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Implanted Children Can Speak, But Can They Communicate?[1]

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Abstract. English language skills were evaluated in two groups of profoundly hearing-impaired children using the *Reynell Developmental Language Scales–Revised* (RDLS; Reynell & Huntley, 1985). The first group consisted of 89 deaf children who had *not* received cochlear implants. The second group consisted of 23 children wearing Nucleus multichannel cochlear implants. The unimplanted subjects provided cross-sectional language data used to estimate the amount of language gains which were expected on the basis of maturation. The Reynell data from the unimplanted group were subjected to a regression by age. Based on this analysis, deaf children were predicted to make half or less of the language gains of their normally-hearing peers. Predicted language scores were then generated for the implant subjects using their preimplant RDLS scores. The predicted scores were then compared to actual scores achieved by the implant subjects at 6- and 12-months post-implant. At 12 months post-implant, the subjects demonstrated receptive and expressive language gains that exceeded by seven months the predictions made on the basis of maturation alone. Moreover, the average language development rate of the implant subjects in the first year of device use was equivalent to that of normally-hearing children. These effects were observed for implant children using both the Oral and Total Communication methods.

Introduction

Multi-channel cochlear implants have been shown to provide substantial benefit to many children in the acquisition of speech skills (Kirk, Diefendorf, Riley, & Osberger, 1995; Osberger, Robbins, Todd, & Riley, 1995; Tobey, Geers, & Brenner, 1994). Although improved speech production is often the focus of parents and teachers working with deaf children, speech skills do not necessarily ensure language competence. Speech refers to oral productions, whereas language is the internalized, abstract knowledge system that is the basis for communication. Language ability is a very strong predictor of reading achievement and, hence, academic success in children (Goldgar & Osberger, 1986). If it could be shown that implants enhance language development, this would be compelling evidence as to the usefulness of cochlear implants in the pediatric population.

Assessing the effects of cochlear implant use on language development is difficult because some improvement in language skills occurs over time as a result of maturation. Due to the considerable variability in language scores over time, an ideal research paradigm would involve comparing the scores of an implanted subject to scores which the same child would have achieved if he had not received a cochlear implant. Given that this is impossible, an alternative method is to make informed predictions about each subject's language performance in the absence of a cochlear implant, and then to compare those predictions to the scores the child actually achieves.

In this paper, we first describe a method used to predict the development of receptive and expressive language skills in deaf children that might be expected with maturation. Then, we longitudinally compare predicted and observed language scores in a group of children using multi-channel cochlear implants to assess the effect of implant use on language development. If the observed language performance over time exceeds that which has been predicted on the basis of maturation alone, then this would suggest that cochlear implant use enhances language development.

Methods

Subjects

Two groups of hearing-impaired subjects participated in this investigation.

Unimplanted Subjects. The first group consisted of 89 profoundly deaf, unimplanted children ranging in age from 16 to 95 months. All subjects wore either a hearing aid or tactile aid, and were audiologically suitable for a cochlear implant. All experienced early onset of deafness; 62 subjects were congenitally-deafened, whereas 27 of the 89 subjects were deafened between birth and 2 years, 11 months of age. Of these subjects, 61% used Total Communication (TC) and 39% Oral communication. The subjects in the unimplanted group provided cross-sectional data on language scores as a function of age that were used to generate predictive equations for language development in deaf children.

Cochlear Implant (CI) Subjects. This group consisted of 23 children wearing multichannel cochlear implants. All CI subjects were prelingually deafened; 11 of the 23 subjects were congenitally-deafened, whereas 12 experienced early, acquired deafness, prior to the age of three years. The average age at onset of deafness was 10 months, and the average age at time of implantation was 4 years, 11 months. Fourteen of the CI subjects used TC, the remaining nine subjects used Oral Communication. The Oral and TC groups were well-matched for age at onset of deafness (mean = .72 years for Oral subjects; .9 years for TC subjects) and age at implantation (mean = 4.98 years for Oral subjects; 4.86 for TC subjects). All subjects wore the Nucleus multichannel cochlear implant; five used the FO/F1/F2 strategy, 11 used the MPEAK strategy, and seven used the SPEAK strategy.

