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Language and Behavioral Outcomes in Children with Developmental Disabilities using Cochlear Implants

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Abstract

Objective—Over the past decade, the number of deaf children with developmental disabilities receiving cochlear implants has increased dramatically. However, little is known about the developmental outcomes of these children post-implantation. The current study evaluated oral language and behavioral outcomes over three years post-implantation in a sample of typically developing deaf children and children with developmental disabilities.

Study Design—A three year longitudinal study of the effects of cochlear implantation on language and behavioral outcomes in children with and without additional disabilities.

Setting—Six cochlear implant centers in the United States.

Patients—The study cohort consisted of 188 deaf children. Eighty-five percent of the sample (n=157) had a single diagnosis of severe to profound hearing loss and 15% (n=31) had an additional disability.

Main Outcome Measures—Oral language was assessed using the Reynell Developmental Language Scales and behavioral outcomes were assessed using the Child Behavior Checklist.

Results—Results using multilevel modeling indicated that deaf children with and without additional disabilities improved significantly in oral language skills post-implantation. However, children with developmental disabilities made slower progress. In terms of specific diagnoses, children with developmental disorders, such as autism, made the slowest progress over time. In addition, behavior problems increased significantly in this group, whereas behavior problems decreased over three years in the typically developing deaf sample.

Conclusions—Overall, given the improvements in expressive and receptive language skills documented over three years, these findings support the use of cochlear implants for deaf children with developmental disabilities.

Introduction

Cochlear implants (CI) are now widely used in young deaf children and have shown tremendous promise in facilitating a variety of developmental outcomes. Specifically, improvements have been shown in oral language, speech perception and recognition, attention, and behavioral development [1, 2, 3, 4, 5]. In the past two decades, behavioral, psychological, and cognitive disabilities were considered contraindications for pediatric

cochlear implantation and CI Centers often refrained from implanting these children [6, 7, 8]. More recently, as cochlear implantation has been extended to younger children, greater consideration has been given to implanting deaf children with other disabilities [9, 10]. However, little is currently known about the outcomes of cochlear implantation for these children. The purpose of this longitudinal study was to evaluate the language and behavioral outcomes of deaf children receiving CIs who had additional co-morbidities (e.g., autism/pervasive developmental disorder, learning disorders, cerebral palsy) in comparison to a large, national sample of deaf children with no other diagnoses.

Despite the fact that there are no guidelines for the use of CIs in children with disabilities, CI surgery for this population is steadily increasing and is estimated to be 30% to 40% of children using CIs [10]. The most prevalent diagnoses reflect developmental disabilities, such as intellectual disabilities and learning disorders. One explanation for this increase is that hearing loss is being identified earlier, with the national uptake of newborn screening. In addition, the FDA has lowered the recommended age for implantation from 24 to 12 months of age, which has led to earlier cochlear implantation. Thus, a larger number of children may be implanted prior to the emergence or identification of certain disabilities (e.g., autism, attention-deficit hyperactivity disorder [ADHD]) [11, 12, 13, 14].

To date, few studies have examined the outcomes of CI children with developmental disabilities and results across these studies have been mixed. Moreover, they have typically relied on retrospective reviews, individual case reports, anecdotal evidence, and studies with small samples [10]. In general, improvements have been observed in auditory and speech perception and spoken communication. However, their performance at baseline has often been lower than deaf children without additional disabilities and their progress has often been slower [9, 10, 15].

A recent, small study evaluated speech perception and intelligibility in 32 children implanted under the age of 3.5 years, with 11 evidencing developmental delays [16]. Results showed that 8 of the delayed children made progress in speech perception and intelligibility, however, not to the same extent as the typically developing children, and 3 made almost no progress at all.

In a slightly larger study of 69 CI children, 19 children were identified as “cognitively delayed” using standardized IQ measures [17]. The authors reported that, over two years, the CI children with cognitive delays achieved benefits similar to those of the typically developing CI children. Both groups of children made significant improvements in speech perception over time. However, children with additional disabilities continued to score lower on oral language than the children without additional disabilities.

