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SPEECH FEATURE PERCEPTION BY PATIENTS USING A SINGLE-CHANNEL VIENNA 3M EXTRACOCHLEAR IMPLANT

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Abstract

In the Swedish cochlear implant project, ten post-lingually deaf patients have been implanted with a single-channel implant with extracochlear electrode. After implantation, the patients went through a longer, structured training and test program. Testing was made 1, 3, 6, 12, 24, and 36 months after surgery. In the test battery, measurements of frequency, time discrimination, and speech perception ability with and without simultaneous lipreading were included. The results of tests in the perception of speech features obtained from ten implanted patients, 12 months after surgery, showed that almost all of them are able to perceive some prosodic information. Only one of the subjects has ability to identify the Swedish vowels with any accuracy. She has also some speech perception ability without support of lipreading. Consonant perception is mostly based on temporal distinctions. The results of the consonant tests show that the subjects make use of informations regarding amplitude and voicing, and presence and absence of friction.

INTRODUCTION

It has long been known that stimulation of the auditory nerve with a weak electric current results in auditory sensation. As early as in 1790, Volta made experiments with electrical stimulation of his ear. During the last two decades the research in the fields of electronics, audiology, speech science, and surgery has made it possible to introduce a limited world of sound to profoundly deaf patients. This has been carried out by cochlear implants which electrically stimulate the auditory nerve. Since the beginning of the seventies, House at the Ear Research Institute in Los Angeles has been implanting deaf patients with a simple single channel cochlear implant (House, 1983). At the same time, research and development have been going on at several laboratories both on single-channel and multi-channel devices. In the eighties, the number of patients with implants has been growing rapidly. It has been estimated that today over 4000 patients have received cochlear implants of various types. As more advanced systems are introduced, the number of patients with implants will undoubtedly grow fast.

In a single-channel extracochlear implant, the active electrode can be placed in the round window niche or inserted in the bone of the promontory. This placement of the active electrode results in that a large number of neurons is stimulated simultaneously. During the last year, very good speech understanding without support of lipreading has been reported from subjects using this type of implant (Hochmair-Desoyer, Hochmair, Burian, & Fischer, 1981).

In the Swedish cochlear implant project reported here, a single-channel extracochlear implant developed in Vienna and manufactured by 3M is used (v. Wallenberg,
Hochmair-Desoyer, & Hochmair, 1985). The project is run at the Dept. of Audiology of the South Hospital (Södersjukhuset), Stockholm, in cooperation with our department.

SUBJECTS
Ten post-lingually deaf patients participated in this study. Criteria for operation were total acquired deafness, an active cochlear nerve, no benefit from hearing aids, strong motivation, a good social back-up, and auditory memories, which excluded them who were born deaf.

<table>
<thead>
<tr>
<th>Subjects:</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
<th>S6</th>
<th>S7</th>
<th>S8</th>
<th>S9</th>
<th>S10</th>
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<td>M</td>
<td>M</td>
<td>F</td>
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<td>M</td>
<td>M</td>
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<td>Age:</td>
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<td>52</td>
<td>42</td>
<td>54</td>
<td>25</td>
<td>49</td>
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<tr>
<td>Years of deafness:</td>
<td>4</td>
<td>27</td>
<td>7</td>
<td>20</td>
<td>46</td>
<td>14</td>
<td>10</td>
<td>2</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>

Progressive hearing-loss: S1, S6, S7, S9, S10.
Meningitis: S2, S5, S8
Otoxic drugs: S4
Scull fracture: S3

Table I. Some data on the ten patients.

MATERIAL AND METHODS
After implantation, the patients go through a longer, structured training and test program. Testing is made 1, 3, 6, 12, and 24 months after surgery. In the test battery, measurements of frequency and time discrimination and speech-perception ability are included. The test battery is developed at our department and primarily used for assessing communication competence of severely hard of hearing persons with a view to determining appropriate rehabilitation strategies (Risberg & Agelfors, 1983). The test program is based on a model of speech perception that includes a number of processing levels. At each level, tests are used to determine how well the speech perception system of the patients is functioning. In this model, the two lowest levels are: I signal transformation and II signal analysis. At higher levels, III phonetic interpretation, the ability to extract basic linguistic information, is tested and on the highest levels, IV information processing ability and V linguistic interpretation. In this study, results on levels II, III, and IV have been evaluated 12 months after implantation.

The following signal analysis measurements (level II) were used:

1. Frequency discrimination with sinusoidal signals.
   Measurements are made in the frequency range 125 Hz-3000 Hz. This test is seen as a general test of the signal analyzing capacity.

