
BEHAVIORAL TECHNIQUES IN AUDIOLOGY AND OTOLGY

Word Recognition by 50 Patients Fitted with the Symbion Multichannel Cochlear Implant*

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ABSTRACT

We describe the word recognition ability of 50 patients who use the multichannel cochlear implant manufactured by Symbion, Inc. The median scores for open set tests involving auditory stimulation alone were: 14% correct (range 0 to 60) for monosyllabic words, 44% correct (range 0 to 100) for spondees, and 45% correct (range 0 to 100) for words in the Everyday CID Sentences. In the visual stimulation condition of the Everyday CID Sentences, the median score was 64% correct (range 0 to 100). In the visual plus auditory stimulation condition, the median score was 99% correct (range 46 to 100). These results demonstrate that relatively good speech understanding can be achieved using a cochlear implant which employs only a few channels of stimulation and which simultaneously activates monopolar electrodes.

In this report we describe the word recognition ability of 50 patients who use the multichannel cochlear implant manufactured by Symbion, Inc. The patients are a subset of the population fitted with the implant who had six electrodes in the cochlea, who had at least four functioning electrodes, who were free from other neurological disorders, and from whom scores were available from several tests of speech identification.

The Symbion implant consists of (1) 6 monopolar electrodes implanted in the scala tympani with remote reference, (2) a percutaneous pedestal to which the electrode wires are attached, and (3) a portable speech processing and electrode stimulation system (Eddington, 1980, 1983). The most apical electrode is located about 22 mm from the round window. The electrodes are spaced at 4 mm intervals. Usually, the four most apical electrodes are

activated. Each electrode is driven by a signal derived from the input signal after bandpass filtering. The center frequencies of the filters for channels 1 to 4 (most apical to most basal electrodes) are 0.5, 1, 2, and 4 kHz. The effectiveness of this implant is of interest on both practical and theoretical grounds.

We wish to know how well the patients are able to understand speech. To this end we have tested the patients with monosyllabic words, spondees, and words in sentences (Everyday CID Sentences). These tests were administered without lipreading. In addition, we have tested the patients with the Everyday CID Sentences in a lipreading alone condition and in a condition allowing both lipreading and auditory comprehension.

The performance of our patients is also of interest from the point of view of cochlear implant design. Those who design implants must have opinions on the following issues: How many channels of stimulation are necessary? Should the channels be activated simultaneously or successively? Should the speech processor extract "features," such as formants, from the signal, or should the processor present the signal to the auditory system in a relatively unprocessed fashion? Should the electrodes be monopolar or bipolar?

Loeb, White, and Jenkins (1983) have noted that electrophysiological theory can provide only limited guidance on these issues and that the development of cochlear prostheses will proceed largely on empirical grounds. In this spirit, we describe the performance of our patients on tests of word recognition.

METHOD

Subjects

The selection criteria for obtaining the Symbion device stipulate that all patients be at least 18 years of age with profound, bilateral, sensory hearing loss. They must be postlingually deafened and cannot obtain significant speech benefit from conven-

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tional hearing aids. The patients must be in good health and psychologically stable.

The 50 patients described in this report are a subset of 80 patients whose records were surveyed initially. Each of the 50 patients had six electrodes in the cochlea, had at least four functioning electrodes, was free from other neurological disorders, and had been tested with several measures of word identification. The patients ranged in age from 19 to 78 years (mean = 46). The length of profound deafness varied from one to 49 years (mean = 11.5). The presumed etiologies of profound deafness included unknown ($n = 23$), congenital or progressive hearing loss ($n = 7$), meningitis ($n = 7$), ototoxic drugs ($n = 5$), Meniere's Disease ($n = 4$), trauma ($n = 3$), and otosclerosis ($n = 1$). A noteworthy characteristic of the meningitic patients was an early onset of profound deafness and a long period of deafness before implantation. Five of the seven patients were deafened at age 10 years or younger. The length of deafness before implantation ranged from 11 to 49 years.

