JAAA 1:7-10 (1990)

Performance of Deaf Children With Cochlear Implants and Vibrotactile Aids

Mary Joe Osberger, Richard T. Miyamoto, Amy McConkey Robbins, Julia J. Renshaw, Stacey W. Berry, Wendy A. Myres, Kathy Kessler, and Molly L. Pope*

Abstract

A longitudinal study is under way to examine the speech perception and production skills of deaf children who use a single- or multi-channel cochlear implant, or a two-channel tactile aid. The speech perception data showed that the majority of subjects who achieved the highest scores on a range of measures used the multi-channel cochlear implant. The production data showed that all three types of sensory aids were effective in promoting production skills, with the cochlear implant users showing the greatest gains in this area.

Key Words: Single-channel cochlear implant, multi-channel cochlear implant, two-channel tactile aid, speech perception, speech production measurement

The purpose of this study is to examine changes in the speech perception and production abilities of deaf children who use either a cochlear implant or vibrotactile aid. There are three groups of experimental subjects: two groups use a cochlear implant (3M/House single-channel device or Nucleus 22-Channel Cochlear Implant System); the third group a wearable, two-channel vibrotactile aid (Tactaid II). Relevant information about the subjects appears in Table 1. All experimental subjects have received an implant or tactile aid because they have little or no residual hearing and receive minimal benefit from conventional hearing aids. Each subject in the tactile aid group has been selected to match a subject with an implant as closely as possible. Immediately after receiving their device, all subjects receive the same amount of intensive training, which continues through the first 6 to 9 months of device use (Robbins et al, 1988).

*Department of Otolaryngology — Head and Neck Surgery, Indiana University School of Medicine, Indianapolis, Indiana

Reprint requests: Mary Joe Osberger, Department of Otolaryngology — Head and Neck Surgery, James Whitcomb Riley Hospital for Children, Suite A56, 702 Barnhill Drive, Indianapolis, Indiana 46202

METHOD

Assessment of Speech Perception Skills

The population under study poses unique challenges in assessing performance with a sensory aid. Many of the children are very young with severely delayed linguistic skills. Most of the tests traditionally used to assess speech perception abilities, even those designed for children, were inappropriate for this population. Several new procedures were developed, or existing ones modified, to meet the needs of this project. The test battery includes discrimination, identification, and comprehension tasks and speech material ranging from isolated words to connected discourse. Some tests are administered in the auditory-only condition (live-voice or recorded format), others with visual cues. The subjects are tested in the predevice condition and at 6-month intervals thereafter.

Table 1 Characteristics of Subjects in Speech Perception Study

Device	*N*	*Onset*	*Age Fit*	*Years Deaf*	*Years Use*
Tactaid II	16	1.2	6.5	5.3	1.4
3M/House	19	2.2	7.9	5.8	2.8
Nucleus	16	2.3	7.6	5.3	1.1

Description of Perception Measures

Only those tests which employ a closed-set response format will be described. The reader is referred to Robbins et al (1988) and Miyamoto et al (1989) for information on additional measures.

The *Change/No Change* test, developed for this project, is designed to assess the children's ability to detect a change in a segmental or suprasegmental feature of speech. The paradigm is based on that of Kuhl (1980), as modified by Sussman and Carney (1989), to assess the perceptual skills of infants. There are nine subtests, each with one feature contrast (syllable length, intonation, fundamental frequency, talker gender, vowel height, vowel place, consonant manner, consonant voicing, and consonant place). A subtest consists of 15 trials with each trial consisting of a string of 10 nonsense syllables spoken by a male talker. For a *no-change* trial, the 10 stimuli are the same. For a *change* trial, the last five stimuli differ from the first five. The child is trained to respond when a change trial occurs.

The *Monosyllable-Trochee-Spondee (MTS)* test (Erber and Alencewicz, 1972) is administered live-voice. It consists of 12 pictured nouns with three different stress patterns. Each item is scored for stress-pattern categorization (MTS:C) and word identification (MTS:I).

The *Minimal Pairs (MinPair)* test, developed for the project, consists of pairs of pictured words with members of a pair differing in terms of vowel height, vowel place, consonant manner, consonant voice, or consonant place. The child points to the picture corresponding to the item presented live-voice by the examiner.

The Hoosier Auditory Visual Enhancement Test (HAVE), also developed for the project, is used to evaluate integration of auditory and visual information. The test consists of three pictured items. Two items are visually similar (e.g., *man* and *pan*) whereas the remaining one is visually distinct (e.g., *fan*). On a given trial, only one of the homophenous words is presented but always with combined auditory and visual cues. Each response is scored on the basis of visual correctness (HAVE:Visual) (i.e., the child selects either one of the visually similar words) and word correctness (HAVE:Word) (i.e., the child correctly selects the target because both auditory and visual cues are perceived accurately).