2. Frequency discrimination with a band-pass filtered pulse-train.
   Band-pass filtered pulse trains of white noise with a band width of 1000 Hz and mid-frequency 500, 1000, 2800 Hz. The stimulus had either a constant repetition rate, or it was frequency modulated at 2 Hz. Testing was done with pulse repetition rates of 125 and 250 pps. The test was meant to simulate intonation of a male and female speaker.
The test measures time-resolution by means of a short interruption in a two seconds long band-pass filtered noise signal. Bandwidth 1000 Hz, mid-frequency 500, 1000, 2800 Hz

4. Periodic/non periodic signals.
The test measures identification time for periodic and non periodic signals. In this test, two signals are used, a pulse train with the repetition frequency 120 Hz and white noise. The signals are band-pass filtered with the same filters as used in test 2 and 3.

SPEECH TESTS
The perception of speech is closely related to the detection of both phonetic and prosodic structures of the speech signal. The prosodic information does not change the time domain as fast as the phonetic information. It contains the information of F0, intensity and temporal spacing of gross acoustic events. It is generally assumed that speech perception with a single-channel implant is confined mainly to the prosodic information.

The test of speech perception (level III, IV) consists of rhyme tests based on acoustic differences as identification of phonemes, syllables, and word stress, intonation, spondee words, and words in context. Word-lists with two or three response alternatives are used in the rhyme tests. The test list ranges in difficulty from gross discrimination to minimal phonetic contrasts. In the test battery used, a test with 12 known spondee words is also included.

The test equipment was a computerized self-instructed test system. Each patient was tested individually and coupled to the test system over the line input of the implant and they adjusted the controls on his/her own stimulator unit to a comfortable level. The patients could repeat the stimulus as many time they wanted before answering.

RESULTS
The results of feature perception in the rhyme tests expressed as total range and median values by ten cochlear implant patients is shown in Fig. 1. Fig. 2 shows the results from the test with 12 known spondee words. The patients S5 and S6 found the test too difficult. Fig. 3 shows the relation between the frequency discrimination ability at 125 Hz for sinusoidal tones and the result on the spondee test.

DISCUSSION
The figures show large variation in results on the different tests. This is typical for cochlear implant patients and has been reported for both single and multi-channel implants. Better results are on the average obtained on the prosody test. The good correlation between frequency discrimination ability at 125 Hz (Fig. 3) and percent correct on the spondee test indicate that a single-channel implant mainly transmits low-frequency information. The correlation obtained \( r = -0.79 \) is one of the highest between any of the signal analysis measures and the ability of word identification. Two subjects stand out as "star"-patients, S1 and S8, see Figs. 2 and 3. Detailed studies have been made of S1:s ability to identify vowels (Agelfors & Risberg, 1987). These studies indicate that she has reasonably good ability to perceive both the first and the second formant of the vowels. On the test with nine long Swedish vowels, she scored 67% correct four years after implantation. These results contradict the hypotheses that a sub
<table>
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<th>PROSODY</th>
<th>TEST</th>
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<tr>
<td></td>
<td>NUMBER OF SYLLABLES (easy)</td>
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</tr>
<tr>
<td></td>
<td>NUMBER OF SYLLABLES (difficult)</td>
<td></td>
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<tr>
<td></td>
<td>INTONATION</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MALE / FEMALE VOICE</td>
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<tr>
<td></td>
<td>VOWEL LENGTH</td>
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</tr>
<tr>
<td>TIME REL.</td>
<td>/p/-/b/, /v/-/d/, /k/-/g/</td>
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<tr>
<td></td>
<td>/a/-/st/-/t/</td>
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</tr>
<tr>
<td></td>
<td>aCa (16 consonants)</td>
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</tr>
<tr>
<td></td>
<td>/a:/,-/a:,-, /a:/,-/a:/</td>
<td></td>
</tr>
<tr>
<td></td>
<td>/i:/,-,/e:,-,/e:/,-/er:/</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b/v:b (9 vowels)</td>
<td></td>
</tr>
<tr>
<td>12 SPONDEE WORDS</td>
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</table>

Fig. 1. Results on the speech feature test and the test with 12 known spondees words for the ten subjects at the testing 12 months after implantation. Total range and mean values are shown.

![Graph showing percent correct scores for 12 spondees words](image)

Fig. 2. Results on the test with 12 known spondees words.

![Graph showing relationship between percent correct and frequency discrimination ability at 125 Hz](image)

Fig. 3. Relationship between percentage correct recognition of spondees words and frequency discrimination ability at 125 Hz.
ject with a single-channel implant can only get low-frequency time-intensity. Some subject apparently get more information in the speech signal. The mechanism behind these differences in result is at present not clear. An explanation that has been suggested is that in some patients', remaining hair cells are stimulated Brokx, Hombergen, & Coninx, 1988).

References