Test Instrument

The *Reynell Developmental Language Scales-Revised* (RDLS; Reynell & Huntley, 1985) was used to assess the English language abilities of the subjects. This assessment tool was chosen for several reasons: it evaluates receptive and expressive language independently, an important criterion, according to child language experts. It has been used extensively with deaf children (Moeller, Osberger, & Eccarius, 1986) and is appropriate for a broad age range, one to eight years of age, allowing repeated test administrations over a relatively long period of time. Normative data are available on 1319 hearing children (Reynell & Huntley, 1985). In addition, the test format involves object manipulation and description based upon questions which vary in their length and complexity. This format reflects real-world communication to a greater degree than do many other language tests (Muma, 1978). Thus RDLS results are considered to more accurately portray a child's communicative competence than does, for example, a single-word vocabulary test (Moeller et al., 1986; Robbins, Osberger, Miyamoto, & Kessler, 1994).

Prediction of Language Development in Deaf Children Without Cochlear Implants

The RDLS was administered once to each of the 89 subjects in the unimplanted group. The test was administered in whatever modality of English each child used, including spoken English, TC (i.e., simultaneous spoken English and Signing Exact English; Gustason & Zawolkow, 1993) or Cued Speech. Each child's responses were converted to a receptive and expressive language age in months. We then performed separate linear regressions of receptive and expressive language as a function of age at time of testing. This allowed us to estimate the rate of language development in deaf children without implants. In other words, we used cross-sectional data from a group of deaf children to obtain regression slopes that could be used to predict the longitudinal changes in individual subjects. We shall refer to the slopes obtained from this regression analysis as "deaf slopes," one for receptive and one for expressive language. The prediction method used in this study assumes that the language age of implanted children would follow a straight line, starting at the child's language age and chronological age at the pre-implant testing session, and increasing according to the corresponding deaf slope.

Comparison of Observed and Predicted Language Performance in CI Children

The RDLS was administered to the 23 implanted children at three intervals using the administration and scoring procedures described above. The preimplant (PRE) measure was obtained approximately 0 to 3 months before initial hook-up. The two postimplant assessments were carried out at approximately 6- and 12-months postimplant (referred to as the POST1 and POST2 intervals, respectively). These three assessments yielded "observed" language scores for each child. Predicted scores were generated for each subject at the same test intervals using the regression equations calculated in the previous analysis. That is, we assumed that these CI subjects' language scores would have increased over time at a rate described by the deaf slopes, if they had not received a cochlear implant. Therefore, predicted scores for a given subject over time are described by a straight line that starts at his pre-implant score and age, and increases according to the deaf slope. At the PRE interval, predicted scores are, by definition, identical to observed scores. Using these data, we performed a two-way repeated measures ANOVA (repeated measures both on the "interval" and the "observed vs. predicted" variables).

One difficulty in comparing the observed and predicted language scores of the implanted children is that communication mode varied across subjects. It is possible that the relationship between observed and predicted scores in the TC and Oral groups were different. To investigate this possibility, we performed an additional analysis. We first separately calculated the average receptive and expressive language gains that were made by each one of the TC and Oral groups from the PRE to the POST1 interval, and from the POST1 to the POST2 interval. These gains then were compared to the language progress that would have been predicted by maturation alone (using the "deaf slopes" to make this prediction) within the Oral and TC groups separately.

Insert Figure 1 about here

Results

Prediction of Language Development in Deaf Children Without Cochlear Implants

In Figure 1, each of the 89 subjects' chronological age is plotted against his or her receptive language age. The dotted, diagonal line indicates the language change expected by a normally-hearing child; that is, language age and chronological age increase in synchrony. The slope of the normal-hearing, diagonal line is 1. The solid line shows a regression by age of the Reynell receptive language data, expressed in age equivalent scores. The r^2 of this regression was 0.61, and the slope was 0.5, suggesting that the receptive language gains to be expected from profoundly deaf children are roughly half those of normally-hearing peers. Thus, we predict that deaf children will show about six months' receptive language growth in one year.

