2005

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IDENTIFICATION OF FACTORS PREDICTING SPOKEN LANGUAGE DEVELOPMENT IN YOUNG CHILDREN WITH A COCHLEAR IMPLANT

by

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An independent study submitted in partial fulfillment of the requirements for the degree of:

Master of Science in Deaf Education

Washington University School of Medicine
Program in Audiology and Communication Sciences

May 20, 2005

Approved by:
Dr. Johanna Nicholas, Independent Study Advisor

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The variability in outcomes for children with cochlear implants has been the subject of recent studies. Researchers have proposed many possible predictors of speech, language, reading, and academic achievement in an attempt to set realistic expectations and rehabilitation goals for these children. The majority of children who are implanted at a young age display significant gains in spoken language development over time. However, there is still more variability in the language development of deaf children with cochlear implants than there is in children with normal hearing. There are still some children who seem to obtain little benefit from their cochlear implant and with the population of implant candidates becoming increasingly younger, it becomes more difficult to assess which children will be successful. In this study, we explore audiological, demographic, and educational variables which may explain the variability in language achievement in cochlear implant users.

Child Characteristics

Etiology of Deafness

Studies show that etiology, or cause, of deafness may be related to outcomes with the cochlear implant. These results, however, may be misleading. When etiology was found to be a significant predictor of outcome, it was often the case that other disabilities were related to the etiology that negatively affected performance. Meningitis is linked with poorer outcomes in several studies (Issacson, Hasenstab, Wohl & Williams, 1996; Bauer, Geers, Brenner, Moog & Smith, 2003). Children with meningitis also display a higher incidence of learning disability, attention deficits, behavioral problems, or other disadvantageous neurological sequelae than children not affected by the disease. It may be these conditions/disorders, caused by the onset of meningitis, that actually delay the progress of implanted meningitis survivors. This issue is further discussed in the 'multiple disability' section below. The Meaningful Auditory Integration Scale (MAIS) scores of implanted children with and without a meningitis history were compared in a study by Quittner and Steck (1991). The scores did not differ significantly when the two groups were compared, meaning that this etiology was not found to be a predictor of auditory performance with a cochlear implant. Therefore, the presence of a history of meningitis may not be the cause of poor performance, and the affects that meningitis can have on other cognitive processes may be related to individual variability in outcome.

Syndromes are defined by the presence of several symptoms that occur together, resulting in a specific outcome. Deafness may be only one aspect of a syndrome that affects a child. Children with syndrome-related causes of deafness scored significantly lower than children with non-syndromic etiologies on tests of receptive language and speech intelligibility. In a study by Rajput, Brown, and Bamiou (2003), the differences between the groups became evident after a year of experience with the cochlear implant (Rajput, Brown & Bamiou, 2003). Performance in children with a genetic etiology of deafness was further explored in a study by Bauer et al. (2003). The presence of the gap-junction protein *GJB2* was found to be a significant predictor of better reading and cognitive performance when compared to children who tested negative for the mutation, but were matched with other cochlear implant recipients on other variables. However, children who did not have the genetic mutation had etiologies that may have been related to CMV or meningitis, both of which have the potential to affect cognitive functioning. The authors attributed the more positive results of *GJB2*-positive children to the isolated damage to the auditory system, which left the cognitive abilities of these children intact (Bauer et al., 2003).

Disability

The effects of severe to profound hearing impairment are widely known to be serious, especially in relation to understanding and using spoken language. Children with disabilities in addition to their auditory deficit may experience further obstacles in learning language and succeeding academically. It may be difficult to close the gap in performance in language and auditory development between hearing-impaired children with learning disabilities and their normally hearing peers. The utility of a cochlear implant in multiply disabled children has been addressed in many studies.

In a study of implanted children with a history of meningitis, those with diagnosed learning disabilities exhibited poorer performance in tests of speech perception and expressive and receptive vocabulary. This finding was important in that the results indicated that the learning disability, not the etiology of deafness, may have been responsible for poorer performance with the implant. Cochlear implants have been found to benefit these children, although their progress is usually slower and less consistent than that of hearing impaired children without learning disabilities (Isaacson et al., 1996). In another study, implanted children with disabilities beyond their hearing impairment were likely to score below average on tests of language, vocabulary, and nonverbal intelligence. This study also indicated that the cochlear implant was beneficial, but progress was slower than is usually expected from comparable non-multiply disabled implant users (Spencer, 2004). Rajput et al. (2003) found a negative correlation between disability score (higher scores indicating higher level of disability) and receptive language development after more than three years experience using the cochlear implant.

In deaf infants and very young children, testing for physical and cognitive delays may be difficult. However, questionnaires and checklists that are sensitive to developmental delays may be used to indicate early signs of disability. The lowest performers in a study of post-implant spoken language development were found to also have mild developmental delays (Hammes et al., 2002).

Intelligence

In most assessments of deaf children, nonverbal intelligence is measured instead of verbal intelligence to avoid confusing language delay with cognitive deficiency. If verbal intelligence tests were used, a deaf child's impaired language and vocabulary development would interfere with the assessment of nonverbal abilities and would misrepresent the child's true abilities. Intelligence has long been thought of as a possible predictor for performance in deaf children with cochlear implants. Although research is inconsistent in finding correlations between overall nonverbal IQ scores and cochlear implant outcomes, several studies have found relationships with specific subtests. These findings raise interesting questions about certain innate abilities that may affect a child's use of the implant.

In a study by Quittner et al. (1991), overall nonverbal IQ was not a significant predictor of meaningful use of auditory information with the implant. However, the Picture Arrangement and Block Design subtests of the WISC-R had a significant positive correlation with higher ratings on the same checklist of use of the implant in everyday listening situations. The Block Design subtest is considered to be the most valid measure of higher level cognitive functioning among the performance subtests on the WISC-R. It is thought to measure concrete and abstract reasoning applied to spatial relationships. In another study, a subtest of visual-spatial performance intelligence was found to be the strongest predictor of receptive language scores in cochlear implant users ages 5 to 11 years (Dawson, Busby, McKay & Clark, 2002). Dawson et al. (2002) also reported that short-term auditory memory accounted for a significant amount of variance in receptive language scores for the deaf children using cochlear implants, but not for hearing children given the same tests. In the study by Bauer et al. (2003), children with the *GJB2* allele variants scored higher on the Block Design subtest and were also found to perform better on language and reading outcomes. Overall performance on the nonverbal intelligence test was not a predictor of the same outcomes. The results found in these studies indicate that there may be specific areas of intellectual functioning that affect how the child can integrate and make use of the stimulation delivered by the cochlear implant. In particular, spatial reasoning tasks seem to be a common predictor of language outcomes for young cochlear implant users.

