
ORIGINAL ARTICLES

SPEECH PERCEPTION, PRODUCTION AND LANGUAGE RESULTS IN A GROUP OF CHILDREN USING THE 22-ELECTRODE COCHLEAR IMPLANT

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Five children out of a group of nine (aged 5.5 to 19.9 years) implanted with the 22-electrode cochlear implant (Cochlear Pty. Ltd.) have achieved substantial scores on open-set speech tests using hearing without lipreading. Phoneme scores for monosyllabic words ranged from 40% to 72%. Word scores in sentences ranged from 26% to 74%. Four of these five children were implanted during preadolescence. The fifth child, who had a progressive loss and was implanted during adolescence after a short period of very profound deafness, scored highest on all speech perception tests. The remaining four children who did not demonstrate open-set recognition were implanted during adolescence after a long duration of profound deafness. Post-operative performance on closed-set speech perception tests was better than pre-operative performance for all children. Improvements in speech and language assessments were also noted. These improvements tended to be greater for the younger children. The results are discussed with reference to variables which may contribute to successful implant use: such as age at onset, duration of profound hearing loss, age at implantation, aetiology, educational program, and the type of training provided.

This paper presents some results for children and adolescents using the cochlear implant in Melbourne. The work has been carried out by the Cochlear Implant Clinic at the Royal Victorian Eye and Ear Hospital and at various schools for hearing impaired children around Melbourne. The cochlear implant hardware has been described previously (eg Clark et al 1984, Blamey et al 1987). The selection, case management, and habilitation procedures used by the Clinic have been described in detail elsewhere (eg Rowland et al 1990). This paper will concentrate on some of the speech perception, speech production, and language results of the children to illustrate the changes that have been observed after implantation and the factors that may affect these changes.

Method

(i) Procedures

All of the children and adolescents were profoundly or totally deaf and were shown to obtain little or no benefit from hearing aids preoperatively. An attempt was also made to assess the child's motivation and potential for oral/aural communication. During the preoperative period lasting 3-6 months, the parents were counselled and contact was made with teachers at the child's school. The Clinic has now established links with most schools for hearing impaired children in Melbourne. Weekly training sessions

were carried out preoperatively. Training covered speech and language development, as well as auditory speech perception skills and familiarisation with procedures that are necessary to program the implant speech processor. Baseline assessments of speech perception, speech production and language were obtained.

Postoperatively, the weekly training was continued with the implant. Assessments were carried out at approximately six month intervals to assess the long term effects of the implant and the training. The assessment tests used were not the same for each child. They were chosen according to the age, language, and cognitive skills of the child at the time of assessment.

The speech perception tests included two open-set tests that were presented with hearing by itself, with lipreading by itself, and with lipreading and hearing together. These were the monosyllabic AB words of Boothroyd (1968), and the BKB sentences (Bench and Bamford 1979). No contextual information or response alternatives were given to the children in the presentation of these tests, and different test lists were used in each condition. In addition to the open-set tests, several closed-set tests were used to indicate the phonetic information available to each child through the implant. The closed-set test results given here are for the segmental speech feature subtests of the PLOTT test (Plant 1984) and the NU-CHIPS test (Elliott and Katz 1980). The PLOTT subtests use minimal pairs of words differing in only one feature (vowel length, vowel place, consonant voicing, consonant manner, or consonant place) of one phoneme in the words. The NU-CHIPS test uses 50 monosyllabic words with four alternative responses for each word. The response alternatives for both tests were represented pictorially, and the child responded by pointing. Open-set and closed-set tests were presented to the children

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using live voice at a normal conversational level at a distance of one metre.

The speech production tests used included the Edinburgh Articulation Test (Anthony et al 1971) of consonant production for some of the children, and the Fisher-Logemann Test (Fisher and Logemann 1971) of vowel and consonant production for others. The children's utterances for these tests were recorded on videotape for later assessment by an experienced speech pathologist.

Many different language assessments were used to cover the ranges of ages and skills of the children and adolescents. Only the results for the Peabody Picture Vocabulary Test (PPVT) (Dunn and Dunn 1981) will be given here, because it was used with all but one of the children to be discussed, and because it is relatively easy to quantify.

