

The Impact of Cochlear Implants on Young Deaf Children

New Methods to Assess Cognitive and Behavioral Development

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Much evidence suggests that, early in life, auditory input and communication are essential for the normal development of language, cognition, and behavior. Thus, deaf children, who experience significant disruptions in auditory input, are likely to show delays not only in the production of oral language but in other important aspects of development such as visual attention and behavioral control. Cochlear implants have shown tremendous promise in restoring auditory information to deaf children and concomitant improvements in speech recognition and production. However, little is known about how cochlear implants affect psychological variables. In this multisite trial, we assess the effects of cochlear implants on a range of developmental outcomes, including visual attention, problem-solving skills, symbolic play, and social adjustment. Measuring these constructs in young children, primarily younger than 2 years, has presented a number of unique challenges. In this article, we describe the methods used to assess these variables in young children and present preliminary findings comparing joint attention and symbolic play skills in a small sample of age-matched deaf and hearing children. As expected, deaf children performed more poorly than hearing children on measures of attention and symbolic play. As auditory input is restored via a cochlear implant, we predict that significant improvements in these variables will be observed.

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There is considerable evidence to suggest that, early in development, auditory input and communication are essential for the normal growth of language, cognition, and behavior. For example, soon after birth, infants look in the direction of sound,¹ and as they mature, they look longer at visual events whose temporal rhythms match what they hear.^{2,3} Across the life span, there is also evidence that sights and sounds that correspond lead to deeper processing of information,^{4,6} which suggests important dependencies between these sensory modalities.⁷ Thus, we have hypothesized that the disruption of auditory input in young deaf children is likely to have multiple cascading effects

on cognitive, behavioral, and social development.^{8,9}

Although a growing number of studies indicate that cochlear implants lead to improvements in language and communication in deaf children,¹⁰⁻¹² less is known about how they affect broader aspects of development such as attention and behavioral control.^{8,13} Previous research on the effects of cochlear implants has been narrowly focused on influences and outcomes in a single domain of development (eg, speech recognition). Fewer studies have examined the benefits of cochlear implantation across multiple domains (eg, cognitive and behavioral) or considered other influences on the child's development, from parental sensitivity to behavioral regulation. Through our research, we hope to advance this type of systematic evaluation of the effects of cochlear implantation on the "whole child."

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In terms of the psychosocial consequences of childhood deafness, several studies have found that hearing-impaired children are at greater risk for behavior problems, emotional difficulties, and delays in academic achievement.¹³⁻¹⁶ For example, in a series of computerized visual attention tasks,¹³ an average of 71% of the hearing-impaired children scored in the borderline/abnormal range vs only 9% of the normal-hearing sample. On a standardized measure of behavior problems¹⁷ completed by parents and teachers, close to half of the parents in the hearing-impaired group rated their children as having clinically elevated levels of behavior problems, particularly those related to impulsivity and inattention, and teachers rated nearly a third of the hearing-impaired children as having a substantial number of behavior problems. Interestingly, we found strong relationships between performance on the visual attention task and ratings of child behavior by parents and teachers. Children who had more difficulty in the selective attention task were also rated as having more externalizing behavior problems. These data fit with other results showing that children with hearing losses tend to score lower than hearing children on tests of verbal skills, academic achievement, and social development.^{18,19}

Lack of auditory input also profoundly affects communication between an infant and caregiver, posing an additional threat to optimal development.^{20,21} All of the available evidence indicates that normal development requires some level of effective communication between parent and child, and since the vast majority of deaf children are born to hearing parents, this “mismatch” between the hearing status of the child and parents may present a significant barrier to both communication and development of the parent-child relationship.^{22,23}

A variety of observational studies have found that hearing mothers of young deaf children tend to engage in more controlling, directive, and intrusive interactions with their children and are less likely to respond contingently to their behavior.²⁴⁻²⁸ These differences in maternal sensitivity are likely the result of difficulties in communication within the dyad and the challenges of meeting the deaf child's needs.²⁹ Free-play assessments have also found consistent evidence that deaf children spend less time than hearing children engaged in joint attention and spend significantly more time alone with objects.³⁰ The ability to engage, direct, and disengage attention may be a precursor for the development of cognitive and communicative competence.²³ In a study comparing visual attention in deaf children using cochlear implants vs hearing aids, researchers found significant improvements in visual attention for the cochlear implant group, and these improvements occurred rapidly, preceding the measured improvements in oral language.⁸

For our study, we hypothesize that increases in auditory input via a cochlear implant will lead to improvements in visual attention as the child becomes more responsive to his or her environment.^{8,9} For example, as the child gains skill in attending to input from the mother, including language, the mother will be more likely to respond in a sensitive and developmentally appropriate manner, which in turn will elicit reinforcement from the child. Studies examining parent-child interactions have

shown that maternal sensitivity is a significant predictor of the development of child language, after controlling for initial levels of language and family characteristics.³¹ Associations among these domains of development are complex, and newer theories indicate that rather than being discrete or separate, the processes linking language to cognition, affect and behavior, are dynamic and bidirectional.^{7,32} Thus, in our work, we plan to measure these variables longitudinally and examine their links and interactions over time.

The present article reports on the progress of an ongoing study recently begun to evaluate a broad range of outcomes in young deaf children receiving cochlear implants. The overarching premise of this larger study is that earlier restoration of auditory input via a cochlear implant will facilitate a more normal trajectory of development in deaf children and potentially assist them in reaching developmental milestones equivalent to those of their hearing peers.

