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B. CHANGES IN SPEECH WITH USE OF AN IMPLANT

Anne-Marie Öster

Abstract

The Vienna/3M extracochlear single-channel implant has been shown to provide information about low frequencies and timing. This limited auditory information allows implant wearers to derive benefits in acoustical awareness, in provision of environmental (non-speech) sounds, as an aid to lip-reading and as a control to their speech production. A person who has been deaf many years has learned to rely on tactile feed-back of his lip and mouth movements to control his speech and voice. The purpose of this study was to examine what happened in the speech production of ten patients who received implants at the South Hospital in Stockholm when they got this new type of acoustic feed-back from the Vienna/3M Prosthesis. It asked the question: "Are there any noticeable changes of the patients' speech or voice and, if so, what changes?" The study reports on acoustical and perceptual analyses after 18-24 months of implant use. To study whether the improvements found were attributable to training effects or to the information provided by the implant, analyses were also made on the direct effect of the implant of two patients. A questionnaire, which the patients and their families responded to, is discussed as well as an attempt to investigate the feedback of the implant by exposing the patients to delayed auditory feed-back.

1. Introduction

Those studies in the cochlear implant literature which deal with adventitiously deaf patients' speech production have reported some improvements in speech production after implantation. In a study of four patients, Iler-Kirk & Edgerton (1983) found that an improvement in voice parameters and fundamental frequency had taken place after implantation. Waters (1986) studied the speech production of three cochlear implant wearers. He assessed their speech pre-therapy and post-therapy when they used the implant during a period of six months. All three patients were judged to have improved production of speech after using their implants. Not only the voice quality, which became less harsh and tense, improved but also the overall timing and pitch control. Ball & Ison (1984) reported on a patient that showed a fundamental frequency range that approached normal with a marked reduction in irregularity after electrical stimulation. East & Cooper (1986) used a questionnaire in order to assess the device, one year following implantation. The implant wearers and their families remarked that the improved modulation of speech volume when using the implant led to increased self-confidence. Plant & Öster (1986) found in a case study of a Swedish female speaker two years after implantation that..."a number of changes had occurred after implantation. At the prosodic level these included a more normal range of fundamental frequency, improved F0-control in signalling emphatic stress contrasts and improvements in durational aspects."
In another study by Öster (1987), the acoustical analyses of the fundamental frequency of two of ten Swedish patients' recorded readings showed that both patients derived benefits in improved speech production, thanks to their single-channel implant. The most positive change seemed to be a lowering of mean fundamental frequency to a more normal value considering age and sex. The most noticeable change, however, occurred in a male patient's speech. The pre-implant recording revealed a high tempo together with an uncontrolled intonation. After implantation, it was obvious that the patient modified and planned his speech production consciously.

2. Material and methods

Subjects

The subjects were ten patients of the Swedish Cochlea-Implant Project at the Department of Audiology, South Hospital in Stockholm. Criteria for operation were total acquired deafness, an active cochlear nerve, no benefit from hearing aids, strong motivation, a good social support and auditory memories, which excluded those who were born deaf.

The cause of the deafness varied among the subjects (meningitis, otosclerosis, ototoxic drugs, progressive hearing loss and scull fracture) as well as the number of years of total deafness.

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<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>
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Table 1. Data of the ten subjects; *) indicates sudden deafness.

Quality of the patients' speech and voice before operation

The speech and voice varied somewhat in quality among the patients before the operation. No one showed unintelligible speech. However, in some cases the speech was unnatural due to individual deviations in pitch, voice quality, loudness control, speech rate, and phrasing.

The age at onset of deafness seems to be very important. Speech arising from deafness acquired at an early age, before speech and language is developed, often shows serious and typical deviations from the speech of normal-hearing persons. If the hearing loss is acquired after puberty, which was the case of the patients in this study, the loss of auditory control will not degenerate voice and speech immediately. Changes, when they do occur, tend to be acquired slowly and gradually. The explanation of this is, according to Zimmermann & Rettaliata (1981), that the post-lingually deafened speaker possesses overlearned speech patterns and that these remain for a long time despite the lack of auditory control.
Plant (1984) showed in a study about the effects of an acquired profound hearing loss on speech production that in the course of time, loss of auditory control may cause monotonous intonation, slow rate, high pitch, nasality, deteriorated voice-quality, and intensity-variations.

**Recordings**

Recorded readings were made prior to the operation and at the time of recurrent testing that occurred, one, three, six, twelve, eighteen, and in five cases, twenty-four months after the operation. The recordings were made in a sound-treated test room with standardized recording methods.

A Studer A 80, 19 cm/sec two-channel tape recorder was used. A contact microphone attached to the subject's trachea recorded the synchronous larynx signal.

**Materials**

The recordings were made when the subjects read a standard passage of 92 words. Two of the subjects also read an unfamiliar text of 56 words two years after implantation in order to study the direct feed-back effect of the implant.

**Speech and voice therapy**

After the operation, all patients were offered speech and voice training at the Pedagogical Department of South Hospital; once a week during the first six months, then once a fortnight, and later, once a month. The training included relaxation and exercises to control breathing, loudness, pitch, stress, speech-rate, and nasality. The number of training sessions varied among the patients owing to necessity and motivation. Every session lasted 45 minutes.