(ii) Children

Twenty children and adolescents have been implanted in Melbourne. From these twenty, I will give results for nine. The others are either too young or have insufficient language to do most of the tests, or have been implanted for less than one year. The children may be divided into three groups as shown in Table 1. The four children in group 1a were aged ten years or less at the time of the operation and had shorter durations of deafness than the children in group 2. There is only one child in group 1b who had a progressive hearing loss and was implanted at age 14. The children in group 2 were all implanted at an older age than group 1a, and had longer periods of profound deafness.

Table 1. Groups of children in the study.

	Age at implantation (y.m)	Duration of profound deafness (y.m)	N	Hearing alone open-set recognition
Group 1a	5.5-10.2	2.5-8.0	4	yes
Group 1b	14.8	0.7	1	yes
Group 2	13.11-19.9	12.7-19.9	4	no

Table 2 shows more details for the children. The first four children are in group 1a, and the fifth is in group 1b. It

Table 2. Details of children in the study. Children 1-4 are in group 1a, child 5 is in group 1b, and children 6-9 are in group 2.

CHILD	AETIOLOGY	ONSET OF LOSS (y.m)	DURATION OF PROFOUND (y.m)	EDUCATIONAL PROGRAM	AGE AT IMPLANTATION (YRS.)
1	Meningitis	3.3	6.11	Auditory/Oral	10.2
2	Meningitis	3.0	2.5	Cueing Supplement	5.5
3	Unknown	Congenital	8.0	Cueing Supplement	8.0
4	Meningitis	1.4	6.10	Auditory/Oral	8.2
5	C.M.V.	Progressive L and R ears	0.7	Auditory/Oral	14.8
6	Usher's syndrome	Congenital	19.9	Cueing Supplement	19.9
7	Usher's syndrome	Congenital	14.11	Cueing Supplement	14.11
8	Mondini	Congenital	14.8	Total communication	14.8
9	Meningitis	1.4	12.7	Cueing Supplement	13.11

will be seen later that these five children achieved some open-set speech recognition through hearing alone. The children in group 2 did not. This is fairly strong evidence that age at implantation and duration of profound deafness are important factors in determining the outcome of cochlear implantation in children. Within groups 1a and 1b, there are various aetiologies, with one congenital profound hearing loss. The other four had some experience of normal hearing. All were enrolled in educational programs with an aural emphasis and in two cases this was supplemented with cued speech. Child 1 was enrolled in a total communication program at the time of implantation but is now integrated into a normal school program. Three out of the four children in group 2 had congenital hearing losses. The length of deafness, and the age at implantation are both longer than for group 1a. All four children used a manual and an oral/aural component in their communication at school.

Results

(i) Speech Perception

Figure 1 shows the current correct scores for the feature discrimination subtests of the PLOTT test presented without lipreading in the most recent (postoperative) assessment. The chance score is 50% and the criterion for a score to be above chance with 95% confidence is 64%. All of the scores exceed this level except for most of the consonant place scores. Visual inspection and statistical analysis both indicate no significant difference between groups 1a and 2 for these subtests. Child 5 in group 1b performed very well. He also scored 90% correct for recognition of a set of eleven vowels in /hVd/ context and 65% for a set of twelve consonants in /aCa/ context.

Figure 2 shows the results for the NUCHIPS Test which consists of 50 monosyllabic words presented without lipreading. A response set of four alternatives, differing mainly in the place and manner of consonants, is used for each word presented. All scores were significantly above the chance score of 25%. Child 5 scored significantly higher than the others, but there were no differences between the four children in group 2 and the four in group 1a. The numbers shown in square brackets indicate the number of

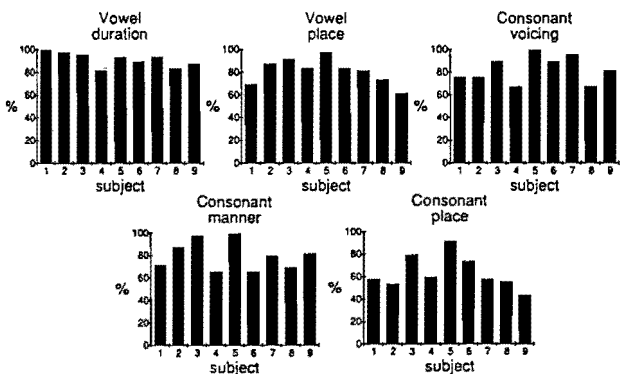


FIG. 1. Percentage correct scores for the feature discrimination subtests of the PLOTT Test without lipreading in the most recent postoperative assessment.