This larger study will be unique in several respects. First, most of the deaf children enrolled will be younger than 2 years, which could highlight the importance of earlier restoration of auditory input for children's development.^{33,34} Second, a range of psychosocial outcomes will be assessed, including the child's visual attention and problem-solving skills, level of symbolic play, and social adjustment. Third, we will attempt to capture the bidirectional processes that potentially lead to successful use of a cochlear implant, including parents' communicative competence, the child's development of oral language, and the quality of the parent-child relationship. Finally, to address the complex set of questions associated with this area of research, we have used a multidisciplinary approach, bringing together expertise from otolaryngology, audiology, speech pathology, and psychology.

Given the young age of the deaf children in our study, it has been challenging to develop age-appropriate tasks to measure our key constructs. In the present article, we will outline the innovative methods we are applying in our ongoing study and will illustrate their use with some preliminary data comparing deaf children with hearing controls.

FREE PLAY

Developmental research commonly uses 10 minutes of free play with a set of age-appropriate toys, typically with the parent present.^{35,36} In our study, we are using one set of toys for children 24 months and younger and a different set for children aged 24 to 60 months. The parent and child are directed to “play as you would at home,” and their interactions are videotaped. Two important constructs are measured in this task: parental sensitivity and joint attention.

Parental Sensitivity

Early in development, parent-child interactions are a key source of emotional attachment, providing the scaffolding for the development of important cognitive and behavioral skills and enhanced opportunities for communicative experiences.³⁷⁻³⁹ Evidence from a variety of studies

indicates that significant disruptions may occur in parent-child interactions between hearing mothers and their infants and toddlers with severe to profound hearing loss.^{20,40,41}

In general, observational studies have shown that, relative to mothers in either hearing or deaf dyads, hearing mothers of deaf children tend to be more controlling in their verbal and nonverbal interactions and show less touch and less positive affect with their deaf children.^{26,42,43} Furthermore, compared with dyads in which hearing status is matched, interactions between deaf children and their hearing parents tend to be shorter and have more frequent interruptions and a greater likelihood of parental domination.⁴⁴⁻⁴⁶ The consequences of these less sensitive interactions may include less secure attachment, difficulties sustaining attention, and slower development of communicative competence.⁴⁷ In a recent prospective study by Pressman and colleagues,³¹ parental sensitivity (using the “emotional availability” construct of Biringen and Robinson⁴⁸) measured in a 15-minute free-play task made significant and unique contributions to the predictions of child language gains for deaf preschoolers over a period of 1 year.

Two types of reliability have been evaluated in tasks assessing maternal sensitivity: interrater reliability and stability over time. Agreement on extent of maternal sensitivity between 2 raters observing parent-child interactions has ranged from 75% to 86%; Cohen κ coefficients have ranged from 0.81 to 0.94.^{23,31,36,49} Stability of this construct was examined in one study⁴⁹ and ranged from 0.39 (age 6-15 months) to 0.48 (age 24-36 months). These data would suggest that maternal sensitivity can be reliably assessed by independent coders and is reasonably stable over time. Through our ongoing study, we will also be able to assess the reliability of this construct across several tasks: free play, problem solving, and “art gallery.” We predict that parental sensitivity prior to cochlear implantation will be associated with greater gains in oral language after implantation. We also predict that parental sensitivity will increase after implantation and will continue to increase over 3 years of follow-up as communication and the parent-child relationship improves.

Joint Attention

Recent evidence suggests that attentional control may be dependent on the integration of multimodal sensory information.^{8,50} Beginning early in development, sound plays a role in organizing visual attention, and it is likely that this tight coupling of what the developing child hears and sees helps to organize the child's behavior and learning.^{7,46}

Several studies examining visual attention using a computerized continuous performance task have shown that deaf children aged 6 to 13 years performed worse than hearing children.¹³ However, the results also indicated that older deaf children using a cochlear implant were able to “catch up” to the performance of their hearing peers.⁸ In a second study,⁹ deaf children using cochlear implants performed better than deaf children using hearing aids. Additionally, performance on the visual attention task was correlated with parents' reports of responsiveness to environmental sounds.⁹ It should be

noted, however, that a recent effort to replicate these results did not find deficits in visual attention in the deaf sample.⁵¹ The reasons for this discrepancy are not clear.

Attentional processes have also been studied in parent-child interaction tasks with young, deaf children. Joint attention—the ability to attend to both a partner and a shared event (or object)—is a well-established developmental process that emerges in the first year of life as the infant begins to regulate attention and affect in dyadic interactions.⁵² The developmental course of joint attention has been well documented in normally hearing children and is positively correlated with language development.⁵³ It begins with simple supported joint attention in which the mother facilitates the child's attention to objects, progressing to coordinated joint attention in which the child alternates attention from a person to an object, and moving finally to symbol-infused joint attention in which symbols (such as language) modulate attentional processes between the individuals in the dyad.^{54,55}

In deaf infants, joint attention appears to develop normally until approximately age 18 months, at which point deficits in language and communication (even using gesture or sign) make it difficult for the deaf child to engage in symbol-infused joint attention.^{30,56} Prezbindowski and colleagues³⁰ found that deaf toddlers between ages 20 and 24 months spent more time in coordinated joint attention than their hearing peers but virtually no time in symbol-infused joint attention compared with their hearing peers, who spent nearly one-third of their time in this engagement state.