More recently, Wiley, Meinzen-Derr and Choo completed a retrospective review of the acquisition of auditory skills in typical and developmentally delayed children one year post-implantation [18]. Fourteen of the 36 children were identified with developmental delays. At the one-year follow-up, both groups evidenced improvements in auditory skills; however, children in the developmentally delayed group had lower scores at baseline and did not “catch up” to their typically developing peers.

A subsequent study by the same authors evaluated post-implant language skills in a sample of 20 deaf children with developmental disabilities compared to age- and cognition-matched controls [19]. Results indicated that CI children with other disabilities scored significantly lower on oral language measures than matched controls. These results converge with a recent study of 66 children who received a cochlear implant and had at least one disability (e.g., developmental disability, CHARGE, cerebral palsy). Functional disability scores,

derived from the Battelle developmental screen, were significant predictors of speech perception scores across a range of ages and duration of implant use [20].

Although oral language has been the focus of CI research, other studies have also reported positive effects of cochlear implantation on behavioral, social, and emotional development [3, 21, 22, 23]. Research has consistently reported that deaf children and children with developmental disabilities have higher rates of behavior problems than children without disabilities [21, 24, 25]. These higher rates of behavior problems may potentially increase parenting stress and family dysfunction [21, 26] and parents report that their children's behavior problems are a greater stressor than the disability itself [27].

Similarly, children with sensorineural hearing loss (SNHL) exhibit higher rates of externalizing behavior problems, such as inattention and aggression (30–38%; [24, 28, 29, 30]) than children with normal hearing (3–18%; [31]). Parents of deaf children also report more internalizing problems (e.g., anxiety, sadness) compared to parents of hearing children (25–38% vs. 2–17%; [28, 29, 32, 33]).

Recent studies showed that deaf children with worse language had higher rates of behavior problems [24, 34]. These studies suggest that language influences behavior problems by limiting the child's ability to effectively communicate with others, or by affecting emotional and behavioral regulation [35]. The current study expanded these results by examining behavior problems over three years post-implantation among typically developing children in a large cohort of young children who received CIs, and compared their performance to children with other comorbidities enrolled in the same cohort.

Participants for this report were drawn from the largest, youngest, nationally representative sample of children with CIs. Our main goal was to compare the oral language development of CI children with and without developmental disabilities over three years after implantation. Children with attention-deficit hyperactivity disorder (ADHD), learning disorders, autism/pervasive developmental disorders, and cerebral palsy were included in this study. Further, we evaluated rates of internalizing and externalizing behavior problems. We tested the following hypotheses: 1) children with developmental disabilities will have lower receptive and expressive language scores compared to typically developing children prior to cochlear implantation, 2) children with developmental disabilities were expected to have a slower rate of growth in oral language skills over three years, 3) children with developmental disabilities will have higher rates of internalizing and externalizing behavior problems at baseline than typically developing children using CIs, and 4) behavior problems were expected to decrease in both groups over time.

Materials and Methods

Participants & Procedures

Participants were part of a larger study, the Childhood Development after Cochlear Implantation Study (CDaCI), a multi-center, national cohort investigation of the effectiveness of pediatric CIs [1, 37]. This is the largest and youngest sample of CI candidates studied longitudinally with annual follow-ups. Participants were recruited from six clinical implant centers and two preschools that enrolled hearing children [1]. The full CDaCI cohort consisted of 188 SNHL and 97 hearing children (for complete demographics of the CDaCI cohort see Fink et al., 2007).

Inclusion criteria were: 1) age under 5 years 2) severe to profound SNHL, and 3) parents committed to educating the child in spoken English. Exclusion criteria included significant cognitive impairment (i.e., Bayley Mental or Motor score of less than 70 or Leiter

International Performance Scale – Revised [Leiter-R] score of less than 66[38, 39] [38, 39]). Children with developmental disabilities, however, were included to increase the generalizability of the findings to a broader population of deaf children receiving CIs. Thus, children with other disabilities in addition to deafness, which were not apparent during the initial evaluation (e.g., attention-deficit disorder) were included. For this study, typically developing deaf children were those referred for CI surgery because of their hearing loss but had no other diagnoses at enrollment (Deaf group). Children who were diagnosed with an additional disability (AD) over the course of the three-year longitudinal follow-up were placed into the AD group (categorized by their primary diagnosis). The developmental disabilities were self-reported by parents through a standardized questionnaire during baseline and follow-up assessments. Further, study clinicians made notes in data collection forms when they encountered difficulties working with children, based on observations and information from the parent. The study protocol did not mandate systematic evaluation of study participants for the clinical diagnoses of these developmental disabilities.