The patients were implanted and tested in 13 different locations in the United States and had worn their sound processors for at least 1 year.

Materials

As part of the standard test protocol for all subjects implanted with the Symbion device, a battery of subtests selected from the revised Minimal Auditory Capabilities Battery (Owens, Kessler, Raggio, & Schubert, 1985) is administered 1 month following fitting of the processor and at succeeding 3 month intervals during the first year. The data reported here are from the tests administered 1 year after the processor was fitted. The tests selected for discussion in this article are the Spondee Recognition Test, the Monosyllabic Word Test, and the Everyday CID Sentence Test.

The Spondee Recognition test is composed of 25 words. The

Monosyllabic Word Test is composed of 50 words (from the NU 6 list). The Everyday CID Sentence Test consists of four lists of 10 sentences. In each list, 50 words are designated as "key" words and are scored as correct or incorrect.

The Spondee Recognition Test and the Monosyllabic Word Test were administered via tape recorder and loudspeaker at 70 dB SPL. The Everyday CID Sentences were administered in three conditions: Auditory information only (live voice), visual information only, and auditory (live voice) plus visual information. A different test list was used in each condition. No feedback was given of correct answers for any condition of any test in the battery.

Spondee recognition scores were available from 50 patients. Monosyllabic word recognition scores were available from 41 patients. For the auditory stimulation condition of the Everyday CID Sentences, 50 scores were available; for the visual stimulation condition, 49 scores were available; and for the auditory plus visual stimulation condition, 49 scores were available.

RESULTS

The results of the monosyllabic word recognition task are shown in Figure 1. The range of performance was 0 to 60% correct. The median score was 14% correct. Of the 16 patients whose scores fell between 0 and 10% correct, 7 patients had lost their hearing following meningitis.

The results of the spondee recognition task are shown in Figure 2. The range of performance was 0 to 100% correct. The median score was 44% correct. Of the 16 patients whose scores fell between 0 and 20% correct, 7 patients had lost their hearing due to meningitis.

The results of the Everyday CID Sentence Test in the auditory stimulation condition are shown in Figure 3. The