In contrast to the studies mentioned above, some research has linked overall performance IQ to speech and language outcomes in implanted children. Geers, et al. (2002) found performance on a nonverbal intelligence test accounted for significant variance in auditory, speech, language, and reading outcomes in children who received an implant between 2 and 5 years. The researchers concluded that nonverbal intelligence was the most important innate predictor of post-implant outcomes. Nonverbal cognitive performance was significantly positively correlated with measures of syntax and pragmatic skills in a small group of participants studied by Spencer (2004). It is possible that overall nonverbal intelligence may be correlated with specific outcomes or measures of these outcomes, which would account for the lack of consistency in the research.

Many studies attempt to control for the affects of intelligence by allowing only children with at least average intelligence scores to participate in studies. However, as the age of implantation continues to decline over time, it becomes more difficult to test for variables such as cognitive functioning. In some cases, developmental scales and measures of early communicative behaviors must take the place of formal intelligence testing in younger populations.

Prelinguistic Communication

Kane, Schopmeyer, Mellon, Wang, and Niparko (2004) attempted to use pre-implant prelinguistic communication behaviors such as gestures, vocalizations, verbalizations, and social-affective signaling to predict formal language outcomes post-implantation. The researchers found a positive relationship that did not reach statistical significance between the measures of prelinguistic and formal language skills. Although very high prelinguistic communication scores did not predict future receptive and expressive language scores, children with very low scores on the prelinguistic measure tended strongly toward low scores on the post-implant formal language test (Kane et al., 2004). When assessing very young children as cochlear implant candidates, poor prelingual communication skills may alert teachers, parents, and therapists to the possible need for extensive work in this area before formal language can develop.

Age of Onset of Deafness and Early Access to Sound

It appears that age of onset of deafness may affect a child's post-implant performance on a range of outcome measures. Even a short period of time during which the child could hear may provide benefits in using the implant effectively or in learning language. Research has shown that the mechanisms necessary for hearing are in place long before a child is fully developed in-utero. Babies can hear and discriminate sound before they are born. Congenitally deafened children do not experience this early auditory stimulation, which may put them at a disadvantage when they first receive this from the cochlear implant. Researchers also hypothesize that there are certain age frames when an infant is more receptive to sound and speech in their environment, which may impact future outcomes. In addition, it is not possible to determine whether the performance outcomes are being affected by age of onset, or other related factors such as etiology or age of identification.

Although congenitally deaf children with a profound hearing loss are almost completely deprived of meaningful sound until implantation, Spencer (2004) found that auditory experience provided by hearing aids before implantation could significantly affect post-implant performance. The children in the study who received early amplification were found to score better on all tests of language and speech testing performance after implantation. However, there was a small sample size, which means these findings can not be generalized to a larger population of deaf children.

Studies have shown that children with some previous access to auditory information may exhibit an advantage over children without this benefit. Geers, Nicholas, and Sedey (2003) found that the onset of deafness after birth predicted better scores for overall language development (combined speech and sign). This advantage was apparent even when the deafness occurred during the pre-lingual period of life. Geers et al. (2002) found similar results in an earlier study of rehabilitative factors affecting cochlear implant users. Children in this study who experienced some period of normal hearing, no matter how small, exhibited a trend of better overall language performance and reading skills. Spencer (2004) found that children deafened by meningitis at age two were the highest performers on a test of receptive and expressive language. However, there were only two such subjects that participated in the study, making it difficult to generalize these findings to the other deaf children with cochlear implants. Spencer (2004) also found that a child with a congenital severe-profound hearing loss that received benefit from hearing aids (as compared to profound hearing loss) performed better on language testing post-implantation. In a different study, age of onset of deafness accounted for a significant proportion of variance in parent ratings of their child's effective use of the cochlear implant (Quittner et al., 1991). Children who were deafened later in life were found to make better use of their implants in everyday listening situations. When early communicative behavior was used as a measure of performance in early implanted subjects, no significant difference was found between children with congenital and acquired deafness (Lutman & Tait, 1995). Age of onset of deafness was not found to be a significant predictor of speech perception outcomes in a study by Daya, et al. (1999). However, the researchers did find that subjects who lost their hearing due to meningitis (non-congenital) tended to show higher rates of improvement in speech perception when compared to congenitally deafened individuals.

Family Characteristics

Parent Involvement/Motivation

Parental involvement and motivation in the cochlear implant process, both pre and post-surgery, has been positively related to outcomes in many studies. Spencer (2004) found that personal parental involvement in the process of deciding upon cochlear implantation and the subsequent educational rehabilitation was positively correlated with linguistic development in implanted children. Those parents who spent a longer period of time deciding on the implant for their child, obtaining information from various resources, tended to be the most actively involved in their child's rehabilitation post-implantation. Parental supportiveness and expectations about outcomes are being increasingly considered in the candidacy process for implanting young children (Knuston, et al., 1991).

Socioeconomic Status

Socioeconomic status (SES) is often considered in relation to outcomes for children. Results from studies related to implanted children have yielded inconsistent results. Higher SES, as determined by parent income and education, was associated with higher levels of language development in a study by Geers, Nicholas, and Sedey (2003). However, a similar measure of SES was not significantly correlated with better outcomes when nonverbal IQ was removed as a factor in performance (Geers et al., 2002). Since many other factors may be related to SES, such as educational opportunities, language exposure and experience, and health, it is difficult to determine how much SES contributes as an independent predictor.

A study by Hoff-Ginsberg (1991) looked at the differences in maternal child-directed language in upper middle-class and working-class mothers. This study was prompted by previous findings that indicated a relationship between a child's vocabulary and syntax, and the characteristics and amount of language used by their mothers (Barnes, Gutfreund, Satterly, & Wells, 1983; Snow, Perlmann, & Nathan, 1987; Tomasello & Farrar, 1986). These characteristics had also been found to vary by the family's social class (Farren & Haskins, 1980). Hoff-Ginsberg (1991) found that the language used by mothers while interacting with their child in various contexts did differ across social class. This variability was thought to be related to general differences in the mothers' conversational style, which was evident in their adult-directed conversation. Although the study did not analyze how this affected the child's language, the ways in which maternal speech was dissimilar had been found in the previous studies to have an effect on child language development. The study indicates that the effects of socioeconomic status on both mother and child language may be much more intricate and complex than variations in income alone. Both internal (attitude and conversational style) and external circumstances (stress and time constraints) may affect mothers of varying social classes differently and can, in turn, influence the diversity and depth of the child's language.