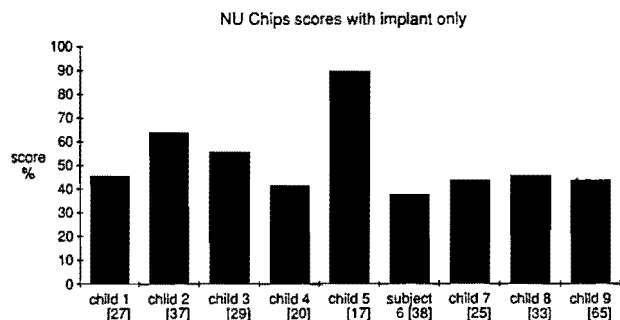


FIG. 2. Percentage correct scores for the NU-CHIPS Test without lipreading at the most recent postoperative assessment. The numbers in square brackets indicate the time between the implant operation and the test (in months).

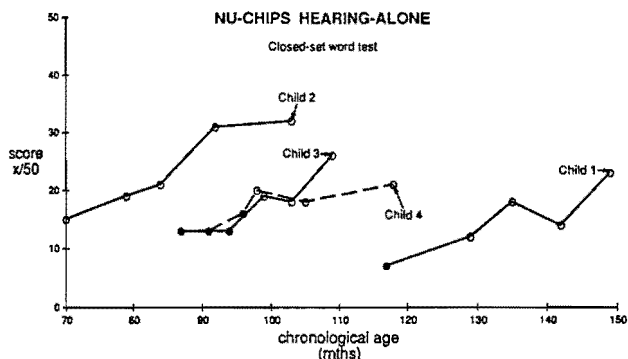


FIG. 3. Scores (out of 50) for Children 1-4 on the NU-CHIPS Test without lipreading at different pre- and postoperative assessments.

months after the operation at which the scores were obtained.

The NUCHIPS Test has been used in repeated measures for all of the children in group 1a. The results are shown in Figure 3. Preoperative scores are shown as filled circles, and postoperative scores as open circles. No preoperative score was greater than chance. All of the final postoperative scores were significantly greater than chance. Three out of the four children showed a significant improvement in scores over time. The fourth child showed a significant improvement in other closed-set perceptual tests.

Open-set AB Word Test scores (see Figure 4) showed a significant improvement when the implant was added to lipreading for most children. The improvement was

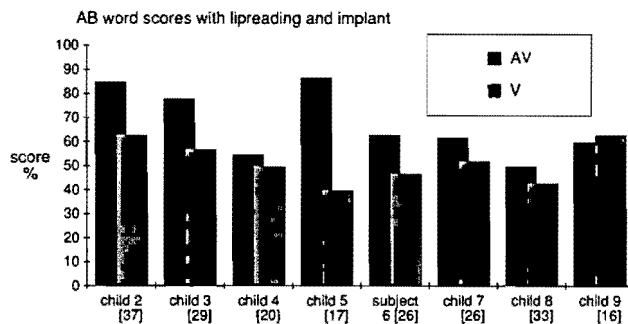


FIG. 4. Percentage correct phoneme scores for the open-set AB word test for lipreading alone (V) and lipreading plus audition using the implant (AV). The numbers in square brackets indicate the time between the implant operation and the test (in months). Child 1 was not tested.

greatest for child 5, and similar for the children in groups 1a and 2. This test was scored on the basis of the number of phonemes correct. On the same test without lipreading, a different pattern of results emerged as shown in Figure 5. Child 5 again scored higher than the others, but there was a difference between groups 1a and 2 as well. All of the children in group 1a achieved reasonable phoneme scores. The scores of group 2 children may be due to chance.

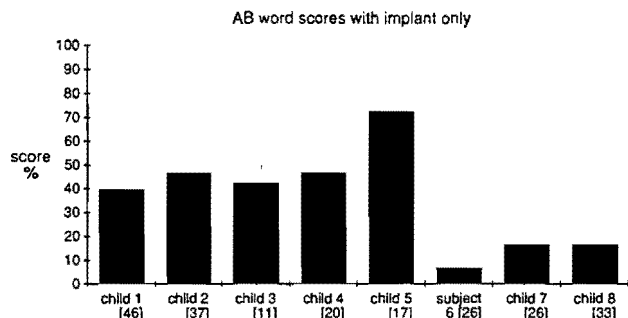


FIG. 5. Percentage correct phoneme scores for the open-set AB word test without lipreading. The numbers in square brackets indicate the time between the implant operation and the test (in months). Child 9 was not tested.