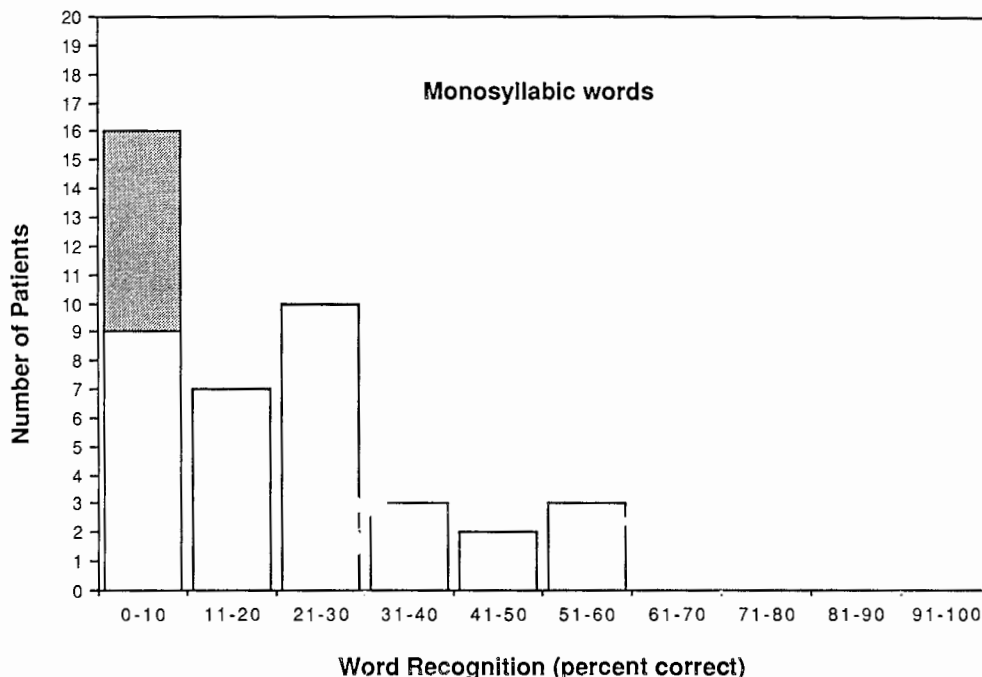


Figure 1. Percent correct monosyllabic word recognition. The shaded portion of each histogram, in Figures 1 to 5, indicates the performance of patients who lost their hearing following meningitis.

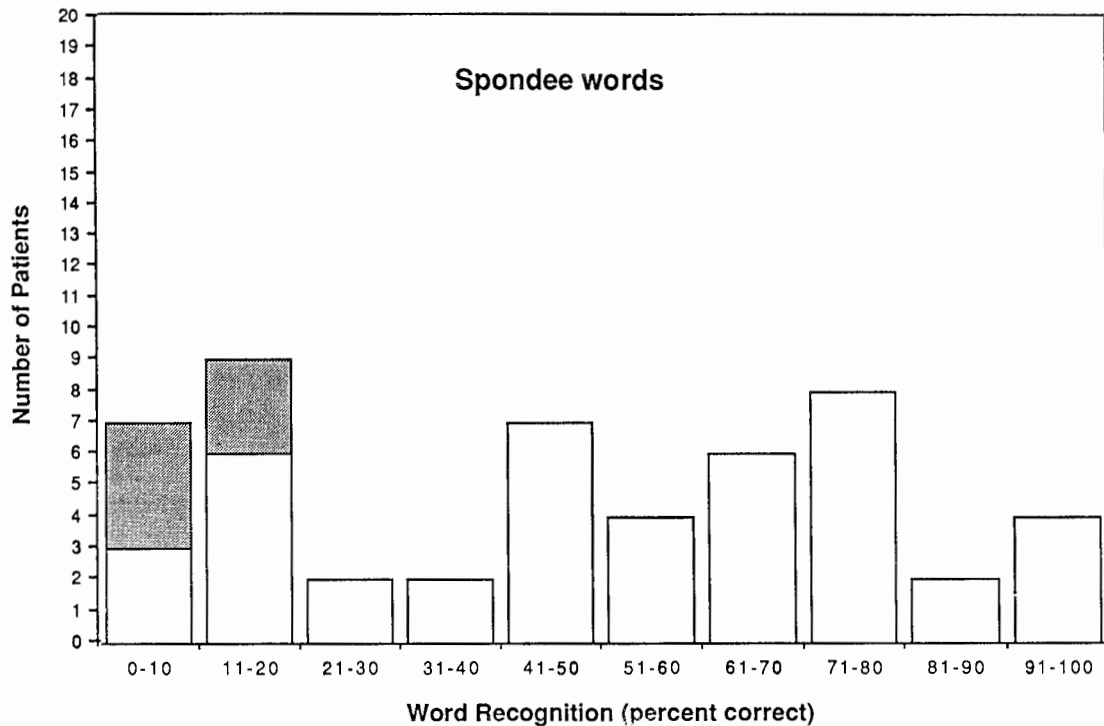


Figure 2. Percent correct spondee recognition.

