based on norms from chronologically age-matched deaf peers. This study supports the growing body of evidence of the benefits of cochlear implants on language comprehension and production.

Summary

Research has demonstrated the positive benefits of cochlear implants on the speech perception, speech production, and language development of young children with prelingual deafness. Anecdotal reports, not described here, have also indicated positive outcomes of cochlear implants on reading skills, academic achievement, and social acceptance (Bonn, 1998; Nevins & Chute, 1995; Radcliffe, 1999), but empirical research in these areas is needed. Additional research examining the performance of children with cochlear implants continues. Future research seems likely to document even more impressive levels of performance, as studies begin to reflect the improved speech processing of the current devices and the trend toward children receiving implants at a younger age. A clearer understanding of the vital role of effective habilitative and educational techniques might also positively influence the level of child performance reported in future investigations.

Implications for Early Childhood Educators

Universal newborn hearing screenings, early identification, advanced technology, heightened public awareness, and positive empirical findings are all likely to increase the frequency in which early childhood educators come in contact with young children with cochlear implants. Unlike their deaf peers, who have only minimal access to auditory cues, children with cochlear implants have the capacity to use the auditory code as the primary source of language development and learning. Early childhood educators are likely to encounter these children in a variety of educational contexts, including inclusive settings. Consequently, it is important that early interventionists and early childhood educators are familiar with cochlear implants, the auditory benefit provided by implants, and the components of a successful habilitative or educational program. The following discussion focuses on the fundamentals of an optimal educational environment for young children with cochlear implants.

A Communicative Link

Children with cochlear implants might benefit considerably from the existence of an established communicative link between the implant center and their school or child-care center (Stojny, Harrison, & Zimmerman-Phillips, 1998). At the implant center, the child is typically seen by a team of professionals, including an audiologist, an otolaryngologist, a speech-language pathologist, and often a psychologist. Elsewhere, a child might be in close contact with a classroom teacher, school speech-language pathologist, itinerant teacher, or child care provider. Professionals obtain important information about the child, and their areas of expertise are essential to maximize the child's education and development. Members of the cochlear implant team have expertise to assess the child's potential with a cochlear implant. They also specialize in the technical aspects of the implant and can resolve problems with the device.

Although audiologists, otolaryngologists, and speech-language pathologists at the implant center might make up the core of the implant team, it is essential to include adjunct members relevant to the life of the candidate, such as the child's teacher or caregiver. Their input is instrumental for decisions regarding cochlear implant candidacy and auditory as well as linguistic goals. For example, they might provide information not readily available to the rest of the implant team, such as the child's academic progress, motivation to communicate verbally, and social skills. In addition, because they observe the child daily, they might be the first to recognize performance changes indicating the need for an adjustment of the child's speech processor map. Each professional contributes a requisite component to the child's success. Parents and teachers become more integral members of the implant team when a communicative link is established between the implant center and the child's school. Ideally, this communicative link is initiated when the child is assessed as a potential candidate for a cochlear implant and then continues indefinitely.

Analytical Therapy Versus Naturalistic Habilitation

As Robbins (1998a) explained, the enhanced auditory capacity afforded by a cochlear implant and the younger age of implantation has altered the focus of habilitative techniques for deaf children with cochlear implants. Traditionally, auditory and linguistic training for children with profound sensorineural deafness has been centered on very narrow, didactic exercises designed to facilitate sound detection, discrimination, identification, and comprehension. Auditory Verbal Therapy is an example of a habilitative program using this type of analytical auditory training exercises to facilitate verbal communication in children with severe to profound hearing loss. These types of structured exercises are advocated particularly for older children who have had limited listening experiences.

Cochlear implants provide deaf children

with auditory information not previously accessible through their hearing aids, particularly at the high frequencies. Therefore, the acquisition of spoken English as a primary language is often a goal for deaf children with cochlear implants. Because of their enhanced auditory capabilities and focus on spoken English, it has been suggested that these children reap greater benefits from a more naturalistic rather than a direct approach to language and auditory learning (e.g., Robbins, 1998a; Nevins & Chute, 1996).

These clinical observations mirror empirical data about children with normal hearing that indicate that young children generally learn more efficiently from naturalistic or incidental experiences than from direct teaching experiences, until the mean length of utterances is at least three morphemes long (Yoder & Warren, 1998). Children with cochlear implants have the potential to enhance their listening and learning skills through real-life experiences. Cochlear implants provide the capability for deaf children to generalize and learn from naturalistic and incidental events at a level not previously possible with conventional hearing aids. Habilitation for these children, therefore, should more closely mirror the education of children with normal hearing. That is, intervention should focus on teaching a broad array of developmentally appropriate targets in a naturalistic environment with the idea that the child will generalize what he or she learns to other contexts and other targets (Robbins, 1998a). For example, parents might focus on getting their 18-month-old child to identify and produce his or her name in the context of daily routines. At preschool, the child might learn auditory or listening skills best in the context of the existing curriculum. The interested reader is referred to Estabrooks (1998) and Robbins (1998a) for creative classroom activities enhancing incidental and generalized learning in young children with cochlear implants.