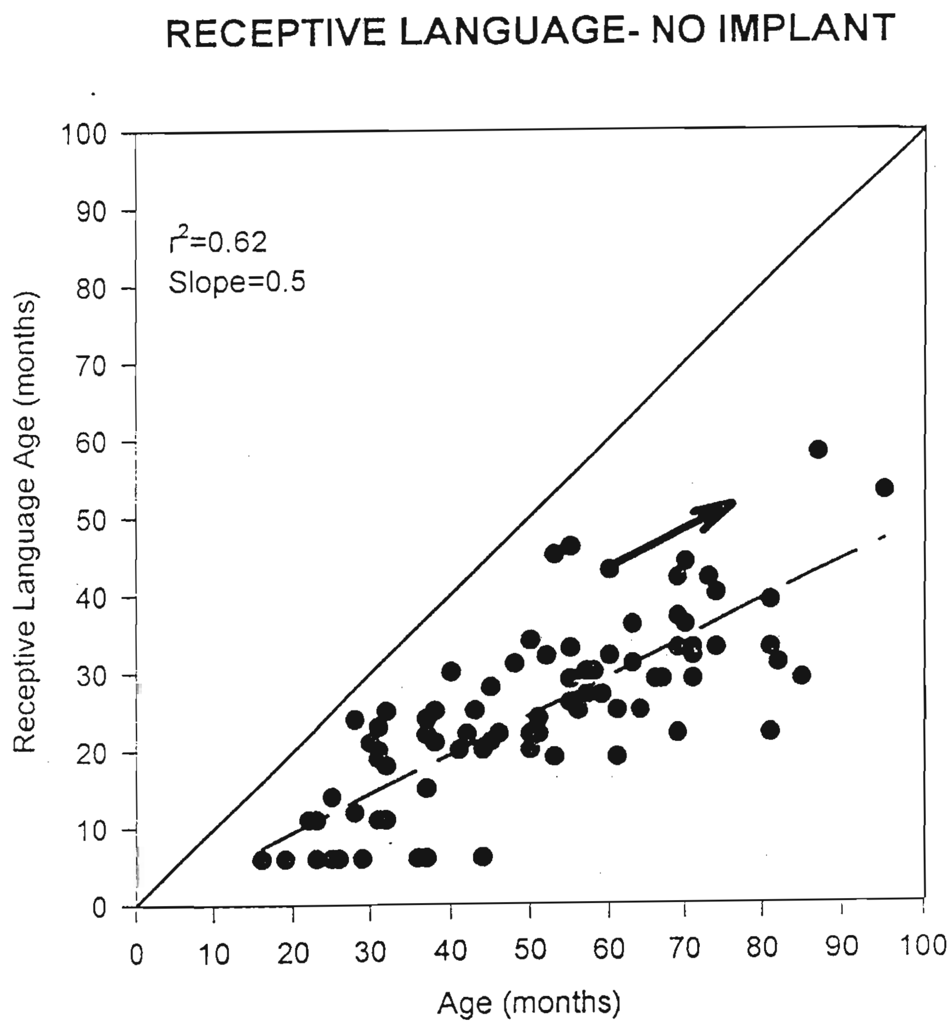

Figure 1. Reynell receptive language data for 89 unimplanted deaf children. Chronological age (in months) is plotted on the x axis and receptive language age is plotted on the y axis. The linear regression is shown by a dashed line, and the solid, diagonal line illustrates receptive language growth expected of a normally-hearing child.

The prediction method described above is illustrated by the arrow in Figure 1, showing the prediction line that corresponds to one specific subject.

The results for the expressive language scores on the RDLS are shown in Figure 2. Note the similar pattern as that for receptive skills, although the r^2 is 0.53 and the expressive deaf slope is only .42, lower than the receptive deaf slope. Based on these expressive language data, we predict that deaf children will show about five months of expressive language progress in one year.

Insert Figure 2 about here

Comparison of Observed and Predicted Language Performance in CI Children

The predicted and observed mean receptive language scores for the group of implanted subjects are shown in Figure 3. The horizontal axis represents chronological age and the vertical axis shows receptive age-equivalent scores, measured in months. The solid diagonal line running through the graph represents the language development expected of a normally-hearing child. The first filled dot is the group average of age-equivalent scores obtained by the children at the pre-implant interval. The open circles represent the mean scores that would be predicted at 6- and 12-months post-implant using the prediction method described above. The slope of language growth predicted for these children without an implant is shown by the broken line. Notice the shallowness of this line relative to that for the normally-hearing child (the solid diagonal line). The two later filled circles represent the language scores actually observed in these implanted children when they were tested at 6 and 12 months post-implant. As a group, these subjects showed language growth that, at one year post-implant, exceeded by 7.1 months the predictions that were made on the basis of maturation alone.