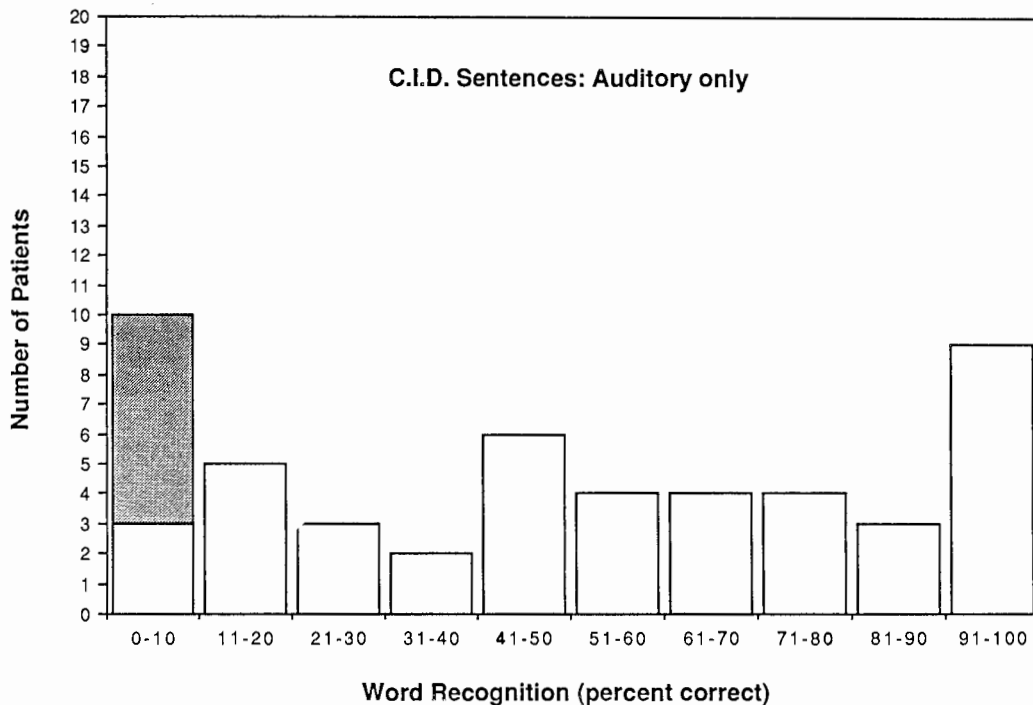


Figure 3. Percent correct recognition for words from the Everyday CID Sentence Test in the auditory stimulation condition.

range of performance was 0 to 100% correct. The median score was 45% correct. Of the 10 patients whose scores fell between 0 and 10% correct, 7 patients had lost their hearing due to meningitis.

The results of the Everyday CID Sentence Test in the visual stimulation condition are shown in Figure 4. The range of performance was 0 to 100% correct. The median score was 64% correct. The patients who had lost their

hearing following meningitis performed relatively well on this task (median score = 74% correct). The range of performance was 34 to 90% correct.

The results of the Everyday CID Sentence Test in the visual stimulation plus auditory stimulation condition are

shown in Figure 5. The range of performance was 46 to 100% correct. The median score was 99% correct. Of the 10 patients whose scores were less than 90% correct, 3 patients had lost their hearing due to meningitis.