Family Size

Several studies have found that smaller family size may be a predictor of better post-implant incomes. Geers, Nicholas, and Sedey (2003) found that implanted children from smaller families may have been predisposed to more highly developed receptive and expressive English language skills. In another study, Geers et al. (2002) found that children with an implant from a smaller family tended to score higher on language tests. However, characteristics particular to the families of the children included in the study did not serve as predictors of linguistic performance overall, provided that there was a sufficient level of motivation and post-implant rehabilitation. Smaller family size may allow parents to spend more time interacting with their deaf child one-on one. This kind of intense language input and exchange can be extremely beneficial to a child with an implant, who is most likely to be language delayed and attempting to make sense of the new speech sounds he or she is hearing. However, it may also be important for a child with a cochlear implant to receive the type of language model that can be provided by normally hearing siblings in larger families.

Educational Characteristics

Classroom Placement

The goal of most auditory-oral educational programs is to "mainstream" the student into a regular education classroom. This setting, being the least restrictive and the closest to the experience of the majority of children, is thought to be most preparatory for real-world educational and occupational experiences. Several studies have sought to determine the effects of classroom placement, ranging from categorical special education to public mainstream, on language outcomes. Geers, Nicholas, and Sedey (2003) found that children who were in a mainstream classroom setting for a longer period of time tended to achieve better overall linguistic competence. Although these findings seem to show that mainstream placement is beneficial, children who are placed in the mainstream are usually at a higher language level to begin with. If a child can not keep up with the mainstream curriculum and requirements, that child is usually not placed in that environment. Therefore, a higher language level may be the precursor to mainstream placement, as opposed to an effect of the placement. Geers (2002) found that class type (public vs. private and mainstream vs. special education) was not strongly related to reading, language, and speech outcomes. The communication mode used within the classroom was the more important factor in determining these outcomes.

Communication Mode

Children in auditory-oral classrooms, with a strong emphasis on speech and auditory skills, often display greater achievements in these very areas. Total-communication programs, which incorporate sign language and spoken language, are often cited in comparison to oral programs. The question remains whether or not an emphasis on oral language will be detrimental or advantageous to young deaf children's linguistic development. It is possible that stressing the development of an oral language system may be too difficult or unclear to a deaf child who is receiving imperfect input from his or her cochlear implant. It is also possible that the use of signs may hinder the development of spoken language, and may result in further confusion about language as a whole.

Subjects in the study by Geers et al. (2002) displayed better outcomes as the emphasis on speech and auditory development in the classroom increased. The children in oral classrooms received the highest levels of exposure to oral language and formal auditory training and were thought to be the most capable of utilizing the information they received from their implants to listen, speak, and read. In fact, communication mode used in the classroom was the strongest overall predictor of auditory and spoken language development in the study. Similarly, Quittner et al. (1991) found that communication mode accounted for significant variance in ratings of children's effective use of sound in everyday listening situations (MAIS). Children in classrooms with an emphasis on oral communication scored significantly higher than children in programs utilizing sign language. It is important to keep in mind, however, that factors related to why a family might choose to place their child in such a program, such as SES and parental education, could influence outcomes.

Several studies have found that communication mode and receptive language are not significantly related, meaning that children in oral and total-communication programs did not differ significantly on tests of receptive language (Geers et al., 2003; Rajput et al., 2003; Geers et al., 2000). However, children in oral communication programs did have significantly higher scores on expressive language competence when a conversational interaction was analyzed (Geers et al., 2003). It is important to note that this expressive language advantage was evident even when the expressive signs of the children using Total-Communication were included in their language scores.

On a test of both receptive and expressive language ability, Spencer (2004) found that children with scores at both the high and low extremes were found to be enrolled in oral communication programs. Children from Total-Communication programs tended to score in the mid-range when compared to the other children with implants in the study. These findings seem to indicate that oral-communication programs may an advantage to some children, but a disadvantage to others. The literature seems to indicate that no one method of communication is appropriate for every deaf child with a cochlear implant and may vary according to the language goals (spoken vs. speech/sign). However, it is always necessary for a child with a cochlear implant to undergo intensive aural rehabilitation if he or she is to obtain the highest possible level of spoken language achievement with the device. Since children in oral-communication programs tend to spend more time listening and depending on sound to communicate, their speech perception and production is likely to improve (Moog & Geers, 1999). The ability to perceive and discriminate speech sounds may provide the foundation for future linguistic development, both expressive and receptive (Geers et al., 2003; Spencer, 2004; Moog & Geers, 1999). In their study, Moog and Geers (1999) found that only two of the ten children with less than average speech perception scores achieved normal language levels. The researchers concluded that speech perception was essential to the development of normal language levels in an oral-communication classroom setting.

Audiological Characteristics

Age of Implantation

As cochlear implantation becomes a more common and trusted option for profoundly deaf children and their families, a great deal of research has been dedicated to the effects of early implantation. Concerns about auditory deprivation at possible ‘critical’ times for language development have been expressed in relation to infants who can not benefit from being immersed in a world of speech as a result of severe to profound hearing impairment. These children often receive little to no benefit from the most powerful of hearing aids. Currently, profoundly deaf babies as young as 12 months of age are approved by the FDA for cochlear implantation (if they meet other candidacy requirements). In emergency situations, where the integrity of the cochlea is in danger due to ossification, infants younger than one year of age have been successfully implanted. Since the decision to surgically implant the device in a very young child is quite difficult on the part of the parent and the clinician, researchers have attempted to discover whether or not early implantation provides advantages in outcome measures post-implantation as compared to later implanted children. If such an advantage exists, it is also important to understand how early the implantation should occur to obtain more positive results, without incurring unwarranted surgical risks.

Many studies have found advantages in post-implant outcomes for children implanted before five years of age. In one study, Geers, Nicholas and Sedey (2003) found that half of the children who were implanted early (before 5 years) reached receptive and expressive language levels that were at or close to the average scores of their normally hearing peers after 4 to 7 years of experience using the implant. However, age of implantation within the group of children implanted under five years of age was not found to be a significant predictor of language performance. Children implanted between two and three years of age did not display a significant linguistic advantage over those children implanted between the ages of four and five (Geers et al., 2003). El-Hakim et al. (2001) found that children who were implanted after 5 years of age were at a significant disadvantage in expressive and receptive vocabulary acquisition rates after implantation. It is important to notice that there was considerable individual variation in the outcomes for both younger and older implanted children, although the earlier implant group exhibited less variability than the older group. Age of implantation was also found to affect trends in school setting over time and experience with the implant. In one study, children implanted before five years of age tended to move from private or special education settings toward mainstream and public school settings. These deaf children, with the benefit of a cochlear implant, moved towards one of the educational goals for all children with special needs, the least restrictive environment (Geers & Brenner, 2003).