Insert Figures 3 and 4 about here

The pattern of results for expressive language in the implanted subjects was similar to that for receptive language (Figure 4). Note the pre-implant score, and the two open circles which are the scores predicted based upon the formula described earlier. The actual scores that the implanted subjects achieved are represented by the filled circles. Comparing the predicted with the actual scores after one year of implant use, there is a 6.9 month advantage of the actual over the predicted score. Note that although the implant subjects' language scores are higher than the corresponding predictions for unimplanted deaf children, their language scores remain significantly below those of their normally-hearing peers. This may be seen in Figure 4 by comparing the position of the closed circles (post-implant language performance) relative to the solid line (normally-hearing subjects).

The variables used in the two-way repeated measures ANOVA analyses were interval (6 or 12 months post-implant) and observed/predicted. There were significant ($p<0.05$) interaction effects for both receptive and expressive language scores, indicating that the difference between observed and predicted values depends on the interval. Post-hoc Student-Newman-Keuls tests indicated that both receptive and expressive observed scores were significantly higher than the corresponding predicted scores at the 12

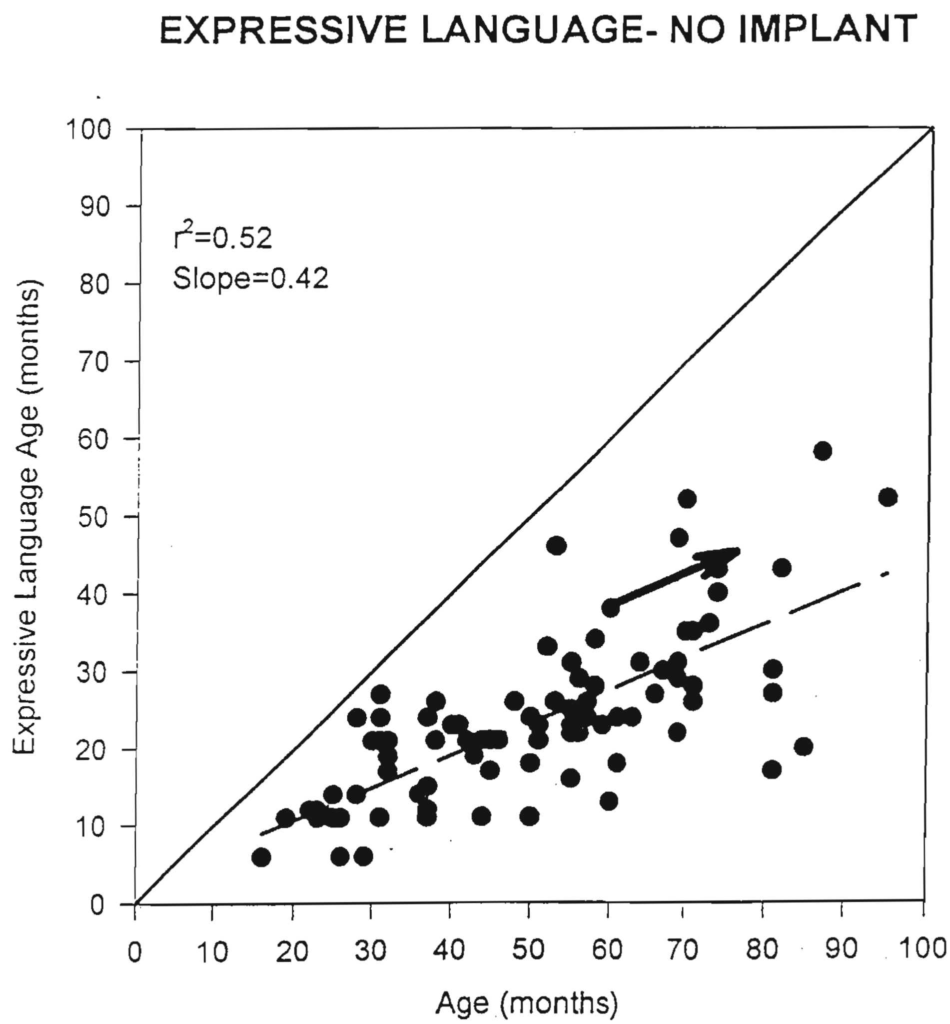

Figure 2. Reynell expressive language data for 89 unimplanted deaf children. Chronological age (in months) is plotted on the x axis and expressive language age is plotted on the y axis. The linear regression is shown by a dashed line, and the solid, diagonal line illustrates the expressive language growth expected of a normally-hearing child.