Results

Cross-sectional data are presented for each group of subjects because insufficient longitudinal data are available at this time. The data, which are summarized in Figure 1, were collected during each subject's most recent evaluation (see Table 1 for mean duration of device use for each group). Performance on the closed-set response tests has been analyzed in terms of the percentage of subjects in each experimental group who scored significantly above chance on each measure, as determined by the binomial distribution. Figure 1 summarizes the percentage of subjects in each group who scored significantly above chance on each of the tests. The HAVE:Visual data are not shown because all subjects obtained a nearly perfect score on this measure. The data in Figure 1 show that on nearly every test the largest percentage of subjects who scored significantly above chance used the Nucleus cochlear implant. This trend was most apparent on the word recognition measures (MTS:I, MinPair, and HAVE:Word). The exception to this trend was the subjects' performance on the stress-pattern categorization task of the MTS test (MTS:C). On this measure, the largest percentage of subjects who scored above chance used the 3M/House device.

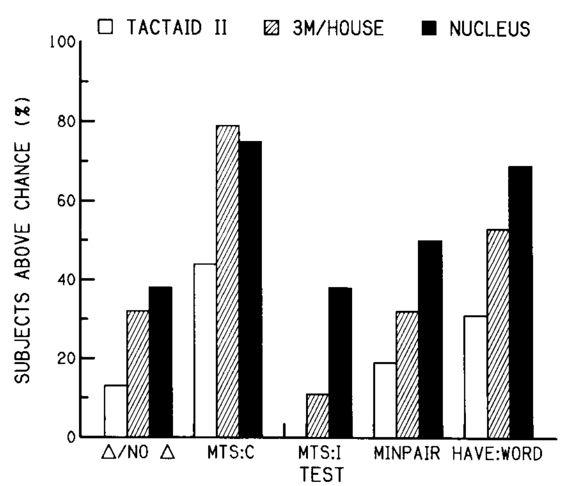

Figure 1 Percentage of subjects in each experimental group who scored significantly above chance, as determined by the binomial distribution, on a range of speech perception measures (Change/No Change test, Monosyllable-Trochee-Spondee:Categorization, Monosyllable-Trochee-Spondee:Identification, Minimal Pairs, and Hoosier Auditory Visual Enhancement:Word).

On all the other measures, the percentage of 3M/House subjects who scored significantly above chance was lower than that of the Nucleus subjects. The smallest percentage of subjects who scored significantly above chance on all tests used the Tactaid II. These data suggest superior performance with a cochlear implant than a two-channel tactile aid, at least on the measures under study. Further, the difference in duration of device use between the single- and multi-channel cochlear implant users suggests a faster rate of learning with the Nucleus device than with the 3M/House device.

Assessment of Speech Production Skills

A wide range of speech production abilities is demonstrated by the subjects in the experimental groups in the pre-device condition. Some subjects have extremely limited speech production abilities, whereas others have speech that is relatively intelligible. Several testing and analyses protocols are used because of these differences (Osberger, 1989). Data collected from only one protocol are presented. This protocol is administered to subjects with the most limited speech production abilities. Typically, their speech contains utterances recognized as sounds of English less than 70 percent of the time with an extremely limited phonetic repertoire.

The protocol involves a scheme of analysis similar to that used to study the speech of normally developing infants. A 6-minute speech sample, elicited from the child during a play situation, is video- and audio-recorded and subsequently analyzed by two speech-language pathologists. If an utterance is perceived as a recognizable phoneme of English, or a reasonable approximation of one, it is classified as *speech*. Sounds that do not represent speech at all (e.g., grunts, growls) are classified as *non-speech*. All other vocalizations are classified as *speechlike*. A fourth category is used to classify undesirable articulatory gestures. The frequency of occurrence of each type of token is then calculated.

The protocol was administered to 4 of the 16 (25 percent) Nucleus subjects, 8 of 19 (42 percent) 3M/House subjects, and 9 of 16 (56 percent) Tactaid II subjects. The difference in the number of subjects in each group who received this protocol reflects differences in speech production abilities in the pre-device condition. Note that a relatively larger percentage of 3M/House and Tactaid II subjects required this protocol compared to the subjects with the Nucleus cochlear implant. The characteristics of the subjects whose speech was analyzed using this protocol are summarized in Table 2.

Results

Figure 2 summarizes the mean percentage of tokens classified as speech relative to the occurrence of other types of tokens (i.e., number of *speech* tokens divided by the sum of all tokens) across time for the three groups of subjects. The data show that the samples of the Nucleus subjects contained a much lower percentage of *speech* tokens in the pre-device condition than did the speech of the other two groups of subjects. Six months after they received their device, all three groups of subjects showed an increase in the percentage of tokens classified as *speech*. The Nucleus subjects continued to show a large increase in the percentage of tokens classified as speech 1.5 years post implant (note that data are available for only one subject at this interval). After the first 6 months of device use, there was essentially no increase, on the average, in the use of *speech* sounds by the 3M/House subjects. Only about half of their utterances were recognized as phonemes of English even after 2 years of device use. The Tactaid II subjects continued to show an increase in their use of speech sounds after 6 months of device use. Additional longitudinal data are needed to determine if this trend continues to occur.