Participants were assessed at baseline (typically two to four weeks prior to implantation for the CI group) and every six months for three years, however, only the yearly assessment points were used for analysis in this report. During all annual follow-up visits, the full battery of language and psychosocial assessments were conducted. Institutional review boards at all centers approved the study protocol.

Measures

Reynell Developmental Language Scales—The Reynell Developmental Language Scales (RDLS) are, well-validated language scales for children one to seven years of age [40]. They have been used with deaf and hearing children [41, 42]. The measure consists of a Verbal Comprehension and Expressive Language scale. Both scales have acceptable split-half reliability coefficients across age groups ranging from 0.74 to 0.93. Raw scores from these scales were used in the data analyses.

Child Behavior Checklist—The Child Behavior Checklist (CBCL) is a well-validated behavior checklist that assesses the intensity of various behaviors [43]. It yields two empirically derived composite scales, Internalizing and Externalizing Behavior Problems, and one Sleep Problem scale. The Internalizing composite consists of four subscales: Emotional Reactivity, Anxious/Depressed, Somatic Complaints, and Withdrawn. The Externalizing composite consists of two subscales: Attention Problems and Aggressive Behavior. All subscales have shown good test-retest reliability (.68 to .87). Internal consistency for this study ranged from .65 to .91. T-scores were used in the data analyses for this measure; higher T-scores indicate more behavior problems.

Analytic Strategy

Multilevel modeling techniques were used to predict oral language and behavior problems using time and group as predictors. The hypothesized final model was specified as follows: Time, defined as time since cochlear implantation, was included as the predictor of interest at Level 1 and Group (Deaf vs AD) was added as a fixed effect at Level 2. The hypothesized final model was compared to a series of alternative models using goodness-of-fit indices, pseudo- R^2 values (i.e., indicators of effect size), and parameter estimates. As recommended by Singer and Willet (2003), we first fit the Unconditional Means Model (UCMM) to the data, which specifies that a child's language/behavior consists only of deviations around his/her mean on language/behavior centered at the population mean [44]. Next, we fit the Unconditional Growth Model (UCGM), which postulates that a child's language/behavior is a function of his/her true change trajectory over time. Finally, we tested socioeconomic status (SES) as a covariate in the models described above as alternative nested models;

however, it was not a significant predictor of baseline performance or the rate of change over time of either of the outcome variable (language, behavior); therefore, SES was removed from the final models. No other factors were included in the models.

Results

Participants

The CDaCI cohort consisted of 188 deaf children. Eighty-five percent of the sample ($n=157$) had a single diagnosis of severe to profound hearing loss and 16.5% ($n=31$) had an additional disability that was diagnosed following enrollment. Diagnoses included Attention Deficit Hyperactivity Disorder (ADHD; $n=12$), Pervasive Developmental Disorder/Autism (PDD; $n=8$), Learning Disability (LD; $n=7$), and Cerebral Palsy (CP; $n=4$).

Comparisons of the demographic data between the deaf (Deaf) and additional disabilities (AD) groups indicated they were similar (see Table 1 for complete demographics). Baseline age for Deaf children was an average of 26.32 months, $SD = 14.35$ whereas AD children were on average 28.55 months, $SD = 15.35$. The mean Pure Tone Average (PTA4) was better in the Deaf group than the AD group ($t(183) = 2.03$, $p < .05$).

Descriptive Statistics

Table 2 presents descriptive statistics for the RDLS, and Table 3 presents CBCL subscales. Means and standard deviations for each variable are presented for each assessment point. Figure 1 illustrates these scores over time for receptive and expressive language. We were able to retain 100% of participants over the three years of follow-up; however, some measures were missed during various assessment points [1].