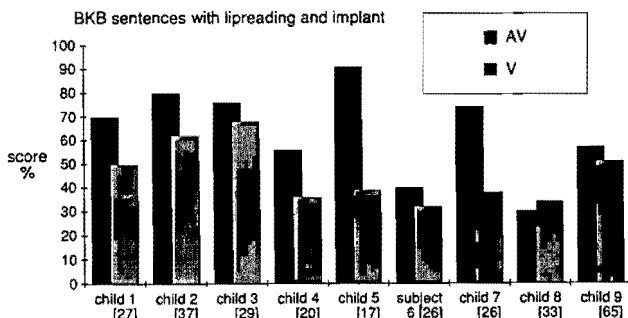


FIG. 6. Percentage correct word scores for the open-set BKB sentence test for lipreading alone (V) and lipreading plus audition using the implant (AV). The numbers in square brackets indicate the time between the implant operation and the test (in months).

Another open-set test with lipreading, the BKB Sentence Test provided similar results to the AB words (see Figure 6). Child 5 showed the greatest improvement. Results for

children in groups 1a and 2 were similar. Although one child in group 2 showed no improvement, this did not lead to a statistically significant difference between the groups. Only five children have been tested with the BKB Sentence Test without lipreading. The other children felt that the test was too difficult to attempt. Figure 7 shows that child 5 scored best, followed by the children in group 1a. Neither of the children tested from group 2 showed any open-set recognition in this test.

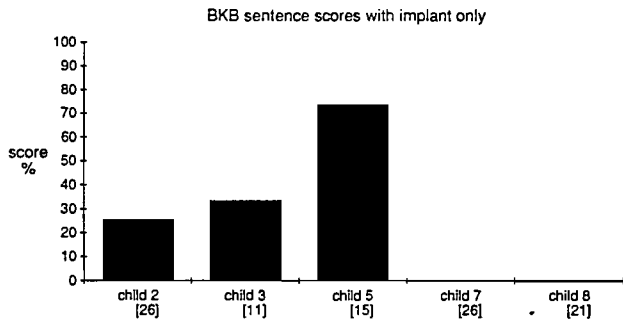


FIG. 7. Percentage correct word scores for the open-set BKB sentence test without lipreading. The numbers in square brackets indicate the time between the implant operation and the test (in months). Children 1, 4, 6 and 9 were not tested.

(ii) Speech Production

Speech production data have been obtained for all children except child 5, whose speech and language were both good before implantation. Three children were tested with the Edinburgh Articulation Test of consonants. All three showed improvements over time as in Figure 8, with the two children from group 1a progressing faster than child 9.

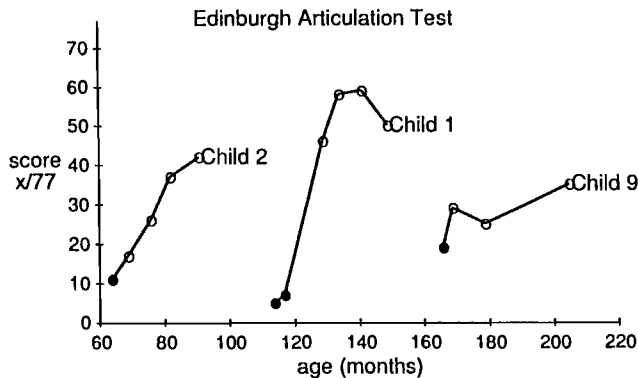


FIG. 8. Scores (out of 77) on the Edinburgh Articulation Test for Children 1, 2 and 9 as a function of age. Preoperative scores are shown by filled circles, and postoperative scores by open circles.

The other children were assessed with the Fisher-Logemann Test of vowel and consonant production as shown in Figure 9. Children 3, 4 and 8 showed marked improvements, with possible slower improvements for children 6 and 7.