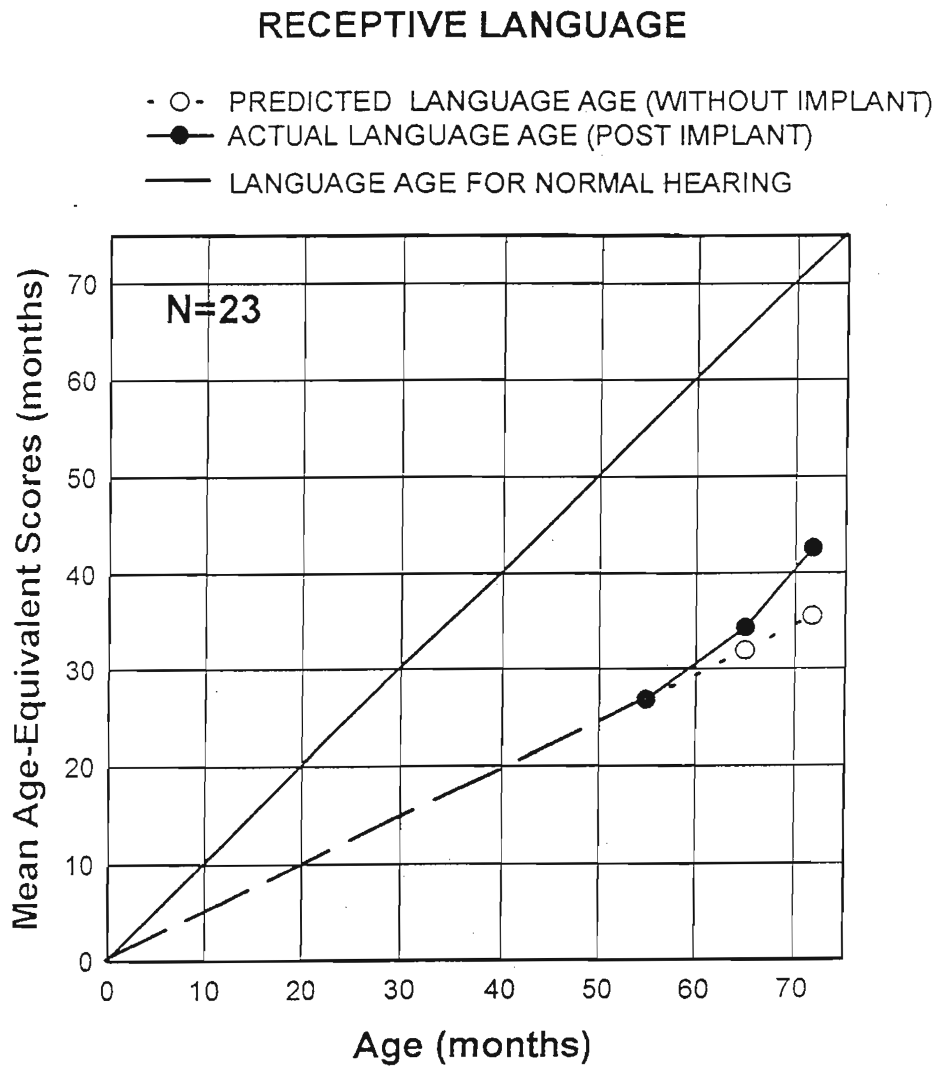

Figure 3. The open circles show the receptive language development that would be predicted for unimplanted children while the filled circles show actual scores obtained from the 23 CI subjects. The solid, diagonal line illustrates receptive language growth expected of a normally-hearing child.