The performance of the meningitic patients in the visual

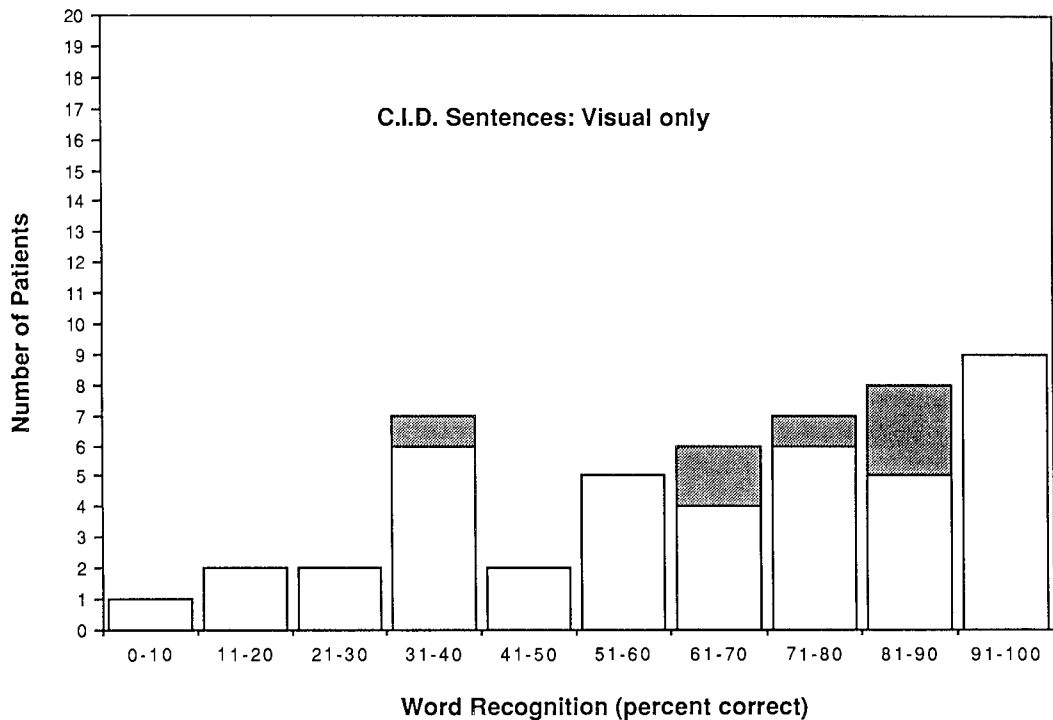


Figure 4. Percent correct recognition for words from the Everyday CID Sentence Test in the visual stimulation condition.

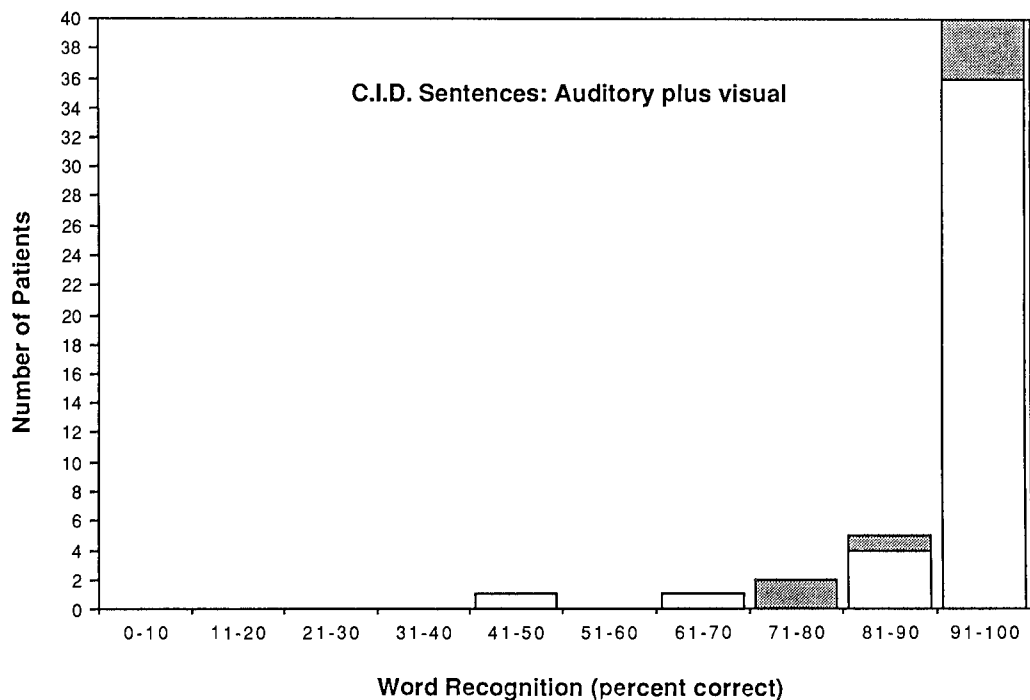


Figure 5. Percent correct recognition for words from the Everyday CID Sentences in the auditory plus visual stimulation condition.