Interrater reliability has been evaluated for joint attention studies using both percentage agreement and Cohen κ . Agreement between coders has ranged from 73% to 100%, and κ coefficients have ranged from 0.61 to 0.74, which indicates that joint attention can be measured reliably.^{23,30,53} Few studies have assessed test-retest reliability in joint attention tasks because as the child's development progresses, their attentional skills are likely to improve.⁵⁷

In the larger study, we will assess joint attention in several tasks, including free play, problem solving, and art gallery, to test the hypothesis that deaf children show deficits in symbol-infused joint attention prior to receiving a cochlear implant but begin to spend more time in this engagement state with their parents after implant surgery. To illustrate this procedure, we coded 3 major levels of joint attention in the 10-minute free-play task for 4 deaf and 4 age- and sex-matched hearing controls using the coding system developed by Prezbindowski et al.³⁰ These children ranged in age from 31 to 50 months; no differences in age were found between the groups (mean age of deaf preschoolers, 40.0 months; mean age of hearing preschoolers, 40.5 months; $t_6=0.08$, $P=.93$). They were also matched for sex, with 3 girls and 1 boy in each group. Caregivers were also matched: 3 mothers and 1 father in both groups. Deaf children had just completed their baseline evaluations prior to implant surgery. Half of the deaf children were using total communication, and half were using oral communication. Most of the deaf children (75%) were in self-contained preschool programs, and 1 child was not currently attending an educational program.

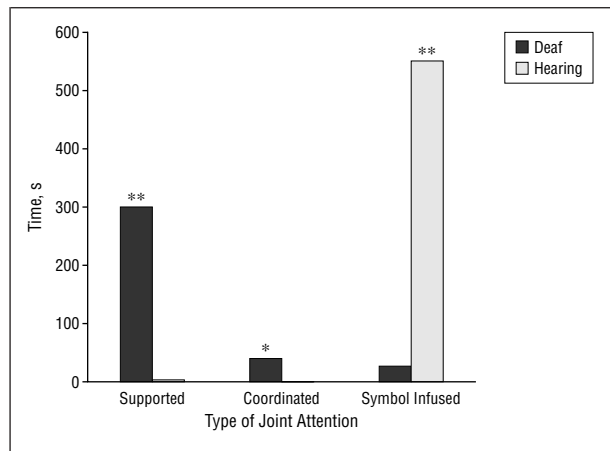


Figure 1. Comparisons of time spent in 3 types of joint attention in a 10-minute free-play task. A single asterisk indicates $P < .01$; double asterisk, $P < .001$.

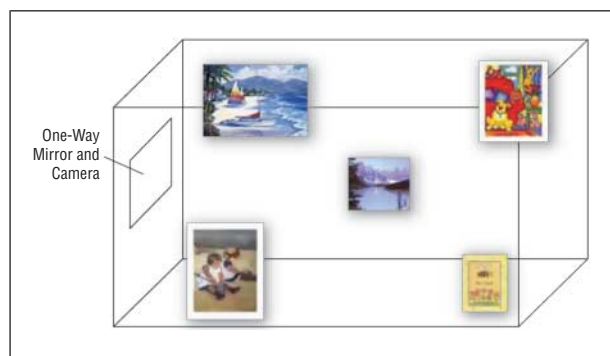


Figure 2. Setup of the room used in the art gallery task.

As predicted, results of these preliminary analyses indicated that deaf children spent significantly more time than the hearing children in supported joint attention (mean, 300.3 seconds for deaf children, 2.5 seconds for hearing controls; $t_6 = 6.85$, $P < .001$) and coordinated joint attention (mean, 37.8 seconds for deaf children, 0.0 seconds for hearing controls; $t_6 = 3.90$, $P < .01$) but significantly less time in symbol-infused joint attention (mean, 26.5 seconds for deaf children, 550.8 seconds for hearing controls; $t_6 = 20.68$, $P < .001$) (**Figure 1**). Interestingly, more detailed analyses of play behaviors showed that deaf children spent significantly more time in solitary play with objects, not interacting with caregivers, than hearing children (mean time for deaf children, 198.8 seconds; mean time for hearing children, 23.75 seconds; $t_6 = 4.90$, $P < .01$). These very preliminary results converge with prior research on differences in attentional states between deaf and hearing children and suggest that the task we are using is sensitive to these differences.

PROBLEM SOLVING

In the problem-solving task, the parent-child dyad spends 5 minutes completing 2 puzzles: one that is easy for the child to complete and one that is very difficult.⁵⁸ We selected different sets of puzzles for the younger (<24 months) and older (24-60 months) children. This task provides an opportunity to measure parental sensitivity (eg, providing assistance in solving the puzzles), the child's

behavioral responses to a difficult and potentially frustrating task, and the number of strategies the child is able to generate to solve the more difficult puzzle. We hypothesized that mothers who are more skilled in facilitating their child's problem solving and who respond more sensitively to their child's affect will have children who generate more solutions to the problem and are better able to regulate their behavior. These variables should be associated with more successful use of a cochlear implant and should improve after implantation.

ART GALLERY

In the art gallery task, the parent-child dyad is asked to look at a series of 5 art pictures that are mounted on the walls of the playroom at different heights (**Figure 2**). Parents are asked to show the pictures to the child over a period of 5 minutes and to determine which picture the child likes best and least. This task has been used in prior studies to assess parental sensitivity and communicative competence in children with atypical language development.⁵⁹ We plan to measure parental sensitivity, joint attention, and communicative competence.