In general, there were no group differences on the receptive and expressive language scales at baseline ($t(44) = 1.67$, $p > .05$; $t(52) = 1.94$, $p > .05$). However, post-hoc analyses comparing language scores by specific diagnosis revealed that only children with ADHD had similar, initial language scores compared to the Deaf group, whereas the language scores of the other AD children were initially lower (see Table 2). Further, children with a PDD/Autism diagnosis had the lowest language scores prior to cochlear implantation. Descriptive analyses also found that after three years, children with ADHD and LD had oral language scores similar to typically developing children using CIs. In contrast, children with PDD or CP scored lower on these measures.

In terms of behavioral outcomes, there were no significant differences among the groups on either internalizing or externalizing behavior problems at baseline, with the exception of higher rates of externalizing behavior problems in children with CP ($p > .05$; see Table 3). After three years of implantation, all children in the AD group had higher rates of externalizing behavior problems ($t(103) = -2.37$, $p < .05$; $t(106) = -3.24$, $p < .05$) than the Deaf group.

Final Models

First, we report the final model in which the specific diagnoses were collapsed into one group. In every case, the hypothesized final model fit the data better than the UCMM, UCGM, and alternative nested models. The final models evaluated the effects of Group (Deaf vs AD) on initial status and rate of change in oral language and behavior problems. We report the results of the final model for each dependent variable in Table 4. Next, we report exploratory models which evaluated the effects of the specific diagnoses on both outcome variables.

Oral Language

On average, children had a receptive language raw score of 6.83 (95% CI: 5.03, 8.62) prior to CI (see Table 4) which increased significantly by 12 points each year ($\beta = 12.06$, $p < .05$). Group status did not significantly predict baseline levels of receptive language ($p > .05$). However, Group status predicted an increased *rate of change* in receptive language; children in the AD group had a slower rate of change compared to children in the Deaf group ($\beta = -2.55$, $p < .05$; Figure 2). On average, children in the AD group improved by 9.5 points each year compared to 12.06 points for the Deaf group. The final model explained 88% of the within-person variability and 41% of the total variability in receptive language development.

Similar results were found for expressive language (see Table 4 and Figure 2). At baseline, children had an average expressive language raw score of 10.28 (95% CI: 8.68, 11.88) (see Table 4). Expressive language improved significantly by an average of 10 points each year ($\beta = 9.58$, $p < .05$). Consistent with the receptive language results, Group status did not predict initial levels of expressive language ($p < .05$), however, Group status predicted rate of change in expressive language. Children in the AD group had a slower rate of change compared to children in the Deaf group ($\beta = -2.28$, $p < .05$; Figure 2). On average, children in the AD group improved by 7.3 points each year compared to 9.58 points for the Deaf group. The final model explained 89% of the within-person variability and 41% of the total variability in expressive language development.

The following results should be interpreted with caution due to the small number of children within each diagnostic group. We evaluated the impact of specific disabilities on the development of oral language. All children improved their oral language, however, children with PDD improved at half the rate of the Deaf group. These children improved on receptive language by an average of 6 points each year ($\beta = -5.93$, $p < .01$), while typically developing Deaf children improved by 12 points ($\beta = 12.06$, $p < .001$). Similarly, in terms of expressive language, children with PDD improved by 5.5 points ($\beta = -4.05$, $p < .01$) compared to 10 points in the typically developing Deaf group ($\beta = 9.58$, $p < .001$). Children with CP also appeared to be improving at a slower rate; however, we were unable to estimate the rate of change for children with CP due to the small sample size ($n=4$). No significant differences in rate of growth of oral language were found for children diagnosed with ADHD or LD. Thus, the group differences observed among the AD individuals were largely driven by the lack of improvement in the PDD group.

Behavior Problems

Similar models were conducted to evaluate the effects of Group on initial status and rates of change in internalizing behavior problems (see Table 4). On average, children had a T-score of 44.59 on the CBCL internalizing scale (95% CI: 43.06, 46.12), with little evidence of any change over time ($\beta = -0.62$, $p = .06$). Group status did not predict initial scores on the CBCL internalizing scale. However, these scores did increase for children in the AD group ($\beta = 2.00$, $p < .05$; Figure 3). The final model explained 8% of the within-person variability and 1% of the total variability in internalizing behavior problems.