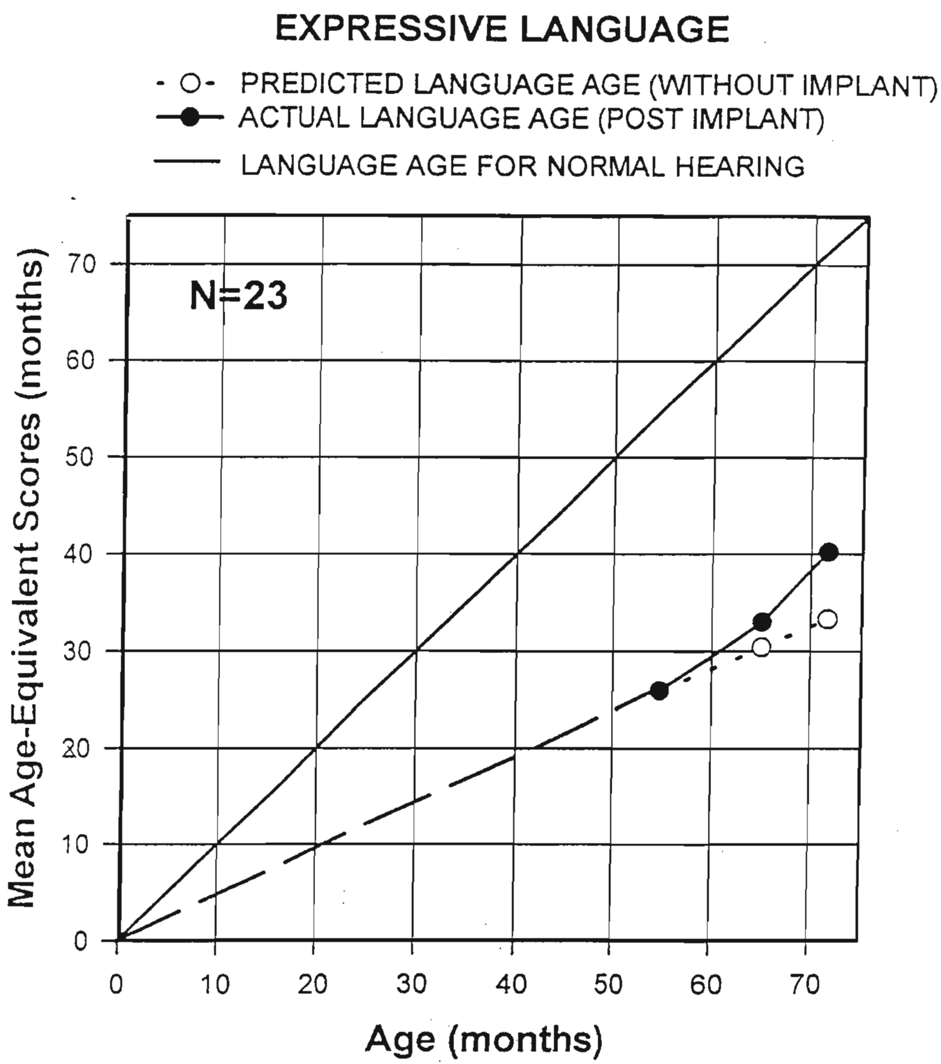

Figure 4. The open circles show the expressive language development that would be predicted for unimplanted children while the filled circles show actual scores obtained from the 23 CI subjects. The solid, diagonal line illustrates the expressive language growth expected by a normally-hearing child.

month interval ($p<0.05$). At the 6-month interval, however, the difference between observed and predicted scores failed to reach statistical significance.

Figure 5 illustrates the average amount of language growth that occurred in the Oral and TC implant groups beyond that expected on the basis of maturation. If the progress achieved was equivalent to that expected by maturation, the bars would be at zero. The top panel of Figure 5 indicates that at 6 months post-implant, the TC children (open bars) had made three months progress beyond that expected on the basis of maturation. The oral subjects (solid bars) also made progress beyond that expected by maturation, but only one month beyond. At 12 months post-implant, the TC group had made an average of seven months gain and the Oral group averaged almost 8 months of language gain beyond that expected through maturation alone. Expressive findings for the two communication groups are shown in the bottom panel of Figure 5. Note the mixed pattern of progress seen in the Oral and TC groups at the two intervals, although by 12-months post-implant, both groups show considerable increases in expressive language beyond those due to maturation.

Insert Figure 5 about here

Discussion

These data suggest that the English language skills of profoundly deaf subjects without cochlear implants improved at a rate that was markedly slower than that of normally-hearing children, a finding that is in agreement with previously-reported studies on language development in deaf children (Osberger, 1986; Levitt, McGarr, & Geffner, 1987). Data from the non-implanted subjects allowed us to calculate rates of language development (deaf slopes) that would be predicted for a deaf child on the basis of maturation alone. Recall that these deaf slopes were .5 for receptive and .42 for expressive language, respectively, suggesting that deaf children would be expected to make language gains at half or less the rate of normally-hearing children.

We found that observed language scores for the subjects with cochlear implants were significantly higher than the predictions made for the same subjects if they had not received cochlear implants. Specifically, after about one year of device use, the implant subjects' mean receptive and expressive language scores were approximately seven months better than those predicted on the basis of maturation. This suggests that the cochlear implant promoted both receptive and expressive language development to a greater extent than would be predicted by maturation alone. In addition, the findings show that the longer the children used their implants, the greater the difference between the observed and predicted scores. Both of these findings are in agreement with our earlier investigations (Robbins et al., 1994; Robbins, 1993).