SYMBOLIC PLAY

During the second year of life, 2 important and complementary representational systems are developing: the verbal system of receptive and expressive language and the system of pretend or symbolic play.^{60,61} There is a great deal of evidence indicating that these 2 systems are interrelated and that as children begin to use words spontaneously and in combination, they also begin to engage in more functional play activities with objects.⁶²⁻⁶⁵ These findings indicate that the emergence and growth of these 2 systems may underlie the development of "representational competence," a manifestation of deeper structures of the child's understanding and use of meaning, representations, and symbols.^{66,67}

In hearing-impaired children, both receptive and expressive language are often delayed, and it appears that in children 3 years and older, there are also substantial delays in cognitive aspects of their play.⁶⁸⁻⁷⁰ In younger children, the results are less consistent. Gregory and Muford⁷¹ conducted a study of deaf children aged 24 to 30 months whose language development was delayed but who did not show evidence of deficits in representational play. Deaf children in this study had difficulty coordinating play with more than 1 object and preplanning their play activities. Similarly, Bornstein and colleagues⁷² found no differences in symbolic play between deaf and hearing 2-year-olds. In a pilot study of 2-year-old deaf and hearing children, Spencer and Deyo⁷³ also found no effects of hearing status on symbolic play. However, expressive language was related to time in play, number of play sequences, and average number of play behaviors in a sequence. In a larger follow-up study with 2-year-olds, Spencer⁷⁴ found no differences between the groups in total duration of symbolic play but found that deaf children spent less time in ordered play sequences and engaged in fewer abstract (preplanned) play activities than hearing children.

Interrater reliability for symbolic play tasks has been calculated using percentage agreement and Cohen κ . Percentage agreement has ranged from 75% to 93% and κ coefficients have ranged from 0.64 to 0.95, which indicates good reliability.^{23,64,75,76} No studies have reported on the stability of symbolic play, since it is expected to change with development.

In our work, we are examining levels of symbolic play adapted from the procedure used by Hill and McCune-Nicolich.⁷⁷ A simple set of toys is presented to the child while the parent is engaged in another task (ie, completing questionnaires), and the child is videotaped in solitary play for 5 minutes. Four sets of toys are chosen and are presented in a randomized order throughout the study.

In a preliminary analysis, we coded symbolic play for 4 deaf and 4 hearing children who were matched for age. We used an adaptation of the coding scheme developed by Belsky and Most³⁵ to categorize the play behaviors of the children into 14 levels.⁷⁸ Preliminary results suggest that the deaf children's play levels ranged from simple manipulation of objects to a basic level of symbolic play involving the use of a meaningless object (eg, wooden block) in a creative way (eg, as a bed). In contrast, hearing children's play was concentrated in the 4 highest levels of symbolic play (**Figure 3**). The hearing children developed sequences of play with and without stories and were able to transform 2 meaningless objects into imaginative play.

Next, we quantified levels of play, assigning scores from 1 to 14. Using an independent samples *t* test, we found significant differences in levels of play between the groups (mean level of symbolic play for the deaf group, 6.75; mean level of play for the hearing group, 12.25; $t_6 = 2.61, P < .04$). These results confirm our hypothesis that deaf children show cognitive deficits in their use of representational or symbolic play. However, it will be important to test this hypothesis with a larger, more representative sample. Once all of the baseline assessments have been completed in our ongoing study, relationships between symbolic play and receptive and expressive language will also be tested. We predict that increased auditory input via a cochlear implant will lead to improvements in spoken language and representational play.

NOVEL NOUN LEARNING

By the end of the second year of life, typically developing children are rapidly learning new vocabulary, and by age 3 years they are highly skilled word learners.⁷⁹ Although a great deal of research has focused on the content and size of children's lexicons,^{80,81} newer studies have begun to focus on the processes that underlie children's word acquisition. Samuelson and Smith⁸² have suggested that young children learn to name new objects by categorizing their similarities in terms of shape; these researchers have proposed a series of 4 steps through which learning object names and attention to the characteristics of shape are causally related.⁸³ Their results show that children who were trained to learn the names of new objects according to their shape also showed dramatic in-

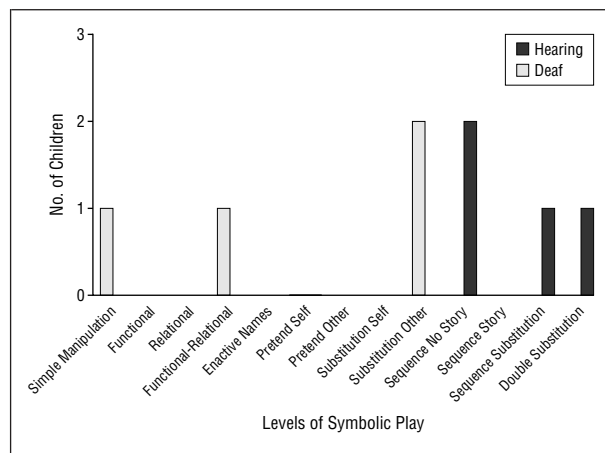


Figure 3. Comparisons of level of symbolic play in age-matched deaf and hearing children.

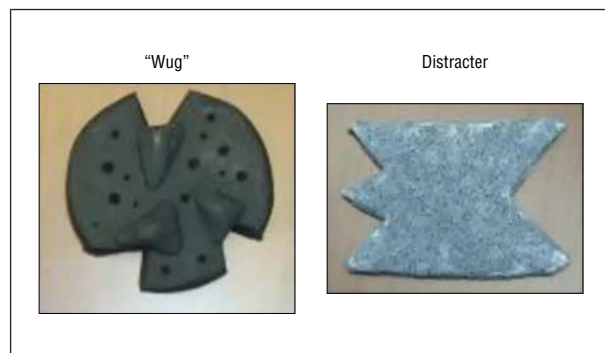


Figure 4. Stimuli for novel noun learning task.

creases in their acquisition of new object names outside the laboratory.

In general, deaf children grow up in a less rich linguistic environment and have more limited access to linguistic input than hearing children. Thus, it is important to consider how this affects their ability to learn new words. Studies of vocabulary development in deaf children have consistently found delays; deaf children's vocabulary size is smaller, their rate of vocabulary growth is slower, and the processes they use to learn new vocabulary also appear to be dependent on their vocabulary knowledge.⁸⁴⁻⁸⁶ In the ongoing study, we are evaluating not only vocabulary development using standardized measures such as the MacArthur Communicative Development Inventory,⁸⁷ but we are measuring the processes by which deaf children learn novel nouns.