In terms of externalizing behavior problems, children had an average T-score of 45.71 on the CBCL (95% CI: 44.07, 47.36) prior to CI. Externalizing behavior problems decreased significantly each year ($\beta = -1.10$, $p < .01$) and Group status did not significantly predict initial reports of externalizing behavior problems. However, Group status did predict the rate at which these problems changed; the Deaf group's externalizing behavior problems decreased over time while these problems increased in the AD group ($\beta = 2.70$, $p < .05$; Figure 3). The final model explained 22% of the within-person variability and 4% of the total variability in externalizing behavior problems.

For internalizing behavior problems, no significant differences in initial scores or rate of change were found between the groups. In contrast, there was a significant decrease in externalizing problems over time ($\beta = -1.09, p < .001$), however, this differed by diagnosis. Children with CP had higher externalizing scores prior to implantation than children in the Deaf group ($\beta = 18.87, p > .001$). Children with CP and LD performed similarly to the Deaf group and experienced a decrease in externalizing behavior problems over time while the ADHD and PDD groups had increases in these problems. On average, children with ADHD increased by 3 points ($\beta = 3.14, p < .02$) and children with PDD increased by 4 points ($\beta = 4.08, p < .01$) each year, whereas the Deaf group decreased by 1 point each year.

Discussion

There is a great deal of evidence showing that CIs improve speech perception, speech intelligibility, communication, and oral language development in deaf children [1, 2, 5]. However, the majority of these studies have examined these outcomes in typically developing children using CIs. Only a handful of studies have examined the developmental outcomes of children with additional disabilities post-implantation [15, 18, 19]. The current study contrasted the changes in oral language and behavioral outcomes in CI children with developmental disabilities with typically developing children using CIs over the first three years after implantation. Our findings provided further insights on a complex issue resulted from evolving criteria for CI candidacy and estimated whether children with developmental disabilities in addition to deafness can benefit from this intervention.

Moderate support was found for our prediction that baseline levels of oral language would differ between the Deaf and AD groups. Although in general, no statistically significant group differences were found in baseline language scores, post-hoc analyses revealed that only the children with ADHD had language scores similar to the typically developing deaf children. Children diagnosed with PDD, CP, or LD had significantly lower initial language scores. These results are consistent with prior studies which have shown that children with developmental delays have lower initial levels of language than typically developing deaf children [10, 18, 19].

Strong support was found for our hypothesis that children with AD would have a slower rate of growth in oral language compared to the Deaf group. On average, children with additional developmental disabilities improved more slowly each year on both the receptive and expressive language measures. However, a more detailed evaluation suggested that children with PDD progressed at half the rate as the Deaf and other diagnostic groups. These results fit with those of prior studies that have reported a slower rate of growth in language among children with developmental disabilities [9, 10, 17]. Although previous studies have evaluated the performance of children with cochlear implants and additional disabilities (i.e. CP, ADHD, autism), they fail to mention particular results per diagnosis due to insufficient data [15, 19, 20]. This is the first study, however, to evaluate outcomes in children with deafness and comorbidities, such as ADHD and LD. Surprisingly, these children performed similarly to typically developing deaf children using CIs.

In terms of behavioral outcomes, our hypothesis that children in the AD group would have higher rates of behavior problems at baseline compared to the Deaf group was not supported. These results are contrary to what might be expected based on the hearing literature, which indicates that children with developmental disabilities and ADHD will have clinically elevated rates of behavior problems [27, 45]. Our results likely reflect the young age of children in the AD group at baseline, an average of 28 months, which is earlier than many of these diagnoses are made. Further, in the presence of early, substantial hearing loss, these diagnoses are even more difficult to make. Given that this is the first study to compare

behavior problems in typically and atypically developing deaf children, there are no studies to serve as comparators. More research is clearly needed in this area.