Research has also shown a significant linguistic advantage for early implantation within groups of children implanted before their fifth birthdays. In children implanted between 14 and 38 months, the congenitally deafened children implanted closer to 14 months of age obtained better scores on the CELF language assessment, which relies heavily on syntax skills. Age of implantation accounted for significantly more variance in CELF scores than non-verbal intelligence. However, age of implantation was not found to be significantly correlated with scores on tests of vocabulary or pragmatic skills (Spencer, 2004). In a study of children implanted between 9 and 48 months, researchers found that being implanted as early as possible was a significant predictor of more positive outcomes with the implant. On average, the younger the child was implanted, the higher the likelihood for that child to develop auditory and oral skills to allow that child to rely on spoken language as a sole means of communication. As age of implantation increased, the children began to lag further behind their hearing age-mates in language skills (Hammes et al., 2002). Clearly, length of auditory deprivation prior to implantation affects the severity of the existing language delay. Both the size of the initial delay at the time of surgery and the subsequent growth rates are important factors in evaluating the benefits of cochlear implantation in children.

A study by Nikolopoulos, O'Donoghue, and Archbold (1999) indicated the importance of length of cochlear implant experience when evaluating device benefit. In this study, the post-implant speech and auditory outcomes of children implanted between 21 and 82 months were recorded over several years. After at least three years of experience using the cochlear implant, children in this study that were implanted earlier exhibited significantly higher performance than the later implanted children. Before the three year mark, however, there was a positive correlation between age of implantation and speech and auditory performance, meaning that children implanted later were at an advantage. The researchers felt that these results were due to a lack of benefit provided by the implant early in the post-implantation period. The positive correlation may have been due to the advantage of age and cognitive development, rather than actual speech and auditory skills. After all children had the advantages of auditory training and participation in an auditory rehabilitation program for a substantial period of time, age of implantation became negatively correlated with performance scores (Nikolopoulos et al., 1999). It has been found that children with the best open-set speech perception skills develop the highest receptive and expressive vocabulary and language skills (Moog & Geers, 1999). These results pose the possibility that early implantation is important for the greatest auditory outcomes, which, in turn, has a positive affect on vocabulary and language performance.

It is important to note that there is considerable individual variability in performance of early and late implanted children reported in most studies. The more positive results of children with early implantation were not consistent for *all* children in the group. There are obviously other factors that must be considered when attempting to predict or explain a specific child's performance with a cochlear implant.

Implant Variables

In addition to the characteristics that the child, family, and educational program bring to a particular situation, the cochlear implant itself may contribute important variance to language outcomes. Geers et al. (2002) found that the overall functioning of the implant was a predictor of a significant amount of variance in language outcomes. Implant function accounted for more variance than the child/family or rehabilitative factors considered in the study. Children with more active electrodes in their individual MAP also displayed better outcomes. Geers et al. (2002) also stressed the importance of replacing old equipment as new technology becomes available. Cochlear implant manufacturers are continuously developing new external equipment (processors) that are often compatible with older internal implant components. The audiologist also plays a significant role in maximizing the benefit a child receives from his or her cochlear implant. A MAP with a wide dynamic range and good loudness growth appears to contribute to better speech, language, and reading outcomes (Geers et al., 2002).

Purpose of the present study

The purpose of the present study was to do a preliminary analysis of child, family, educational, and audiological factors that may predict scores in receptive and expressive spoken language development at age 4.5 years in children who received an implant by their 3rd birthday. It is predicted that age at cochlear implantation (or duration of use, which is the same variable in this study) will be the most highly predictive factor. It was also of interest to see whether parent report of vocabulary scores at age 3.5 years was predictive of overall language at 4.5 years.

METHOD

Participants

Seventy-two children from across the United States and Canada who received a cochlear implant between the ages of 12 and 37 months of age were participants in this independent study project. The data from these children was obtained from an ongoing study on the effect of age of cochlear implantation (Nicholas & Geers, 2004). In that study, children were tested on two dates: first at 3.5 (± 2 mos.) years of age, and again at 4.5 (± 2 mos.) years of age. The children had been using a cochlear implant for at least 18 months at the second testing date. All participants had documented normal or above normal nonverbal intelligence and had no conditions other than hearing loss that would be expected to interfere with the development of communication. All children had been consistently enrolled in an auditory-oral or an auditory-verbal program of intensive speech and language therapy since receiving the implant and came from families in which English was the primary language and/or the only langue spoken to the child at home. All hearing losses were presumed to be congenital as children were excluded from the study if there was any evidence or suspicion that the child had once had normal hearing or had a progressive hearing loss. The children were implanted with a Cochlear Corporation, Advanced Bionics Corporation, or Med-El cochlear implant. Finally, all children had a full insertion of the electrode array at the time of surgery and had no interruption of implant use for a period greater than 30 days.

Administrators at host sites, including hospitals, schools, child development centers, and auditory-verbal therapy practices, were asked to review their rosters for all children who met the criteria detailed above. The parents of the children who met the criteria were given a letter describing the study and a release of information form to sign if they were interested in participating. A research team member then traveled to the child's school or therapy location and completed the data collection in that setting.

A detailed description of the participants can be found in Appendix A (see Appendix A). A Parent Questionnaire was completed by each parent at the 3.5 year testing date (see Appendix B). In the initial general information section of the questionnaire, parents were asked to provide information about the child's birth date and gender. In addition, the parent answered a question about the child's current educational placement (*The child is currently enrolled in _____ program since _____*). The parent was also asked to list any previous programs the child was enrolled in and the respective dates (*Previous programs ______ Dates: ________*).

Pregnancy and delivery information was taken from the 'health information' section of the parent questionnaire. The parent responded to questions asking if there was anything unusual about the pregnancy, delivery, or labor (ex: confined to bed, operation). The 'health information' section also contained a question about the baby's weight in lbs and ounces. In this section, the information about hospital stays provided information about NICU stays. Parents also answered a question about ear infections (*Any history of ear infections?*) and childhood illnesses (a list of common illnesses was provided as well as an open ended question about the child's overall health). A specific question about diagnosed disabilities in addition to deafness was also listed in the 'health information' section (*Has the child been diagnosed with any problems in addition to the hearing loss? e.g. ADD, CP, Developmental Delay, Learning Disabled, Speech Problems*). The parent was also asked who the diagnosis was made by and when.