For children in our ongoing study with a vocabulary of 50 words, as determined by parent report on the MacArthur Communicative Development Inventory, we measure their ability to learn novel nouns using procedures developed by Smith and colleagues⁸³ and Landau et al.⁸⁸ Interrater reliability on this task has been reported above 90%.⁸⁵ After a brief warm-up (naming simple objects using simple nouns such as "cup" and "ball") a novel object (called a "wug") is presented to the child along with a distracter object. The shapes of these 2 objects are quite different (**Figure 4**). The experimenter names the exemplar wug and presented it and the distracter object 3 times to the child, alternating their physi-



Figure 5. Puppet skits used to measure visual attention in very young children.

cal orientations. A series of generalization trials followed in which the wug retained its shape but was presented in a different color and texture (eg, changed from black to green and/or smooth to fuzzy). The child's ability to learn the novel noun was quantified by his or her correctly identifying the wug.

Our results are not final, but we predict that novel noun learning will improve after implantation and that enhanced auditory input via a cochlear implant will accelerate the child's ability to learn novel words over time using the processes documented in hearing children.

VIGILANCE AND SUSTAINED ATTENTION

The development of visual selective attention in children has been measured in a variety of tasks, including discrimination learning, speeded classification, and vigilance tasks.⁸⁹ In all of these tasks, younger children have more difficulty than older children inhibiting responses to the target information. Despite the importance of sustained and selective attention for learning and behavior, little is known about its development during the toddler or preschool period.⁹⁰ Our ongoing study will provide an opportunity to examine the development of sustained and selective attention in infants, toddlers, and preschoolers.

In hearing-impaired children, prior research suggests that school-age deaf children have significant deficits in visual selective attention compared with age-matched peers on tasks that involved no sound.^{8,9,13} Further, visual selective attention improved in children after cochlear implantation.⁸ There are several possible explanations for these results. Perhaps integrated multimodal input (auditory and visual) is necessary for the development of complex cognitive processes such as visual selective attention. Another possibility is that multimodal information allows individuals to more efficiently divide their attention (division of labor hypothesis) because they can rely on the auditory system to alert them when shifts in their visual field are needed. For deaf children, who must simultaneously use vision to accomplish specific tasks and to monitor their broader environment,⁹¹ visual selective attention as measured in a continuous performance task may be less adaptive in the real world.⁹² The findings of deficits in visual attention

in deaf children all come from studies of school-age children. Thus, in our ongoing study we aim to measure visual selective attention in much younger, deaf children before and after cochlear implantation.

Measuring visual attention in very young children has been a major challenge in our current research. Drawing on the extensive work of Ruff and colleagues,^{90,93} who measured visual attention reliably in infants as young as 5 months, we have adapted their puppet skits for our purposes (**Figure 5**). Interrater reliability was calculated using Pearson correlation coefficients, which ranged from 0.91 to 0.99.^{93,94} This indicates that coders can reliably measure visual attention in this task.

Twenty short puppet skits, lasting between 9 and 20 seconds, are presented to children on a standard VHS videotape while their eye movements and directed looking are continuously recorded. To measure sustained attention, we assess the child's visual attention to the video during the latencies between skits, which vary from 5 to 20 seconds. The puppet skits also vary in their salience from low (ie, less colorful puppets and less active skits) to high (ie, very colorful puppets like a dragon and more action on the stage). The puppet task allows us to measure sustained attention during the skits and vigilance during the latency periods.

Because we are more interested in the cumulative experience of sound and its effects on visual attention than in sound as an orienting cue in the task, the puppet skits do not contain any sound. We predict that visual attention will be poorer in the deaf children than in the hearing children but that it will improve in deaf children after a cochlear implant. Once the children in our ongoing study reach age 2.5 to 3.0 years, we will be able to use a more conventional continuous performance task to measure selective attention.

CONCLUSIONS

In sum, a major aim of our ongoing study is to evaluate the longitudinal effects of cochlear implants in young deaf children. Although oral language development is the primary outcome of our study, we are convinced that access to auditory information is likely to have profound positive effects on children's cognitive, behavioral, and social development. Rather than viewing these as separately developing systems, we anticipate there will be dynamic, interactive, and synergistic effects among these variables. As the young child begins to respond to auditory input, his or her ability to regulate attention and behavior will likely increase, which in turn will lead to improvements in the parent-child relationship and a richer context of communicative experiences. Similarly, as parents are able to respond more sensitively to their child's affective and communicative behaviors, they will be more successful in facilitating their child's attempts to master new cognitive and communicative challenges and thus in nurturing a more satisfying parent-child relationship.

Our emphasis on earlier cochlear implantation, before there are significant structural and functional changes in the brain,⁹⁵ also has important and potentially positive developmental consequences. We believe that this

offers deaf children the best hope of achieving a more normal trajectory of development. Although this has presented unique methodologic challenges, it is likely to lead to a better understanding of how the restoration of auditory input affects child development.