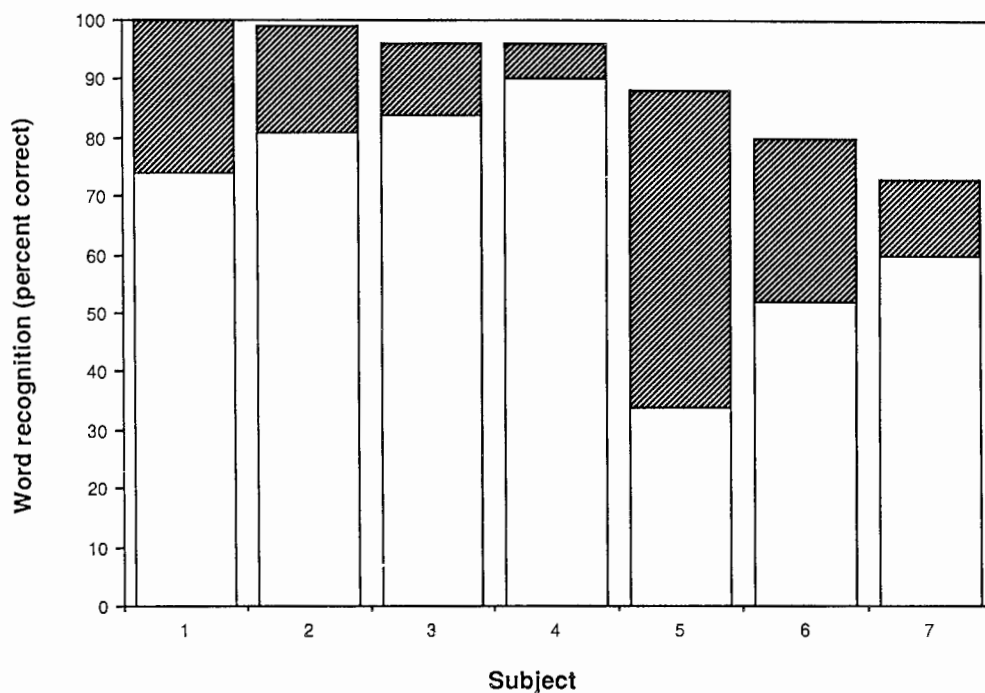


Figure 6. Percent correct recognition for words from the Everyday CID Sentence Test by seven patients whose deafness followed meningitis. Performance in the visual stimulation condition is indicated by the height of the open histograms. Performance in the auditory plus visual condition is indicated by the height of the shaded histograms.

Table 1. Correlations among subject variables and performance on tests of word recognition.

	Tests				
	Monosyllable recognition	Spondee recognition	CID (A)	CID (V)	CID (A + V)
Patient's age	-0.292	-0.039	-0.101	-0.327*	-0.298*
Length of deafness	-0.212	-0.404**	-0.264	0.314*	0.030

Note. CID, Everyday CID Sentence Test; A, auditory presentation; V, visual presentation; A + V, auditory plus visual presentation.

* $p < 0.05$.

** $p < 0.01$.

plus auditory condition of the Everyday CID Sentence Test is shown in Figure 6. All patients experienced better intelligibility in the visual plus auditory condition than in the visual stimulation condition. The range of improvement was 6 to 54%. The mean improvement was 22% (this mean score was limited by a ceiling effect for 2 of the 7 patients).

Correlations

The correlations among two of the patient variables—age and length of deafness—and the measures of speech recognition are shown in Table 1. A small, but significant, negative correlation was found between age and performance in the visual stimulation condition of the Everyday CID Sentences [$r(48) = -0.32, p < 0.05$] and in the