Our last hypothesis, which predicted a decrease in behavior problems over time was partially supported. Although typically developing deaf children with CI evidenced no change in their internalizing behavior problems and a *decrease* in their externalizing behavior problems, the AD group reported increases in externalizing behavior problems. At the end of three years, 13% of the AD children exhibited externalizing behavior problems within the at-risk to clinically elevated range compared to 7% in the Deaf group. These results are consistent with prior literature showing that children with ADHD or other intellectual disabilities have higher rates of externalizing behavior problems compared to children without these diagnoses [46, 47, 48]. In addition, our findings suggest that health care providers, parents and teachers may need more assistance in managing behavior problems in deaf children with CI who have other disabilities. Note that the model for internalizing behavior problems accounted for less variance in this outcome, which may be because these types of problems (e.g., sadness, anxiety) are less salient in young childhood and are often overlooked.

Limitations & Future Directions

This study had several limitations. First, we had a small sample of children with specific comorbid diagnoses. Although the repeated assessments over time provide information to improve the precision of our estimates, the small sample nonetheless precluded more detailed analyses on the outcomes related to these diagnostic categories. By design, the CDaCI study excluded children with significant cognitive impairments through pre CI screening. Thus, children with developmental disabilities in this sample reflected children with diagnoses that may not have been apparent during the initial evaluation, but are encountered in real-world clinical settings. In addition, we did not include families whose primary language was not English; however, bilingual families committed to educate their children in English were included in the study sample. Therefore, the generalizability of our results to non English speaking CI children is unclear. Another future direction is to compare children with developmental disabilities who have received CIs and those who have not. This comparison would demonstrate more clearly whether a deaf child with developmental disabilities would truly benefit from a cochlear implant.

Finally, we only compared these children in terms of their language and behavioral development in this report. Several other important parameters might also differ between these groups, such as speech perception, speech intelligibility, auditory discrimination, and social-emotional development.

Clinical Implications

The results of this study have important implications for evaluating children for CI surgery. Our findings indicated that severe to profound SNHL children with additional disabilities can make significant gains in receptive and expressive language with a CI, although their growth, on average, may not be as rapid as typically developing deaf children. In fact, all of the children with comorbid diagnoses made improvements in their language skills, with autistic children making the slowest progress. Current clinical practices of early implantation (e.g., below two years of age) mean that some of these disabilities may not have been identified prior to implantation. Our results provide some reassurance that the CI intervention strategy is likely to benefit children with these disabilities.

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Figure 1.
Plots of mean receptive and expressive language raw scores over time by diagnosis.

Figure 2.

Growth in receptive and expressive language on the RDLS for children with and without disabilities. These values are based on the best fit models (see Table 4), which include assessment point and group. These figures show the slower rate of increase in the AD group compared to the Deaf group.

Figure 3.

Change in internalizing and externalizing behavior problems over three years post-implantation. No significant changes were found in internalizing behavior problems for both groups. The left panel figure shows that T-scores on internalizing behavior problems remain fairly stable over time for both groups. In contrast, externalizing behavior problems remained stable for the Deaf group, but increased for the AD group (see right panel figure).

Table 1

Demographics at Baseline Prior to Cochlear Implantation

Characteristic	Deaf (n=157)		AD (n=31)	
	Mean(SD)	Median(Range)	Mean(SD)	Median(Range)
Age in months	26.32(14.35)	24.00(56.00)	28.55(15.35)	27.00(51.00)
Age at onset of hearing loss in months	2.66(6.98)	0.00(44.00)	3.38 (9.38)	0.00(44.00)
Age at diagnosis of deafness in months	10.58 (10.56)	7.00(45.00)	10.65(10.46)	7.00(44.00)
Age at first hearing aid use in months	13.27(10.62)	11.00(44.00)	13.45(10.95)	11.00(46.00)
Age at surgery in months	27.92(14.23)	25.00(54.00)	30.13(15.12)	30.00(53.00)
PTA4 (better ear)	104.06(16.32)	103.75(65.00)	110.56(16.17) *	117.50(50.00)
Onset of hearing loss % (n)				
Sudden	6% (9)		7% (2)	
Progressive	35% (55)		29% (9)	
Congenital	55% (87)		58% (18)	
Cause of hearing loss % (n)				
Genetic/hereditary	28% (44)		29% (9)	
Aminoglycosides	0.6% (1)		3.2% (1)	
Cytomegalovirus	1.9% (3)		--	
Hyperbilirubinemia	3.8% (6)		--	
Meningitis	3.8% (6)		3.2% (1)	
Prematurity	2.5% (4)		3.2% (1)	
Cause unknown/unclear	59% (93)		61.3% (19)	
Gender % (n)				
Male	48% (76)		45% (14)	
Female	52% (81)		55% (17)	
Race % (n)				
White	75% (118)		71% (22)	
African-American	9% (14)		10% (3)	
Asian	6% (9)		7% (2)	
Other	7% (11)		10% (3)	
Ethnicity % (n)				