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REFERENCES

- Mendelson MJ, Haith MM. The relation between audition and vision in the human newborn. *Monogr Soc Res Child Dev.* 1976;41:72.
- Kuhl P, Meitsoff A. Speech as an intermodal object of perception. In: Yonas A, ed. *Minnesota Symposia on Child Psychology Volume 20: Perceptual Development in Infancy.* Hillsdale, NJ: Erlbaum; 1988:235-266.
- Walker-Andrews AS, Lennon E. Infants' discrimination of vocal expressions: contributions of auditory and visual information. *Infant Behav Dev.* 1991;14:131-142.
- Morongiello B. Effects of collocation on auditory-visual interactions and cross modal perception in infants. In: Lewkowicz DJ, Lickliter R, eds. *The Development of Intersensory Perception: Comparative Perspectives.* Hillsdale, NJ: Erlbaum; 1994:235-264.
- Perrot DR, Saberi K, Brown K, Strybel TZ. Auditory psychomotor coordination and visual search performance. *Percept Psychophys.* 1990;48:214-226.
- Roberts K, Jacobs M. Linguistic versus attentional influences on nonlinguistic categorization in 15-month-old infants. *Cogn Dev.* 1991;6:355-375.
- Smith LB, Katz DB. Activity-dependent processes in perceptual and cognitive development. In: Gelman R, Au TK, eds. *Perceptual and Cognitive Development.* San Diego, Calif: Academic Press; 1996:413-445.
- Quittner AL, Smith LB, Osberger MJ, Mitchell TV, Katz DB. The impact of audition on the development of visual attention. *Psychol Sci.* 1994;5:347-353.
- Smith LB, Quittner AL, Osberger MJ, Miyamoto R. Audition and visual attention: the developmental trajectory in deaf and hearing populations. *Dev Psychol.* 1998;34:840-850.
- Geers AE, Nicholas J, Tye-Murray N, et al. Effects of communication mode on skills of long-term cochlear implant users. *Ann Otol Rhinol Laryngol Suppl.* 2000;185:89-92.
- Svirsky MA, Robbins AM, Kirk KI, Pisoni DB, Miyamoto RT. Language development in profoundly deaf children with cochlear implants. *Psychol Sci.* 2000;11:153-158.
- Tomblin J, Spencer L, Flock S, Tyler R, Gantz B. A comparison of language achievement in children with cochlear implants and children using hearing aids. *J Speech Lang Hear Res.* 1999;42:497-509.
- Mitchell T, Quittner A. Multimethod study of attention and behavior problems in hearing-impaired children. *J Clin Child Psychol.* 1996;25:83-96.
- Freeman RD, Malkin SF, Hastings JO. Psychosocial problems of deaf children and their families: a comparative study. *Am Ann Deaf.* 1975;121:391-405.
- Quittner AL, Glueckauf RL, Jackson DN. Chronic parenting stress: moderating versus mediating effects of social support. *J Pers Soc Psychol.* 1990;59:1266-1278.
- Schlesinger H, Meadow K. *Sound and Sign: Childhood Deafness and Mental Health.* Berkeley: University of California Press; 1972.
- Achenbach T. *Manual for the Child Behavior Checklist and 1991 Child Behavior Profile.* Burlington: University of Vermont, Dept of Psychology; 1991.
- Davis A, Bamford J, Wilson I, Ramkalan T, Forshaw M, Wright S. A critical review of the role of neonatal hearing screening in the detection of congenital hearing impairment. *Health Technol Assess.* 1997;1:i-iv, 1-176.
- Davis J, Effenbein J, Schum R, Bentler R. Effects of mild and moderate hearing impairments on language, educational, and psychosocial behavior of children. *J Speech Hear Disord.* 1986;51:53-62.
- Marschark M. Origins and interactions in the social, cognitive, and language development of deaf children. In: Marschark M, Clark MD. *Psychological Perspectives on Deafness.* Hillsdale, NJ: Lawrence Erlbaum Assoc Inc; 1993:7-26.
- Stinson M, Lang H. Full inclusion: a path for integration or isolation? *Am Ann Deaf.* 1994;139:156-159.
- Gregory S, Hindley P. Annotation: communication strategies for deaf children. *J Child Psychol Psychiatry.* 1996;37:895-905.
- Meadow-Orlans KP, Spencer PE. Maternal sensitivity and the visual attentiveness of children who are deaf. *Early Dev Parenting.* 1996;5:213-223.
- Koester LS. Face-to-face interactions between hearing mothers and their deaf or hearing infants. *Infant Behav Dev.* 1995;18:145-153.
- Meadow K, Greenberg M, Erting C, Carmichael H. Interactions of deaf mothers and deaf preschool children: comparisons with three other groups of deaf and hearing dyads. *Am Ann Deaf.* 1981;126:454-468.
- Meadow-Orlans KP, Steinberg AG. Effects of infant hearing loss and maternal support on mother-infant interactions at 18 months. *J Appl Dev Psychol.* 1993;14:407-426.
- Musselman C, Churchill A. Conversational control in mother-child dyads: auditory-oral versus total communication. *Am Ann Deaf.* 1991;136:5-16.
- Spencer P, Gutfreund M. Directiveness in mother-infant interaction. In: Moores D, Meadow-Orlans K, eds. *Educational and Developmental Aspects of Deafness.* Washington, DC: Gallaudet University Press; 1990:350-365.
- Spencer P, Lederberg A. Communication and language of young deaf children and their mothers. In: Adamson L, Ronski M, eds. *Communication and Language Acquisition: Discoveries From Atypical Development.* Baltimore, Md: Brooks Publishing; 1997:203-230.
- Prezbindowski AK, Adamson LB, Lederberg AR. Joint attention in deaf and hearing 22 month-old children and their hearing mothers. *J Appl Dev Psychol.* 1998;19:377-387.
- Pressman LJ, Pipp-Siegel S, Yoshinaga-Itano C, Deas A. Maternal sensitivity predicts language gain in preschool children who are deaf and hard of hearing. *J Deaf Stud Deaf Educ.* 1999;4:294-304.
- Thelen E, Smith L. *A Dynamic Systems Approach to the Development of Cognition and Action.* Cambridge, Mass: MIT Press; 1994.
- Cheng AK, Grant GD, Niparko JK. Meta-analysis of pediatric cochlear implant literature. *Ann Otol Rhinol Laryngol Suppl.* 1999;177:124-128.
- Osberger MJ, Zimmerman-Phillips S, Koch DB. Cochlear implant candidacy and performance trends in children. *Ann Otol Rhinol Laryngol Suppl.* 2002;189:62-65.
- Belsky J, Most RK. From exploration to play: a cross-sectional study of infant free play behavior. *Dev Psychol.* 1981;17:630-639.
- NICHD Early Child Care Research Network. Child care and mother-child interaction in the first three years of life. *Dev Psychol.* 1999;35:1399-1413.
- Bakeman R, Adamson L. Coordinating attention to people and objects in mother-infant and peer-infant interaction. *Child Dev.* 1984;55:1278-1289.
- Vygotsky L. *Thought and Language.* Cambridge, Mass: MIT Press; 1962.
- Sroufe L, Egeland B, Carlson E. One social world: the integrated development of parent-child and peer relationships. In: Collins WA, Laursen B, eds. *Relationships as Developmental Contexts: The Minnesota Symposia on Child Psychology.* Mahwah, NJ: Lawrence Erlbaum Assoc Publishers; 1999:241-261.
- Meadow-Orlans K. Effects of mother and infant hearing status on interactions at twelve and eighteen months. *J Deaf Stud Deaf Educ.* 1997;2:26-36.
- Musselman C, MacKay S, Trehub S, Eagle R. Communicative competence and psychosocial development in deaf children and adolescents. In: Beithman JH, Cohen NJ, Konstantareas MM, Tannock R, eds. *Language, Learning, and Behavior Disorders: Developmental, Biological, and Clinical Perspectives.* New York, NY: Cambridge University Press; 1996:555-570.
- Musselman C, Churchill A. Conversational control in mother-child dyads: auditory-oral versus total communication. *Am Ann Deaf.* 1991;136:5-16.
- Meadow-Orlans KP, Steinberg AG. Effects of infant hearing loss and maternal support on mother-infant interactions at 18 months. *J Appl Dev Psychol.* 1993;14:407-426.
- Lederberg AR. Interaction with deaf preschoolers and unfamiliar hearing adults. *Child Dev.* 1984;55:598-606.
- Lederberg AR, Mobley CE. The effect of hearing impairment on the quality of attachment and mother-toddler interaction. *Child Dev.* 1990;61:1596-1604.