In the 'family section,' parents were asked to answer questions about the child's living situation, language environment, parent age and education level, ethnicity, and income. Parents were asked to place a check next to the income category that their family income fit into to gain income information. Parents also marked next to the ethnicity that best described their child. The choices are listed in the table below. The majority of children came from families earning over $60,000, which is not typical of the general population. The majority of children were white (not Hispanic). The parent questionnaire listed spaces for mother and father's age, mother and father's occupation, and mother and father's highest level of education completed. The survey also specified that the information provided should apply to the "person or persons living with the child, regardless of whether or not they are the child's natural parents." Information about single-parent households was taken from a question that asked the parent to list the adults presently living with the child. The 'family information' section also asked specifically whether the child was "regularly exposed to a language other than spoken English." If the parent answered yes, he or she was asked to provide the language used, who it was used by, and how often the child was exposed to it.

Audiological variables were taken from both the Parent Questionnaire and an Audiological Questionnaire completed by the child's current audiologist (see Appendix B). In the 'Audiological Information' section of the Parent Questionnaire, the parent was asked at what age the hearing loss was first suspected and diagnosed (in years and months). The section also contained a question about the age when the child first used a hearing aid and how frequently the hearing aid was used (rarely, sometimes, mostly, or all waking hours). The parent was also asked if the child continues to wear a hearing aid in his or her non-implanted ear. Finally, the Parent Questionnaire contained a question about problems experienced with the implant (*Have there been any problems associated with using the implant? If yes, please describe.*). Problems listed included electrical surges, over stimulation, redness and lymphademitis, processor replacement, re-implantation, software problems, and electrodes turned off. The incidence of problems with the implant within this population was very low (six out of seventy-two experienced problems). The audiologist provided information about the type of implant, processor, and processing strategy. Exact age of implantation was also confirmed using the Audiological Questionnaire. Audiological records provided information about the child's better ear pure tone unaided threshold before implantation. A quantitative summary of participant characteristics can be seen in Appendix A.

Design and Procedure

In addition to the Parent Questionnaire described above, the child's audiologist completed Audiological Questionnaires when the participant was 3.5 and 4.5 years of age. Parents of seventy-one out of the seventy-two children had completed MacArthur Child Development Inventory forms ("Words and Sentences" form) when their child was 3.5 years old. This instrument was used to determine the size of the child's vocabulary at that point in their development. The mean number of words produced on this measure was 362.6 (s.d. = 184.7), with a range of 8 – 679. Individual scores on this measure will be correlated with scores on the language testing done at 4.5 years to see whether they have predictive value. Participants were administered the Preschool Language Scale - III (PLS-III; Zimmerman, Steiner, & Pond, 1992) at age 4.5 years.

Independent Variables

The independent variables of interest for this independent study were: gender, MacArthur CDI number of words score, ear infection history, family income, parent education, age of first educational intervention, type of educational intervention, age of hearing loss diagnosis, age of implantation, age hearing aids were received, and pre-implant better ear unaided pure tone thresholds.

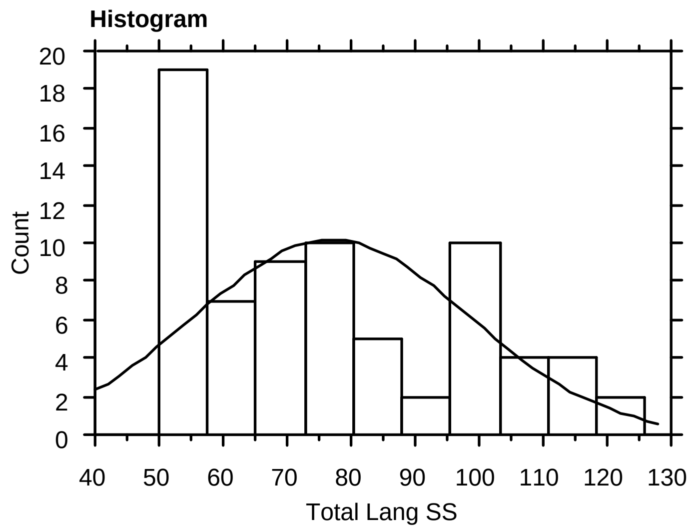
Dependent Variable

The Preschool Language Scale - 3 (PLS-3) was used to assess each child's receptive and expressive language skills. The PLS-3 contains two subscales, Auditory Comprehension and Expressive Communication. The Auditory Comprehension (AC) subscale is used to evaluate the child's receptive language skills in the areas of attention, semantics, structure, and integrative thinking skills. The Expressive Communication (EC) subscale is used to evaluate expressive language skills in the areas of vocal development, social communication, semantics, structure, and integrative thinking skills. Raw scores are initially obtained for each subscale and are then converted into standard scores. The average range of standard scores for the PLS-3 is 85-115. The Auditory Comprehension and Expressive Communication scores can be combined to form a Total Language standard score. The Total Language score provides a broader look at a child's overall language development. The PLS-3 is age-referenced with a national sample of normally hearing children ages birth to 6 years.

RESULTS

Figure 1 depicts the Total Language standard scores for the seventy-two participants on the dependent variable measure, the Preschool Language Scale 3 (PLS-3). The modal score fell in the 50 - 60 range of scores, which is three or more standard deviations below the average standard score ($M = 100$) for normally hearing age-mates. However, there are several participants falling at or above the average standard score for normally hearing children in the same age group and the mean for the group is 76.97 (s.d. = 21.53; range 50 – 126).

Figure 1 Preschool Language Scale-3 Total Language standard scores distribution



Child Characteristics

The mean PLS-3 Total Standard scores divided by gender were as follows: male mean = 77.50 (s.d. = 20.74; range = 50–126), and female mean = 76.19 (s.d. = 22.57; range = 50–121). Results of an unpaired *t*-test revealed that there were no significant differences by gender (at the .05 alpha level).

The mean PLS-3 Total Language standard scores for children without ear infections (N=23), up to three ear infections (N=29), and more than three ear infections (N=20) were as follows: No diagnosed ear infections, mean = 79.7 (s.d. = 22.8; range = 50-126), from one to three infections, mean = 76.00 (s.d. = 21.58; range = 50-117), and for more than three ear infections, mean = 75.3 (s.d. = 20.7; range = 50-113). An analysis of variance revealed no significant difference on PLS-3 scores that could be attributed to differences in ear infection history.