The age of implantation might influence the type of learning environment most optimal for children with cochlear implants. Based on their clinical experience, Nevins and Chute (1996) have suggested that the age of the child at the time of implantation dictates whether the intervention program should emphasize direct or indirect instruction. Whereas older children and adults might benefit substantially from direct instruction and rote exercises to facilitate the development of auditory skills, younger children are likely to derive greater listening and language benefits from contextualized and incidental experiences.

Although it has not been empirically demonstrated, clinical observation attests that, in addition to their naturalistic learning experiences, most children with cochlear implants will require structured auditory exercises to advance their listening skills. Estabrooks (1998) suggested that these structured activities are most effective when they incorporate meaningful communication skills appropriate for the child's linguistic and cognitive levels, and occur as a natural consequence of an activity. Ideally, the clinician or educator conducting the therapy session will integrate language goals into the listening tasks. Traditional auditory training which is slightly modified, might greatly enrich the meaningfulness of the task for the child. For further suggestions for designing meaningful listening activities, the reader is referred to Estabrooks (1998), Nevins and Chute (1996), and Robbins (1998b).

Supporting Parental Efforts

Parents and the home environment might have the greatest impact on the auditory development of the child in the early years of implant use. Young children often interact with their parents off and on many hours a day, 7 days a week, year in and year out. The cumulative effect of this environment, either positive or negative, has shown to be quite substantial (e.g., Hart & Risley, 1995). For that reason, the role of early childhood professionals should be to equip parents to provide an enriched language environment for their child.

Likewise, one can presume that the effects of a cochlear implant on a child's language development will depend, to some extent, on the level of use of the device. Compliance with wearing the devices is one of the more frequent issues facing parents of young implant recipients. A strong-willed child might balk at having to wear the device or might remove the transmitting coil. Educators and clinicians can assist parents by discussing with them some strategies to help with the use of the device. Rewarding the child with stickers or providing other reinforcements might be effective. When consistent daily routines and guidelines for device use are established early, the child will be more likely to use a device as he or she gets older.

Educational Environment and Children With Cochlear Implants

Since the founding of schools for deaf children in the United States, the controversy over what constitutes appropriate educational placement for deaf children has persisted. Deaf children younger than 3 years of age are likely to receive services through an early intervention program, which might provide home-based, self-contained classroom based, or inclusive classroom-based programs. Deaf children over the age of 3, however, might be found in a variety of educational settings, using various communication modalities. They can be found in residential programs, special day classes, resource rooms, and inclusive classrooms. Although inclusion has been the dominant trend in the broader special education field, widespread segregation of deaf children into special classes and schools has been maintained throughout the 1990s. It is likely that the use of cochlear implants in young children will facilitate the trend towards inclusion in the field of deaf education. The enhanced speech and English language skills afforded by a cochlear implant should better equip deaf children for placement in mainstream settings. As the age of implantation becomes lower, it is likely that deaf children with cochlear implants will become more common place in typical community preschools and child care settings. In these early childhood settings, deaf children with cochlear implants will have the advantage of an enriched auditory language environment and proficient peer speech models.

Children with cochlear implants throughout the world might use a variety of different modes of communication. The communication modality used to educate deaf children has long been the focus of a heated debate. This controversy is beyond the scope of this paper. It is important, however, that early childhood educators are aware of this debate. Specifically, some experts who work with children with cochlear implants believe that children with cochlear implants should receive an auditory-verbal education. For more information on the auditory-verbal approach, the interested reader is referred to Estabrooks (1994).

It is the opinion of the authors that no one communication modality is appropriate for every child. It is important that the child's needs and abilities are carefully evaluated to determine the suitability of a particular communication system. Successful implant users can be found in oral, auditory-verbal, cued-speech, and total communication (TC) educational environments. Regardless of the primary communication modality, it is most important that the educational program has an aggressive auditory component. We emphasize this not to dismiss the value of manual communication, but to support the parents' desire that their child acquires verbal language. A cochlear implant in itself is not sufficient to make the child an oral communicator. It is the responsibility of the early childhood professionals to support parents in their decision to teach their child verbal language by providing an educational environment rich with auditory stimulation. A strong auditory emphasis is most often characteristic of oral, auditory-verbal, and cued-speech programs, but tends to be less apparent in TC programs. This is not to say that a TC environment is no longer appropriate once a child receives an implant. On the contrary, children with cochlear implants do not become oral communicators overnight. Continued use of a TC approach might be the most effective means for facilitating language growth in a child with a cochlear implant. Nonetheless, it is essential that the child be exposed to an enriched auditory environment as many hours a day as possible. There is a great need for a strong commitment to maximize the auditory component within a TC approach. In addition, it might be necessary for the school staff to adjust their expectation and teaching priorities, especially if manual communication is the focus of the child's current educational placement.