Analyses are underway to examine changes in the children's phonetic repertoire over time as a function of type of device. An initial examination of the relationship between the children's perception and production skills suggests that improvements in speech production can occur even if a child is only able to discriminate changes in speech features on perception tasks.

Table 2 Characteristics of Subjects in Speech Production Study

Device	*N*	*Onset*	*Age Fit*	*Years Deaf*
Tactaid II	10	1.5	5.3	3.8
3M/House	8	1.2	5.4	4.1
Nucleus	4	1.0	5.2	4.1

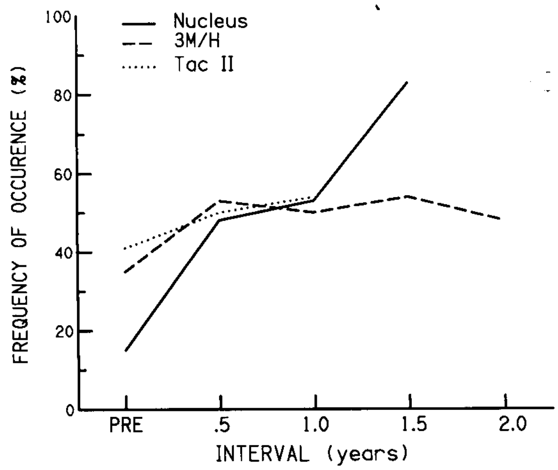

Figure 2 Percentage of tokens classified as *speech* relative to the occurrence of other utterances in the spontaneous speech samples of three groups of subjects in the pre-device condition and at 6-month intervals thereafter. The number of subjects whose data were averaged at each interval is: Nucleus (n=4 in the pre-condition and 0.5 year, n=2 at 1.0 year, and n=1 at 1.5 years); 3M/House (n=8 in the pre-condition, n=7 at 0.5 year, n=5 at 1.0 years, n=3 at 1.5 years, and n=4 at 2.0 years); Tactaid II (n=10 in the pre-condition and 8 at 0.5 and 1.0 years).

The speech production data, reported for those subjects with the most reduced speech skills in each group, showed that all three types of sensory aids were effective in promoting an increase in the use of phonemes of English after 6 months of device use. The most dramatic improvement in production skills was made by the subjects with the Nucleus device. The relationship between perception and production abilities is complex. Subjects demonstrated improvement in their ability to produce speech even though they could not identify words through their device. Additional analyses are underway to clarify this relationship. That is, a child need not demonstrate auditory word recognition abilities for improvements in speech production skills to occur.

SUMMARY AND CONCLUSIONS

The perception data show that the largest percentage of subjects who scored significantly above chance on a battery of closed-set speech perception measures used a cochlear implant. It is noteworthy that the subjects who most often scored above chance used the multichannel implant even though they had less experience with their device than the single-channel users. Although a smaller percentage of subjects scored significantly above chance on the measures with a vibrotactile aid, these subjects, nevertheless, received more benefit from this device than they did with conventional hearing aids. Conclusions cannot be reached about the superiority of one sensory modality over another until a more sophisticated multichannel instrument is evaluated.

Acknowledgments. The assistance of Linda Hesketh, M.S. and Allison Sedey, M.A; University of Wisconsin, Madison, WI, Michael A. Novak, M.D. and Jill B. Firszt, M.A. of the Carle Clinic, Urbana, IL, and Susan Zimmerman-Philips, M.S. and Paul D. Kileny, Ph.D. of the University of Michigan, Ann Arbor, MI, in the collection of data is gratefully acknowledged. This research was supported by grants DC000415 and DC000423 from NIH-NIDCD.

REFERENCES

Erber NP, Alencewicz CM. (1972). Audiologic evaluation of deaf children. *J Speech Hear Res* 41:256–267.

Kuhl P. (1980). Perceptual constancy of speech-sound categories in early infancy. In: Yeni-Konshian GH, Kavanagh JF, Ferguson C, eds. *Child phonology.* Vol 2. New York: Academic Press, 41–66.

Miyamoto RT, Osberger MJ, Robbins AM, Renshaw JJ, Myres WA, Kessler KK, Pope ML. (1989). Comparison of sensory aids in deaf children. *Ann Otol Rhinol Laryngol* 98:2–7.

Osberger MJ. (1989). Speech production in profoundly hearing-impaired children with reference to cochlear implants. In: Owens E, Kessler DK, eds. *Cochlear implants in young deaf children.* Boston: College-Hill Press, 257–282.

Robbins AM, Osberger MJ, Miyamoto RT, Renshaw JJ, Carney AE. (1988). Longitudinal study of speech perception by children with cochlear implants and tactile aids: progress report. *J Acad Rehabil Audiol* 21:11–28.

Sussman JE, Carney AE. (1989). Effects of transition length on perception of stop consonants by children and adults. *J Speech Hear Res* 32:151–160.