Improvements depended on training received by the children, as indicated by the preoperative increases for children 3 and 4 (shown by solid circles in Figure 9). The improvement also depended on the starting level, as shown by the rapid improvement of child 8 compared with the other group 2 children. Differences between the groups of

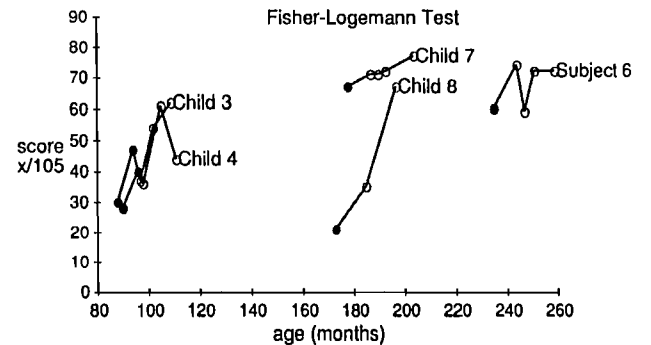


FIG. 9. Scores (out of 105) on the Fisher-Logemann speech production test for Children 3, 4, 6, 7 and 8 as a function of age. Preoperative scores are shown by filled circles, and postoperative scores by open circles.

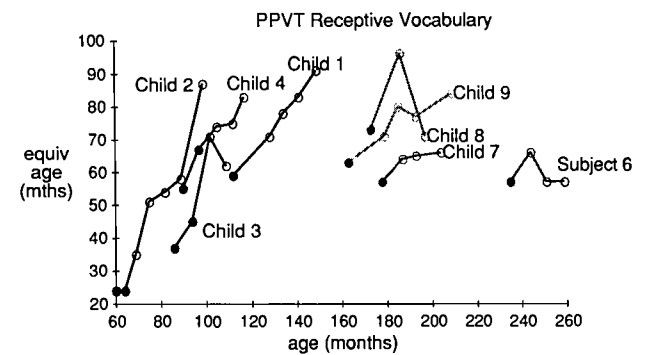


FIG. 10. Equivalent ages of normally hearing children with similar vocabulary levels derived from the revised Peabody Picture Vocabulary Test as a function of true age. Preoperative results are shown by filled circles, and postoperative results by open circles.

children may also be related to the training which was more frequent and more regular for the younger children.

(iii) Language

Figure 10 shows scores on the PPVT for all children in groups 1a and 2. The scores are expressed in terms of the equivalent age of normally hearing children with similar vocabulary. All of the equivalent ages at the latest data collection time fell between 5 years and 8 years (60-96 months) regardless of the true ages of the children which ranged from 8 years to 21 years. The differences between children were reflected in the slopes of the lines, with younger children progressing more rapidly than older ones. It was particularly encouraging to note that child 2 had progressed from a level 40 months below his true age at the last preoperative evaluation to a level only 12 months below this true age at the latest evaluation.

Summary

At the most difficult level of speech perception (ie open-set recognition without lipreading) five children out of nine were able to score better than chance.

At less difficult levels, such as improvement of lipreading on open-set tests, and in closed-set tests without lipreading, there were no significant differences between groups 1a and 2.

Child 5 with the shortest period of deafness, preceded by a long period of less severe hearing impairment, was closest to postlinguistically deafened adults and scored best on all perceptual tests.

Children in groups 1a and 2 showed continuing improvements over time in perception, production and language.

The improvements tended to be faster for the younger children.

All of the children described were everyday users of the implant and derived benefits from the device in conjunction with lipreading, in closed-set speech recognition, and recognition of environmental sounds.

Acknowledgments

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*H*earing is the foundation of language itself — the origin of that universal compact by which men have agreed to fix on certain sounds as the signs of their ideas, and by which each is enabled to communicate to the other his thoughts, his knowledge, and his affections, by a course so lucid and so direct. Oratory, that science so essential in the government of nations, and so useful in the promulgation of morality and religion, by the impressive combination which it presents of natural and artificial language, is also the offspring of this sense.

Suppose poetry, music, oratory, and language itself, to be at once lost to the world, and what a subtraction do we make from the sum of human happiness and intelligence! The most universal vehicle of knowledge at present employed in society would be at once destroyed, and the foundation of the great mass of our social enjoyments taken away.

But in proportion as it is capable of administering to the improvement both of our morals and our happiness, it is likewise adapted for the destruction of the one and of the other. It was into the ear of Eve that the serpent first poured the poison of sin and death.

GERALD GRIFFIN
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