Because simultaneous speaking and signing is difficult, many parents and teachers who sign, speak to deaf children with a weak voice or no voice at all (Nevins & Chute, 1996). To enhance the auditory environment, parents and teachers should be encouraged to use their full voices when signing to the child. In addition, it is important that the child engages in verbal communication as much as possible. The child must be motivated to communicate verbally. This might initially involve getting the child's attention, establishing understanding, and correcting communication breakdowns.

Conclusion

By bypassing the damage in the inner ear and stimulating the auditory nerve directly, cochlear implants have augmented the auditory capabilities of children with profound sensorineural deafness. Research has indicated that children with cochlear implants have superior speech perception, speech production, and language skills compared to their peers without cochlear implants. Although empirical data are not yet available, anecdotal reports indicate that cochlear implants might also promote reading achievement, academic success, and social adjustment in children with prelingual deafness. By maintaining a communicative link with the implant center, using naturalistic and meaningful teaching techniques, supporting parental efforts, and providing an enriched auditory environment, early childhood educators and practitioners can make significant contributions to the success of a young child with a cochlear implant.

REFERENCES

Balkany, T. (1993). A brief perspective on cochlear implants. *New England Journal of Medicine, 328,* 281–282.

Bonn, D. (1998). Tune in early for best results with a cochlear implant. *Lancet, 352,* 1836.

Carney, A. E., Osberger, M. J., Carney, E., Robbins, A. M., Renshaw, J., & Miyamoto, R. J. (1993). A comparison of speech discrimination with cochlear implants and tactile aids. *Journal of the Acoustical Society of America, 94,* 2096–2049.

Clark, G. M., Cowen, R. S., & Dowell, R. C. (1997). *Cochlear implantation for infants and children.* San Diego, CA: Singular Publishing.

Engen, E., & Engen, T. (1983). *Rhode Island Test of Language Structure.* Baltimore: University Park.

Ertmer, D. J., Kirk, K. I., Sehgal, S. T., Riley, A. I., & Osberger, M. J., (1997). A comparison of vowel production by children with multichannel cochlear implants or tactile aids. *Ear and Hearing, 18,* 307–315.

Estabrooks, W. (1994). *Auditory Verbal Therapy for Parents and Professionals.* Washington, DC: Alexander Graham Bell Association for the Deaf.

Estabrooks, W. (1998). *Cochlear implants for kids.* Washington, DC: Alexander Graham Bell Association for the Deaf.

Geers, A. E. (1997). Comparing implants with hearing aids in profoundly deaf children. *Otolaryngology Head and Neck Surgery, 117,* 150–154.

Geers, A. E., & Moog, J. S. (1994). Spoken language results: Vocabulary syntax, and communication. *Volta Review, 96.* 131–148.

Geers, A. E., & Tobey, E. A. (1995) Longitudinal comparison of the benefits of cochlear implants and tactile aids in a controlled education setting. *Annals of Otology, Rhinology, and Laryngology, 166 (Suppl.),* 328–329.

Hart, B., & Risly, T. R. (1995). *Meaningful differences in the everyday experience of young American children.* Baltimore: Paul H. Brookes.

Hasenstab, M. S., & Tobey, E. A. (1991). Language development in children receiving Nucleaus multichannel cochlear implant. *Ear and Hearing, 12,* 55–65.

Henderson, D., Salvi, R. J., Boettcher, F. A., and Clock, A. E. (1994). Neurophysiology correlates of sensory-neural hearing loss. In J. Katz (Ed.) *Handbook of clinical audiology* (4th ed.). Baltimore: Williams and Wilkens.

Lane, H., & Bahan, B. (1998). Ethics of cochlear implantation in young children: A review and reply from a Deaf-World perspective. *Otolaryngology Head and Neck Surgery, 119,* 297–308.

Meyer, T. A., Svirsky, M. A., Kirk, K. I., Miyamoto, R. T. (1998). Improvements in speech perception by children with profound prelingual hearing loss. Effects of device communication mode and chronological age. *Journal of Speech, Hearing, and Language Research, 41,* 846–855.