Both children using Oral language and those using TC demonstrated an increased rate of language learning with the cochlear implant. Given that the implant is an auditory sensory aid, one might expect to see greater benefit for Oral subjects, whose language learning is primarily mediated through the auditory modality, than for TC subjects, whose language learning is strongly, though not exclusively, visual. That the cochlear implant provided language benefit for both groups is particularly encouraging, in light of the fact that at least 75% of deaf children in the United States are educated in Total Communication programs.

The possibility also exists that the cochlear implant has a global, multi-sensory effect on language learning. This would be consistent with the recent findings of Quittner, Smith, Osberger, Mitchell, and

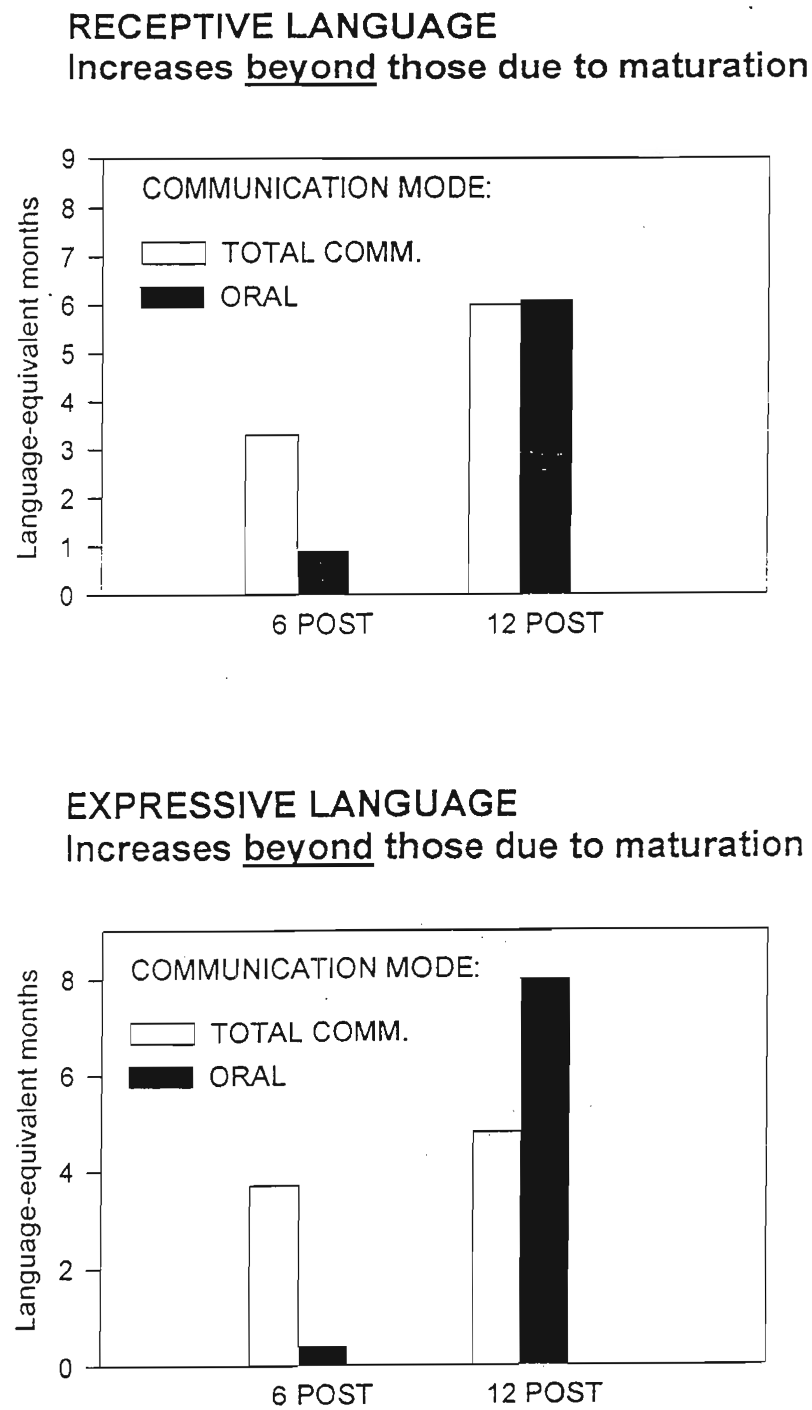

Figure 5. Average amount of language growth (in months) beyond that due to maturation in implant subjects using Total Communication (open bars) and Oral Communication (solid bars). The top panel shows receptive language results, the bottom panel shows expressive language results.