Family Characteristics

The mean PLS-3 Total Language standard scores for children from families within several yearly income categories were as follows: Less than $45,000 per year (N=14), mean = 67.143 (s.d. = 18.38), between $60,000 and $90,000 per year (N=15) mean = 78.6 (s.d. = 21.54), and above $90,000 per year (N=20), mean = 85.5 (s.d. = 21.56). Analysis of variance revealed a statistically significant relationship between family income and language outcomes for children ($F(2, 46) = 3.243$, $p = .0481$). Post-hoc test revealed that children from the lowest income group were found to have significantly lower scores when compared to children from the highest income group.

The mean PLS-3 standard scores for the highest level of education achieved by either parent can be found in Table 1.

Table 1 Mean PLS-3 scores split by highest level of parent education.

	Did not finish high school	**High School**	**Some College**	**Bachelor's Degree**	**Master's Degree**	**PhD**	**Not Reported**
Mean	54.000	63.167	79.750	74.897	86.800	86.167	-
Std. Deviation	-	10.534	14.841	22.098	15.753	31.996	-
Count	1	6	4	39	15	6	1

Because there were too few cases in each educational category for statistical analyses, educational categories were collapsed. The two remaining categories were education "Up through Bachelor's Degree" and "Graduate Degree." Comparing these two groups with a *t*-test revealed a significant advantage for the children who had at least one parent with a graduate degree ($t(70) = -2.95$, $p = .0043$).

Educational Characteristics

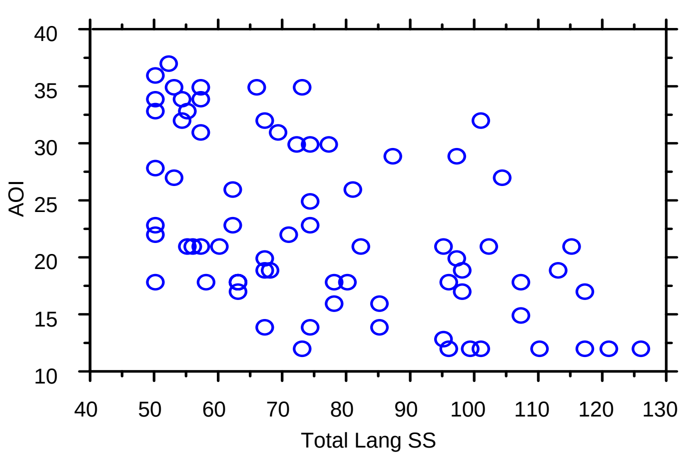
The age at first educational intervention (in months) and the type of educational setting that the child was enrolled in (Auditory-Verbal therapy, group classroom setting, individual therapy) was determined using information recorded on the Parent Questionnaire. Age of educational intervention and type of educational setting were then correlated with PLS-3 Total Language standard scores. No significant effect of age at first educational intervention or type of educational services was found.

Audiological (Implant) Characteristics

There was a significant negative correlation between the participant's age at hearing loss diagnosis and Total Language standard score (*r* = -.405, p = .002). In this study, children who were diagnosed at an earlier age tended to score higher on the language outcome measure.

Statistical analysis revealed a significant negative correlation between age of implantation and PLS-3 Total Language standard scores at 4.5 years (*r* = -.548, p < .0001). This finding indicates that children implanted earlier in life tended to score higher on PLS-3 at age 4.5 years. A scatterplot depicting the relationship between these variables is found in Figure 2.

Figure 2 Relationship of Age of Implantation and PLS-3 scores.



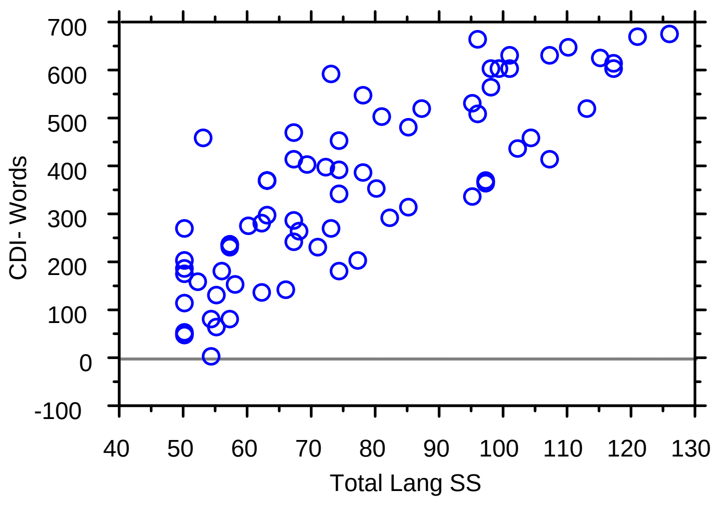
Statistical analyses revealed a significant negative correlation between the age the child first received his or her hearing aids and PLS-3 Total Language standard scores at 4.5 years (*r* = -.405, p = .0006). This indicates that children in this study who received hearing aids later in the preschool period tended to score lower on PLS-3.

No significant correlation between unaided pre-implant better ear pure tone thresholds and total language standard scores on the PLS-3 was found. This finding indicates that pre-implant hearing level was not related to the language outcome measure.

<u>MacArthur CDI Number of Words Score at 3.5 yr</u>

A statistically significant positive correlation (*r* = .827, p < .0001, n = 71) between MacArthur CDI Number of Words score at age 3.5 years and PLS-3 Total Language standard score at age 4.5 years was found. A scatterplot of the relationship between these variables is presented in Figure 3. This indicates that a parent-report measure of productive spoken vocabulary at age 3.5 years is highly predictive of the child's overall spoken language development at age 4.5 years.

Figure 3 Scatterplot of MacArthur CDI at 3.5 and PLS-3 at 4.5 years



The complete correlation matrix for these variables can be seen in the Appendix C.

DISCUSSION

The variables that were found to be significant predictors of spoken language acquisition by age 4.5 years were: age of implantation, age of diagnosis, age started hearing aid use, MacArthur CDI words score at age 3.5 years, highest parent education level, and family income.