Characteristic	Deaf (n=157)		AD (n=31)	
	Mean(SD)	Median(Range)	Mean(SD)	Median(Range)
Hispanic	19% (30)		23% (7)	
Non-Hispanic	78% (122)		74% (23)	
Communication mode ^a % (n)				
Speech	19% (29)		26% (8)	
Sign	18% (28)		23% (7)	
Simultaneous/speech emphasis	20% (31)		13% (4)	
Simultaneous/sign emphasis	6% (9)		10% (3)	
Other/undecided	38% (60)		29% (9)	
Parental education % (n)				
< High school	7% (11)		10% (3)	
Completed High school	15% (23)		10% (3)	
Some college	30% (47)		26% (8)	
Completed college	48% (76)		52% (16)	
Parental income % (n)				
< \$15,000	8% (12)		10% (3)	
\$15 – 29,999	12% (19)		10% (3)	
\$30 – 49,999	22% (34)		26% (8)	
\$50 – 74,999	17% (26)		16% (5)	
\$75 – 100,000	14% (22)		13% (4)	
> \$100,000	16% (25)		19% (6)	

^a Children in this study were cochlear implant candidates and all parents committed to teach their children spoken English. These categories, therefore, represent the primary communication mode used prior to enrolment in this study.

* $p < .05$

Table 2
Means & Standard Deviations for Language Variables by Diagnosis & Assessment Point

		Deaf Mean (SD)	AD Mean (SD)	ADHD Mean (SD)	PDD Mean (SD)	LD Mean (SD)	CP Mean (SD)
Baseline^a							
	Receptive Language	6.31 (10.07)	3.29 (8.42)	6.27 (12.91)	0.86 (1.46)	1.86 (3.24)	1.33 (1.53)
	Language Age	15.03 (4.75)	13.95 (4.04)	15.46 (6.30)	< 13 months ^b	13.06 (0.42)	< 13 months ^b
Expressive Language	Raw score	10.03 (10.38)	6.82 (7.36)	9.18 (10.29)	4.29 (2.43)	6.57 (6.29)	4.67 (2.31)
	Language Age	17.96 (4.97)	16.74 (2.60)	17.65 (3.89)	<16 months ^b	16.49 (1.55)	<16 months ^b
12 Month							
	Receptive Language	20.21 (15.95)	14.52 (13.84)	16.92 (17.53)	12.14 (14.55)	18.50 (5.32)	5.50 (3.68)
	Language Age	22.05 (10.31)	18.37 (8.32)	20.20 (10.77)	16.79 (8.61)	19.83 (2.99)	13.43 (1.05)
Expressive Language	Raw score	20.87 (12.07)	16.00 (9.82)	19.25 (11.56)	13.43 (10.21)	17.50 (3.62)	8.50 (6.56)
	Language Age	22.34 (8.46)	19.18 (5.82)	20.90 (7.76)	18.37 (5.62)	18.67 (1.97)	16.20 (0.54)
24 Month							
	Receptive Language	32.77 (17.50)	23.43 (17.14)	28.25 (18.43)	18.25 (19.40)	30.00 (10.62)	9.50 (4.44)
	Language Age	30.26 (12.74)	23.98 (11.19)	26.66 (11.42)	22.09 (14.87)	26.83 (6.15)	15.48 (1.78)
Expressive Language	Raw score	30.32 (13.02)	21.67 (12.59)	25.08 (13.81)	16.13 (13.93)	27.67 (5.61)	13.50 (6.25)
	Language Age	28.94 (11.08)	23.84 (8.13)	25.07 (10.05)	20.46 (8.20)	25.00 (4.00)	17.70 (2.41)
36 Month							
	Receptive Language	41.06 (14.15)	33.31 (19.90)	41.27 (16.51)	19.88 (22.05)	37.29 (21.01)	30.67 (4.51)
	Language Age	36.39 (14.00)	30.92 (14.00)	35.83 (13.07)	23.71 (16.32)	33.13 (13.75)	27.00 (3.00)
Expressive Language	Raw score	38.06 (14.62)	30.14 (15.74)	35.45 (13.78)	22.00 (19.35)	32.43 (15.70)	27.00 (4.00)
	Language Age	36.45 (14.19)	30.16 (12.36)	34.27 (12.83)	25.73 (14.84)	31.27 (10.20)	24.33 (2.52)