46. Swisher MV. Learning to converse: how deaf mothers support the development of attention and conversation skills in their young deaf children. In: Spencer PE, Erting CJ, Marschark M, eds. *The Deaf Child in the Family and at School: Essays in Honor of Kathryn P. Meadow-Orlans*. Mahwah, NJ: Lawrence Erlbaum Assoc; 2000:21-39.
47. Bornstein MH. Infant into conversant: language and nonlanguage processes in developing early communication. In: Budwig N, Uzgiris IC, eds. *Communication: An Arena of Development*. Stamford, Conn: Ablex Publishing Corp; 2000.
48. Biringen Z, Robinson J. Emotional availability: a reconceptualization of research. *Am J Orthopsychiatry*. 1991;61:258-271.
49. NICHD Early Child Care Research Network. The effects of infant child care on infant-mother attachment security: results of the NICHD study of early child care. *Child Dev*. 1997;68:860-879.
50. Bertenthal B, Campos J. New directions in the study of early experiences. *Child Dev*. 1987;58:560-567.
51. Tharpe AM, Ashmead DH, Rothplatz AM. Visual attention in children with normal hearing, children with hearing aids, and children with cochlear implants. *J Speech Lang Hear Res*. 2002;45:403-413.
52. Moore C, Dunham PJ. *Joint Attention: Its Origins and Role in Development*. Hillsdale, NJ: Erlbaum; 1995.
53. Tomasello M, Farrar MJ. Joint attention and early language. *Child Dev*. 1986;57:1454-1463.
54. Adamson LB, Chance SE. Coordinating attention to people, objects and language. In: Wetherby AM, Warren SM Reichle J, eds. *Transitions in Prelinguistic Communication: Perspectives to Intentional and Presymbolic to Symbolic*. Baltimore, Md: Brookes; 1998:15-37.
55. Butterworth G, Jarrett N. What minds have in common is space: spatial mechanisms serving joint visual attention in infancy. *Br J Dev Psychol*. 1991;9:55-72.
56. Spencer P, Waxman R. Joint attention and maternal attention strategies: 9, 12, and 18 months. In: *Maternal Responsiveness and Child Competency in Deaf and Hearing Children: Final Report, Grant HO23C10077*. Washington, DC: US Dept of Education; 1995.
57. Spencer P. Looking without listening: is audition a prerequisite for normal development of visual attention during infancy? *J Deaf Stud Deaf Educ*. 2000;5:291-302.
58. Easterbrooks M, Goldberg W. Toddler development in the family: impact of father involvement and parenting characteristics. *Child Dev*. 1984;55:740-752.
59. Deckner DF, Adamson LB, Bakerman R. Rhythm in mother-infant interactions. *Infancy*. 2003;4:201-217.
60. Bloom L. *Language Development: From Two to Three*. New York, NY: Cambridge University Press; 1991.
61. McCune-Nicolich L. Toward symbolic functioning: structure of early pretend games and potential parallels with language. *Child Dev*. 1981;52:785-797.
62. Lewis V, Boucher J, Lupton L, Watson S. Relationships between symbolic play, functional play, verbal and non-verbal ability in young children. *Int J Lang Comm Dis*. 2000;35:117-127.
63. McCune L. A normative study of representational play in the transition to language. *Dev Psychol*. 1995;31:198-206.
64. Striano T, Tomasello M, Rochat P. Social and object support for early symbolic play. *Dev Sci*. 2001;4:442-455.
65. Tamis-LeMonda CS, Bornstein MH. Specificity in mother-toddler language-play relations across the second year. *Dev Psychol*. 1994;30:283-292.
66. Piaget J. *Play, Dreams and Imitation*. New York, NY: Norton; 1962.
67. Vygotsky LS. Play and its role in the mental development of the child. *Soviet Psychol*. 1967;5:6-18.
68. Casby MW, McCormack SM. Symbolic play and early communication development in hearing-impaired children. *J Commun Disord*. 1985;18:67-78.
69. Gatty J. *The Effects of Deafness on Play in Four-Year-Old Boys* [dissertation]. Boston: University of Massachusetts. *Dissertation Abstracts Int*. 1990;51:737A.
70. Vygotsky L. *Mind in Society*. Cambridge, Mass: Harvard University Press; 1978.