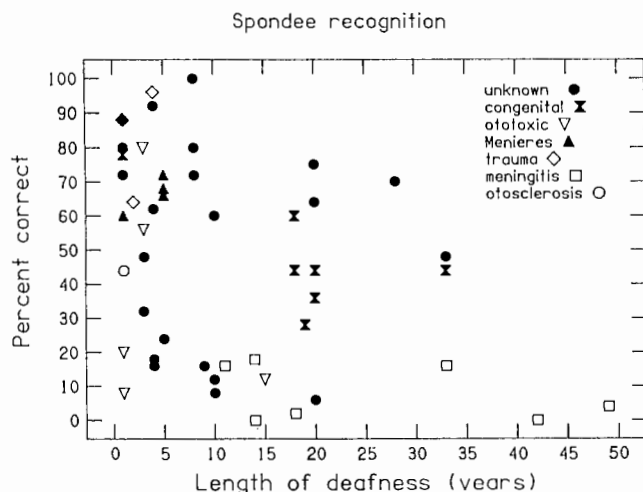


Figure 7. Percent correct spondee recognition as a function of length of profound deafness. Each symbol type indicates the performance of a different group of patients.

auditory plus visual condition [$r(48) = -0.298, p < 0.05$].

A significant negative correlation was found between length of deafness and spondee recognition [$r(49) = -0.40, p < 0.01$]. A small, but significant positive correlation was found between length of deafness and performance in the visual stimulation condition of the Everyday CID Sentences [$r(48) = 0.31, p < 0.05$].

Spondee recognition as a function of length of deafness is shown in Figure 7. Visual inspection indicates that the correlation between length of deafness and spondee recognition may have been influenced significantly by the presence of three meningitic patients who had been deaf for more than 30 years. When all of the meningitic patients were eliminated from the data pool, the correlation between length of deafness and performance was not significant [$r(42) = -0.19$, $p = 0.199$].

DISCUSSION

In the "Introduction" we noted the comment by Loeb et al (1983) that the design of cochlear implants would proceed largely on empirical grounds. From this point of view, the results described here must be viewed as encouraging. On the test which best represents face to face communication, the visual plus auditory condition of the Everyday CID Sentences, the median score was 99% correct. On the test of auditory comprehension in which there was semantic and syntactic information as well as phonetic information, i.e., the auditory stimulation condition of the Everyday CID Sentences, the median score was 45% correct. Nine of the 50 patients achieved scores of 90% correct or better. Even on the tests of auditory comprehension in which normally occurring linguistic information was absent, overall performance was above chance. The median scores for spondee and monosyllabic word recognition were 44 and 14% correct, respectively. Some patients achieved remarkably good scores, e.g., 100% correct for spondees and 60% correct for monosyllabic words.

Length of Deafness

We might suspect that destruction of neurons in the cochlea followed by long-term auditory deprivation would lead to especially poor speech understanding. This may be the case for the three meningitic patients who had been profoundly deaf for more than 30 years (Fig. 7). However, when the meningitic patients were removed from the data pool, no significant correlation was found between length of deafness and auditory comprehension. Inspection of Figure 7 suggests that the patients who were without auditory stimulation for 25 years could benefit about as much from an implant as those who were without auditory stimulation for 5 years or less.

Implant Design

A convincing argument can be made, based on the results of speech identification tests with channel vocoders

(e.g., Halsey & Swaffield, 1948) and on the results of tests of current spread in the cochlea (van den Honert & Stypulkowski, 1987), that, for cochlear implants (1) many channels of stimulation should be better than fewer; (2) channels should be activated successively, rather than simultaneously, to avoid current interaction; and (3) that bipolar electrodes, which reduce the spread of current, should be preferred over monopolar electrodes. The level of performance reported here for patients fitted with a device which uses relatively few channels of stimulation and which simultaneously activates monopolar electrodes suggests that the conditions described above are not necessary conditions for achieving relatively high levels of word recognition. Indeed similar levels of word recognition have been reported for patients who use the Symbion device and for patients who use the Nucleus device (Tong et al., 1980) which extracts speech features, which uses 22 channels, and which activates bipolar electrodes in a non-simultaneous manner (Gantz, McCabe, Tyler, & Preece, 1987; R Tyler, unpublished data).

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