^aThe RDLS is not validated for ages younger than 12 months; hence, spoken language development is numerically not ascertainable through RDLS for the youngest group at baseline.

^bThe floor of RDLS language age measure is coded as "<13 months" for comprehension and "<16 months" for expression. Language age measures below the RDLS floor are numerically not ascertainable through RDLS.

Table 3
Means & Standard Deviations for Behavior Problems by Diagnosis & Assessment Point^a

	Baseline	12 Month	24 Month	36 Month
Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Internalizing Behavior				
Deaf	45.28 (9.67)	42.55 (10.51)	43.72 (9.76)	42.11 (9.37)
AD	44.96(9.33)	45.72(8.54)	48.36(10.96)	48.13(7.20)
ADHD	43.10 (10.92)	45.00 (9.34)	45.75 (11.62)	47.50 (9.59)
PDD	46.57 (7.07)	48.00 (7.98)	54.43 (8.00)	47.67 (5.75)
LD	41.00 (6.57)	43.40 (6.84)	42.80 (11.84)	43.00 (--) ^b
CP	52.75 (9.74)	47.67 (12.22)	51.50 (12.02)	54.00 (1.41)
Externalizing Behavior				
Deaf	45.69 (10.30)	43.88 (10.12)	43.31 (10.15)	41.52 (10.19)
AD	46.27(13.69)	49.00(10.51)	49.73(9.57)	50.18(9.72)
ADHD	42.44 (11.53)	48.58 (11.83)	50.13 (9.61)	47.67 (12.66)
PDD	40.86 (6.37)	46.33 (8.41)	51.25 (9.32)	49.00 (5.77)
LD	46.00 (9.45)	47.80 (9.37)	44.80 (10.52)	50.50 (12.02)
CP	64.75 (20.26)	58.00 (10.58)	59.00 (--) ^b	61.50 (7.78)

^a100% of participants were retained; however some families did not complete the CBCL at the last assessment

^bStandard deviation was not able to be completed because only one child completed this assessment

Note. Means and standard deviations are based on T-score values.

Table 4

Final Multilevel Models Predicting Developmental Outcomes

	Parameter	Receptive Language	Expressive Language	Internalizing Behavior	Externalizing Behavior
Fixed Effects					
Initial status	Intercept	γ_{00} 6.83 *** (0.91)	10.28 *** (0.81)	44.59 *** (0.78)	45.71 *** (0.84)
	Group	γ_{01} -3.10 (2.22)	-3.12 (1.99)	0.78 (1.87)	2.15 (2.05)
Rate of change	Intercept	γ_{10} 12.06 *** (0.46)	9.58 *** (0.37)	-0.62 (0.33)	-1.10 *** (0.34)
	Group	γ_{11} -2.55 * (1.11)	-2.28 * (0.88)	2.00 * (0.81)	2.71 ** (0.84)
Variance Components					
Level 1	Within-person	σ_{ε}^2 35.26 (2.82)	19.65 (1.56)	41.99 (3.79)	33.44 (3.10)
Level 2	In initial status	σ_0^2 98.94 (11.59)	85.54 (10.58)	52.11 (9.93)	77.16 (11.70)
	In rate of change	σ_1^2 23.61 (3.47)	15.37 (2.15)	1.86 (1.70)	5.10 (1.93)
	Covariance	σ_{01} 11.59 (4.93)	0.48 (3.48)	-0.36 (3.46)	-3.91 (4.18)

Note.

* $p < .05$

** $p < .01$

*** $p < .001$