Audiological characteristics, such as age of implantation, age of diagnosis, and age aided were all negatively correlated with Total Language standard scores. These findings demonstrate the importance of early identification of hearing loss through newborn hearing screenings. When children are diagnosed with hearing loss early, the process of habilitation can begin at a younger age. Children who received hearing aids immediately following diagnosis, and received a cochlear implant at a young age, acquired language at higher levels when compared to children who began this treatment process at a later time in their development. Research findings have proposed the possibility of a critical period for language development (Ruben, 1997; Hammes et al., 2002). It is possible that this inverse relationship between early audiological intervention and overall language outcomes is due to the initiation of sound and language input during a critical point in the child's development. Although most children with cochlear implants did not achieve language scores on par with their normally hearing peers, children who received their cochlear implants at a younger age were more likely to be closer to that goal than later implanted children.

It is important to recognize the relationship between age of implantation and duration of experience with the device in this study. Because all children were tested at age 4.5 years, children who were implanted at an earlier age also had more experience using the implant and receiving auditory information than children who were diagnosed and implanted later in life.

Therefore, in this preliminary study, age of implantation and duration of use are redundant variables.

The strong positive correlation between participant's scores on the MacArthur CDI at 3.5 years and the PLS-3 at 4.5 years shows that children who had larger vocabularies were more likely to develop greater spoken language skills. The MacArthur scores were predictive of later language outcomes, which can be helpful in providing rehabilitation to young cochlear implant users. Children with low vocabulary scores on the MacArthur CDI may require more intensive language instruction to develop their vocabularies and help them reach goals in the future.

The family characteristics of parent education and income were significant predictors of child language acquisition. While there were not enough parents in the present study representing lower education levels, in this study those children who had at least one parent with a graduate degree were the most likely to have above-average test scores (as compared to other deaf children with cochlear implants).

There was a significant difference in language outcomes between children from families that made less than $45,000 per year and more than $90,000 per year. Some of the same characteristics related to income, such as mother's communicative style, child-parent interaction, and educational opportunity, appear to have an effect on the language development of children with cochlear implants (Hoff-Ginsberg, 1991). Children coming from the highest income category scored significantly better on the PLS-3 when compared to children from the lowest income category. The income distribution of families participating in the current study were not representative of the national population as whole, making these findings difficult to generalize to other populations. However, the average income of families of children with cochlear implants may differ from the general population and may be closer to the distribution found in this study. The majority of children that participated in the study attended specialized oral schools for the deaf, which tend to attract families with higher incomes. This may be due to the expense associated with the schools (which tend to be private), as well as the ability of higher income families to relocate as a means of enrolling their child in one of these schools. Children from lower income families may not have the same opportunity to attend schools specializing in auditory-oral special education.

This independent study, being a preliminary study, can inspire future research that looks at some of the independent variables in more depth. As the participants get older, growth rate analysis can be used to explore the relationships between age of implantation and duration of use effects. This was not possible in the current study because the effects of duration of use could not yet be determined. In addition, other factors could be explored in more detail than was possible in this independent study. The effects of parental involvement in the child's education and language development process could be looked at in relation to spoken language development. An intelligence assessment could also be completed with the participants to determine whether nonverbal intelligence is related to the dependent variable. As time passes, the educational settings of the participants are also likely to change. It would be interesting to determine if there was a relationship between educational setting over time and language development. Finally, it would be helpful to determine the relative importance of each of the predictive factors discussed in this independent study compared to each other.

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Appendix A

		N
Gender		
	Male	36
	Female	36
Pregnancy		
	Normal	64
	Complications	5
	Not Reported	3
Delivery		
	Normal	61
	Complications	10
	Not Reported	1
Birth Weight		
	Underweight (< 5.5 lbs.)	10
	Average (5.5 – 9.5 lbs.)	58
	Overweight (> 9.5 lbs.)	2
	Not Reported	2
NICU Stay		
	Yes	4
	No	68
Ear Infections		
	None	23
	1 –3	29
	> 3	20
Illness		
	Allergies	4
	Asthma	2
	Chicken Pox	2
	Chicken Pox and Dermoid Cyst	1
	Chicken Pox, Pneumonia, and Sinusitis	1
	CMV	1
	Convulsions and High Fever	1
	Convulsions and Meningitis	1
	High Fever	1
	High Fever, Heart Failure, and Failure to Thrive	1
	High Fever and Sinusitis	1
	Mastoiditis and Cellulitis	1
	Pneumonia	1
	Pneumonia and Staph Infection	1
	Pylorec Stenosis	1

	Scarlet Fever	1
	Sinusitis	4
	Viral Meningitis	1
Multiple Disabilities		
	Balance	1
	Developmental Delay	3
	Gross and Fine Motor	3
	Oral-Motor	3
	None Reported	62
Income		
	$5,000 - $15,000	1
	$15,000 – $30,000	3
	$30,000 - $45,000	5
	$45,000 – 60,000	6
	$60,000 - $75,000	10
	$75,000 - $90,000	5
	$90,000 or above	19
	Not Reported	23
Ethnicity		
	American Indian or Alaskan Native	1
	Black (Not Hispanic)	3
	White (Not Hispanic)	54
	Asian or Pacific Islander	4
	Hispanic	3
	Other or Unknown	7
Father's Education		
	Did not complete high school	3
	High School	12
	Some College	3
	Bachelor's Degree	33
	Master's Degree	13
	PhD	6
Mother's Education		
	Did not complete high school	3
	High School	11
	Some College	5
	Bachelor's Degree	45
	Master's Degree	4
	PhD	3
Single Parent		
	Yes	4
	No	67
	Not Reported	1
Bi-Lingual Environment and		

Frequency of Exposure		
	Yes	11
	Rare	1
	Occasional	2
	Frequent	2
	Daily	6
	No	61
Frequency of Hearing Aid Use Pre-implant		
	Rare	2
	Sometimes	2
	Most of the time	21
	All Waking Hours	47
Type of Implant and Speech Processor		
	Advanced Bionics	27
	Platinum Speech Processor	22
	S-Series Speech Processor	5
	Cochlear	44
	Esprit Speech Processor	1
	Sprint Speech Processor	43
	Med-El	1
	Tempo+	1
Type of Speech Processing Strategy		
	ACE	42
	CIS	8
	HiResolution	3
	MPS	4
	SAS	13
	SPEAK	2
Problems with Implant		
	Yes	6
	No	66
Hearing Aid on Contralateral Ear		
	Yes	5
	No	67