71. Gregory S, Mugford K. The development of symbolic play in young deaf children. In: Rodgers D, Sloboda J, eds. *The Acquisition of Symbolic Skills*. New York, NY: Plenum; 1983:221-231.
72. Bornstein MH, Selmi AM, Haynes OM, Painter KM, Marx ES. Representational abilities and the hearing status of child/mother dyads. *Child Dev*. 1999;70:833-852.
73. Spencer P, Deyo D. Cognitive and social aspects of deaf children's play. In: Marschark M, Clark M, eds. *Psychological Perspectives on Deafness*. Hillsdale, NJ: Erlbaum; 1993:65-91.
74. Spencer P. The association between language and symbolic play at two years: evidence from deaf toddlers. *Child Dev*. 1996;67:867-876.
75. Casby M, McCormack S. Symbolic play and early communication development in hearing-impaired children. *J Commun Disord*. 1985;18:67-78.
76. Shore C, O'Connell B, Bates E. First sentences in language and symbolic play. *Dev Psychol*. 1984;20:872-880.
77. Hill PM, McCune-Nicolich L. Pretend play and patterns of cognition in Down's syndrome children. *Child Dev*. 1981;52:611-617.
78. NICHD Study of Early Child Care. *Phase I Instrument Documentation*. 1999:180-184. Available at: <http://secc.rti.org/instdoc.doc>. Accessed June 17, 2003.
79. Bloom P. *How Children Learn the Meanings of Words*. Cambridge, Mass: MIT Press; 2000.
80. Golinkoff RM, Hirsh-Pasek K, Hollich G. Emerging cues for early work learning. In: MacWhinney B, ed. *The Emergence of Language*. Mahwah, NJ: Erlbaum; 1999:305-329.
81. MacWhinney B, ed. *The Emergence of Language*. Mahwah, NJ: Erlbaum; 1999.
82. Samuelson L, Smith LB. Early noun vocabularies: do ontology, category structure, and syntax correspond? *Cognition*. 1999;71:1-33.
83. Smith LB, Jones SS, Landau B, Gershkoff-Stowe L, Samuelson L. Object name learning provides on-the-job training for attention. *Psychol Sci*. 2002;13:13-19.
84. Lederberg AR, Spencer PE. Vocabulary development of deaf and hard of hearing children. In: Clark MD, Marschark M, Karchmer M, eds. *Context, Cognition, and Deafness*. Washington, DC: Gallaudet University Press; 2001:88-112.
85. Lederberg AR, Prezbindowski AK, Spencer PE. Word-learning skills of deaf preschoolers: the development of novel mapping and rapid word-learning strategies. *Child Dev*. 2000;71:1571-1585.
86. Mayne A, Yoshinaga-Itano C, Sedey A. Receptive vocabulary development of infants and toddlers who are deaf or hard of hearing. *Volta Rev*. 1998;100:29-52.
87. Fenson L, Dale PS, Resnick JS, et al. *The MacArthur Communicative Development Inventory: Words and Gestures*. San Diego, Calif: Singular Publishing Group Inc; 1993.
88. Landau BB, Smith LB, Jones SS. The importance of shape in early lexical learning. *Cogn Dev*. 1988;3:299-321.
89. Aslin RN, Smith LB. Perceptual development. In: Rosenzweig MR, Porter LW, eds. *Annual Review of Psychology*. Palo Alto, Calif: Annual Reviews; 1988:435-473.
90. Ruff HA, Lawson KR. Development of sustained, focused attention in young children during free play. *Dev Psychol*. 1990;26:85-93.
91. Swisher MV. Visual reception of sign language in young deaf children: is peripheral vision functional for receiving linguistic information? In: *Second International Symposium on Cognition, Education, and Deafness, Working Papers*. Washington, DC: Gallaudet University Press; 1989:33-46.
92. Mitchell TV. *How Audition Shapes Visual Attention* [dissertation]. Bloomington: Indiana University Bloomington; 1996.
93. Ruff HA, Capozzoli M, Dubiner K, Parrinello R. A measure of vigilance in infancy. *Infant Behav Dev*. 1990;13:1-20.
94. Ruff H, Capozzoli M, Weissberg R. Age, individuality, and context as factors in sustained visual attention during the preschool years. *Dev Psychol*. 1998;34:454-464.
95. Ryugo D, Rosenbaum B, Kim P, Niparko J, Saada A. Single unit recordings in the auditory nerve of congenitally deaf white cats: morphological correlates in the cochlea and cochlear nucleus. *J Comp Neurol*. 1998;397:532-548.