Miyamoto, R. T., Kirk, K. I., Svirsky, M. A., & Sehgal, S. T. (1999). Communication skills in pediatric cochlear implant recipients. *Acta Otolaryngologia, 119,* 219–224.

Miyamoto, R. T., Kirk, K. I., Todd, S. L., Robbins, A. M., & Osberger, M. J. (1995). Speech perception skills of children with multichannel cochlear hearing aids or hearing aids. *Annals of Otology, Rhinology, & Larynogology, 166* (Suppl.), 334–337.

Miyamoto, R. T., Osberger, M. J., Todd, S. L., Robbins, A. M., Stroer, B. S., Zimmerman-Phillips, S., & Carney, A. E. (1994). Variables affecting implant performance in children. *Laryngoscope, 104,* 1120–1124.

Miyamoto, R. T., Robbins, A. M., Osberger, M. J., Riley, A. I., & Kirk, K. I. (1995). Comparison of multichannel tactile aids and multichannel cochlear implants in children with profound hearing impairments. *American Journal of Otology, 16,* 8–13.

Miyamoto, R. T., Svirsky, M. A., Kirk, K. I., Robbins, A. M., Todd, S., & Riley, A. (1997). Speech intelligibility of children with multichannel cochlear implants. *American Journal of Otology, Rhinology, and Laryngology, 106,* 35–36.

Miyamoto, R. T., Svirsky, M. A., & Robbins, A. M. (1997). Enhancement of expressive language in prelingually deaf children with cochlear implants. *Acta Otolaryngology, 117,* 154–157.

Nevins, M. E., & Chute, P. M. (1995). Success of children with cochlear implants in mainstream educational settings. *Annals of Otology, Rhinology, and Laryngology, 166* (Suppl.), 100–102.

Nevins, M. E., & Chute, P. M. (1996). *Children with cochlear implants in educational settings.* London: Singular Publishing.

Osberger, M. J., Fisher, L., Zimmerman-Phillips, S., Geier, L., & Barker, M. J. (1998). Speech recognition performance of older children with cochlear implants. The *American Journal of Otology, 19,* 152–157.

Osberger, M. J., Maso, M., & Sam, L. K. (1993). Speech intelligibility of children with cochlear implants, tactile aids, or hearing aids. *Journal of Speech and Hearing Research, 36,* 186–203.

Radcliffe, D. (1999). As implant technology advances, number of potential candidates grows. *The Hearing Journal, 52*(5), 23–31.

Robbins, A. M. (1998a, April). Two paths of auditory development for children with cochlear implants. *Loud and Clear, 1*(1), 1–4.

Robbins, A. M. (1998b, June). Two paths of auditory development for children with cochlear implants. *Loud and Clear, 1*(2), 1–4.

Robbins, A. M., Kirk, K. I., Osberger, M. J., & Ertmer, D. (1995). Speech intelligibility of implanted children. *Annals of Otology, Rhinology, and Laryngology, 166* (Suppl.), 399–401.

Scarborough, H. S. (1990). Index of Productive Syntax. *Applied Psycholinguistics, 11,* 1–22.

Spencer, L. J., Tye-Murray, N., & Tomblin, J. B. (1998). The production of English inflectional morphology, speech production and listening performance in children with cochlear implants. *Ear and Hearing, 19,* 310–308.

Strojny, L., Harrison, J, & Zimmerman-Phillips, S. (1998). Making the Connection: The school, implant center, and family. *Loud and Clear,* 1(3), 1–4.

Svirsky, M. A., & Meyer, T. A. (1999). Comparison of speech perception in pediatric Clarion cochlear implant and hearing aid users. *Annals of Otology, Rhinology, and Laryngology, 177 (Suppl.),* 104–109.

Tomblin, B. J., Spencer, L., Flock, S., Tyler, R., & Gantz, B. (1999). A comparison of language achievement in children with cochlear implants and children using hearing aids. *Journal of Speech, Language, and Hearing Research, 42,* 497–511.

Tye-Murray, N., Spencer, L., & Woodworth, G. G. (1995). Acquisition of speech by children who have prolonged cochlear implant experience. *Journal of Speech and Hearing Research, 38,* 327–337.

Vermeulen, A. M, Beijk, C. M., Brokx, J. P., van den Borne, S., & van den Broek, P. (1995). Development of speech perception abilities of profoundly deaf children: A comparison between children with cochlear implants and those with conventional hearing aids. *Annals of Otology, Rhinology, and Laryngology, 166* (Suppl.), 215–217.

Yoder, P. J., & Warren, S. F. (1998). Maternal responsivity predicts the prelinguistic communication intervention that facilitates generalized intentional communication. *Journal of Speech and Hearing Research, 41,* 1207–1219.

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