Katz (1994) who reported increases in selective visual attention in children following cochlear implantation, and with anecdotal reports by parents and teachers of children's improved attention to task following implantation. Such an effect might explain the benefit demonstrated by both Oral and TC subjects in the present study.

It is also possible that the rapid change in the rate of language learning rate following implantation may relate to the children's new-found ability to acquire language incidentally, through the overhearing of everyday conversations. This natural exposure to spoken language communication is the avenue by which normally-hearing children learn their language skills, and is generally unavailable to profoundly deaf children who must be directly and explicitly taught every spoken language structure they know. Access to natural conversation through the implant would allow these children the exposure to language that previously was inaccessible.

It is interesting to note that, at least for the first year after implantation, increases in receptive and expressive language scores for implanted children matched that of the normally-hearing group. In consequence, the gap in absolute scores between implanted and normal children remained roughly constant during that first year post-implant, instead of increasing. If this result happened to be true for subjects implanted earlier, and was consistent beyond one year post-implant, the case for earlier implantation would be considerably strengthened. The younger a deaf patient is, the smaller the gap between his language age and chronological age. If the auditory information provided by a cochlear implant prevented the language gap from increasing (as our data suggest), early implanted children would have an excellent chance of achieving near-normal language development. In consequence, it is crucial to extend these studies in two directions: looking at subjects implanted earlier in life, and following them for longer periods of time post-implantation.

The results of the present study demonstrate an important consequence of cochlear implants, namely, the foundation of language development above and beyond that anticipated from maturation alone. Thus, not only do children display improvement in speech perception and speech intelligibility with cochlear implants, but they show significant increases in their rate of language development.

References

Goldgar, D. & Osberger, M.J. (1986). Factors related to academic achievement. In M.J. Osberger (Ed.) *Language and Learning Skills of Hearing-Impaired Students*. *ASHA Monograph,* **23**, 87-91.

Gustason, G. & Zawolkow, E. (1993). *Signing Exact English*. Los Alamitos, CA: Modern Signs Press.

Kirk, K.I., Diefendorf, A., Riley, A, & Osberger, M.J. (1995). Consonant production by children with multichannel cochlear implants or hearing aids. *Advances in Otorhinolaryngology*, **50**, 154-159.

Levitt, H., McGarr, N. & Geffner, D. (1987). Development of language and communication skills in hearing-impaired children. *ASHA Monographs*, **26**.

Moeller, M.P., Osberger, M.J. & Eccarius, M. (1986). Receptive language skills. In M.J. Osberger (Ed), *Language and Learning Skills of Hearing-Impaired Students. ASHA Monograph,* **23**, 41-53.

Muma, J.R. (1978). *Language Handbook*. Englewood Cliffs, NJ: Prentice Hall.

Osberger, M.J. (1986). Language and learning skills of hearing-impaired students. *ASHA Monographs,* **23**.

Osberger, M.J., Robbins, A.J., Todd, S.L. & Riley, A.I. (1995). Speech intelligibility of children with cochlear implants. *The Volta Review*, **5**, 169-180.

Quittner, A.L, Smith, L.B, Osberger, M.J., Mitchell, T.V., & Katz, D.B. (1994). The impact of audition on the development of visual attention. *Psychological Science*, **5**, 347-353.

Reynell, J.K. & Huntley, M. (1985). *Reynell Developmental Language Scales-Revised, Edition 2.* Windsor, UK: NFER Publishing.

Robbins, A.M. (1993). Language evaluation of children with cochlear implants. Paper presented at the *Third International Conference on Pediatric Otolaryngology*, Jerusalem, Nov. 1993.

Robbins, A.M., Osberger, M.J., Miyamoto, R.T. & Kessler, K.S. (1994). Language development in young children with cochlear implants. *Advances in Otorhinolaryngology*, **50**.

Tobey, E.A., Geers, A., & Brenner, C. (1994). Speech production results: Speech feature acquisition. *The Volta Review*, **96**(5), 109-129.