Table A1. Description of participants: Categorical variables

Appendix A

	N	Mean	SD	Minimum	Maximum
Age of Diagnosis (in months)	72	10.7	8.1	1	30
Age of Implantation (in months)	72	22.7	7.6	12	37
Age Aided (in months)	71	11.9	8.1	1	30
Age of Educational Intervention (in months)	69	17.8	10.7	1	41
Better Ear PTA thresholds pre-implant	71	108 dB	10.3	76.7 dB	120 dB

Table A2. Description of participants: Continuous variables

Appendix B

Parent Questionnaire

Early Implantation Study

Johanna Nicholas, Ph.D. (314) 977-0172

Child's Name ____ Today's Date ________________

Birthdate ____________________________________ Gender __________________________

Your Name ___________________________________ Relationship _______________________

Complete Address ____

Home Telephone (________)______________________

Date of First Filming ________________ (Child's Age: ______ Years _____ Months)

Date of Second Filming ______________ (Child's Age: ______ Years _____ Months)

The child is currently enrolled in _____________________________ program since ____________

Previous programs _______________________________________ Dates: _________________

_______________________________________ Dates: _________________

Audiological Information

What do you think caused the child's hearing loss? _____________________________________

____

Age when first suspected ____ years _____ months Age at diagnosis ____ years ____ months

Age first used a hearing aid _____ years _____ months

How frequent was hearing aid use? Rarely Sometimes Mostly All waking hours

Does the child continue wearing a hearing aid in non-implanted ear? Yes No

Where was the implant surgery done? ____

Surgeon ____

Date of Original Implant Surgery _____________________ (Please give specific dates if possible)

Date of Implant Hook Up ___________________________

Appendix B

Have there been any problems associated with using the implant? Yes No

If yes, please describe ____

____

What individual and organization provide support for your child’s implant? _________________

____

Address & Phone Number ____

Health Information

Anything unusual about the pregnancy (confined to bed, operation, exposure to illness)

____

Anything unusual about the delivery or labor? ____

How much did the baby weigh? ________ lbs _______ ounces

Were there any complications - breathing, blue or yellow color, difficulty sucking/swallowing, etc?____

Any additional health information about mother or child? _______________________________

____

Has the child ever been hospitalized? Yes No If yes, why, when and where?

____

____

If the child regularly takes medication, please explain. __________________________________

Describe the child’s general health ____

____

Any history of ear infections? How frequently and how were they treated? _________________

____

Appendix B

At what age did the child have any of the following illnesses

Chicken Pox ________________	Tonsillitis ________________	Sinusitis ______________
Measles (red) ________________	Pneumonia _______________	High Fever ____________
German Measles _____________	Mastoiditis _______________	Meningitis ____________
Rheumatic Fever _____________	Osteomyelitis _____________	CMV ________________
Fainting/Blackout ____________	Convulsions ______________	Encephalitis ___________

Allergies ____

Other ____

Has the child been diagnosed with any problems in addition to the hearing loss? (e.g. ADD, CP, Developmental Delay, Learning Disabled, Speech Problems)   Yes   No

If Yes, what diagnosis was made and by whom? _______________________________________

____

Family Information

Who is the child presently living with?

Adults (names and relationships) ____

Children (names and ages) ____

Is your child regularly exposed to a language other than spoken English?   Yes   No

If Yes, (a) What Language? ________________ (b) By Whom? ________________________

(c) How often? ___________________________ (d) Since what age (in months) ____________

Appendix B

The following information applies to the person or persons living with the child, regardless of whether or not they are the child's natural parents.

Father's Age ________ Highest level of education completed _____________________________

Occupation: ____ Full time ____ Part-time _____

Mother's Age ________ Highest level of education completed ____________________________

Occupation: ____ Full time ____ Part-time _____

Federal law requires us to document the ethnicity of all children who participate in federally -funded studies. This ensures that all ethnic groups are adequately represented. Please indicate the ethnicity of your child below:

________ American Indian or Alaskan Native

_________ Asian or Pacific Islander

________ Black, not of Hispanic Origin

_________ Hispanic

________ White, not of Hispanic Origin

_________ Other/Unknown ________________

The following is being collected for demographic purposes only. Completion is optional.

Family Income: _________ Under $5,000/year _________ $5,000 - $15,000

_________ $15,000 - $30,000 _________ $30,000 - $45,000

_________ $45,000 - $60,000 _________ $60,000 - $75,000

_________ $75,000 - $90,000 _________ $90,000 or above

Appendix B

Audiological Questionnaire

Early Implantation Study

Today's Date: ____

Child's Name: ___________________________________ Birthdate: ______________________

Your Name: _________________________________Title: ___________________

School or Clinic: ____
____

Complete Address: ____
____

Telephone (   ) _______________________________________

What is your understanding regarding the date of diagnosis and cause of hearing impairment?

____
____

Have audiological services been provided by any other institutions? If so, who?
____

Degree of Unaided Hearing Loss (prior to Implantation): __________________________________

Degree of Aided Hearing Loss (prior to Implantation): ____________________________________

Date of Original Implant Surgery ____________________   # Electrodes Inserted ___________________

Date of Initial Stimulation ____

Have there been any changes - replacement surgery, change in processor, etc?   Yes   No
If yes, what was done and when?

Type of Processor: ___________________________________

Programming Strategy: ________________________________

Appendix B

Have any electrodes been eliminated due to aberrant stimulation, poor sound quality, etc? If so, please give date, number eliminated and reason.

____

____

Are there any other noteworthy remarks regarding this child's audiological information or cochlear implant?

____

____

Please attach copies of child's audiogram prior to implantation (including both aided and unaided thresholds for each ear), documents regarding the implant surgery, child's audiogram post-implantation, and the current MAP.

Appendix C

	Total Language SS	Age Aided	Age of Implan tation	Pre-implant better ear PTA	Age of Diag. of Hearing Loss	Age of Educ. Interv.	MacArthur CDI-Words Score
Total Language SS	1.000	-.395*	-.543*	-.046	-.354*	-.190	.827*
Age Aided	-.395*	1.000	.694*	-.042	.973*	.343*	-.503*
Age of Implant.	-.543*	.694*	1.000	-.203	.634*	.304	-.599*
Pre-implant better ear pure tone threshold (PTA)	-.046	-.042	-.203	1.000	-.048	.152	-.083
Age of Diagnosis of Hearing Loss	-.354*	.973*	.634*	-.048	1.000	.320*	-.426*
Age of Educational Intervention	-.190	.343*	.304	.152	.320*	1.000	-.206
MacArthur CDI Words Score	.827*	-.503*	-.599*	-.083	-.426*	-.083	1.000*

Table C. Correlation matrix. * = p < .05