**3. Instrumental analyses**

**Fundamental frequency distribution analysis**

The pitch was analyzed by using a computer program developed by Ternström (1983) of the Dept. of Speech Communication and Music Acoustics. The program uses the signal from the contact microphone placed at the subject's larynx when reading the recorded passage and gives graphics printouts of pitch contour, mean values, standard deviation, and histograms with statistics. We used a linear frequency scale of 50-400 Hz with a class width of 1 Hz.

The program also calculates the duration between the first and the last sample, that is, the total reading time. The percentage of time occupied by pauses less than and greater than 0.2 sec separates pauses between utterances from voiceless segments. The time of pauses over 0.2 sec was subtracted from the total reading time which was then divided into the total number of syllables in the passage and the rate of articulation was estimated as the number of syllables per second.

**Speech waveform perturbation analysis**

In four cases, acoustic analyses of waveform perturbations were performed in order to determine if the voice quality had changed after the operation. The distribution of the relative frequency differences between adjacent pitch periods in the voiced parts of connected speech was registered. Small perturbations are natural even in normal speech,
but large perturbations give rise to a rough voice quality (Hammarberg, 1986). A large
distribution of frequency differences is connected with large perturbations while the
peakedness is connected with a more stable voice quality.

Perceptual ratings

Representative and clinically relevant voice parameters for the perceptual evaluation
were chosen by the Department of Logopedics and Phoniatrics, Huddinge University
Hospital, Stockholm. Six professional speech pathologists and two logopedic students
rated six laryngeal and three supralaryngeal parameters using a 7-point interval scale.
The articulation and the overall impression were evaluated by the degree of divergence
from normal, where 0 corresponded to "nothing," 3 to "moderate" and 6 to "very
much/general." Pitch was also rated on a 7-point scale from "far too low" to "far too
high." Four voices were repeated once to establish the reliability of the ratings.

Questionnaire

The subjects and their relatives were asked to subjectively form an opinion of
speech/voice changes after implantation. They answered questions like, "Do you think
that the control of the voice has changed after the implantation? If so, in what way? Do
you think that the ability to perceive speech/lip-read has changed after implantation? If
so, in what way?"

4. Results

Pitch

Fig. 1 shows a representative fundamental frequency distribution of a female pa-
tient's voice (S1) pre-implant and two years after implantation. The mean F0 is lowered
from 265 Hz to 219 Hz which is a more normal pitch of a 30-years old female.

The results of the F0-analyses of all ten subjects in Fig. 2 show that most of the pa-
tients' mean pitch values were pre-implant within the values of Kitzing (1979) for adult
men (mean value 110 Hz - a standard deviation of 15 Hz) and for adult women (mean
value 193 Hz - a standard deviation of 15 Hz). The dotted lines in Fig. 2 show normal
pitch range values of men and women aged 21-70 years (see Kitzing, 1979). After im-
plantation the changes in mean F0 towards more normal values have occurred in most
cases.

The mean pitch values of subjects S2, S7, and S1 diverge pre-implant to a great de-
gree from the normal mean values of the same sex. After implantation, changes in mean
F0 have taken place, indicating more normal values. The pitch changes of S1 and S2
have been acquired gradually but mostly during the first year after implantation. The
changes in mean F0 are in all cases improvements, even in the case of S6, who raises
her pitch. The pitch value of S9, which moves away from normal values after implanta-
tion was, however, not judged in the perceptual evaluation as lowered post-implant.

The result of the fundamental frequency analyses can be interpreted so, that the sub-
jects can make use of the low-frequency feed-back of the implant to control and monitor
their voice pitches.
Fig. 1. F0-distribution of the female patient’s voice: preimplant and two years after implantation.

Fig. 2. The mean pitch values preimplant and postimplant of ten subjects. The dotted lines show normal pitch range values of men and women aged 21-70 years, according to Kitzing (1979).
Rate of articulation

The F0-analysis program also calculates the total duration of the speech sample excluding pauses greater than 200 ms. From these measures, the rate of articulation was estimated. In Fig. 3, the rates of articulation of our ten subjects are compared with those reported by Goldman-Eisler (1961). Goldman-Eisler found "that the speed of the actual articulation movements producing speech sounds occupied a very small range of variation of 4.4 to 5.9 syllables per second." The results obtained in the post-implant condition appear to represent a small but apparent shift towards a more normal rate of articulation, irrespective of whether the rate before operation was fast or slow.

<table>
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<tr>
<th>PRE. IMPLANT</th>
<th>POST. IMPLANT</th>
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<tr>
<td>*</td>
<td>4.4 - 5.9</td>
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<tr>
<td>S1</td>
<td>5.1</td>
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<td>S2</td>
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<td>S3</td>
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Goldman-Eisler (1956) showed in an investigation ..."that what is commonly perceived as the speed of talking is determined by the halts and pauses which interrupt the flow of speech rather than by the speed at which the actual speech movements are performed." The result of the analyses showed that some subjects (S2, S5, S8, S9) got a slower rate of articulation after implantation. Considering Goldman-Eisler's finding, it is not surprising that the relatives in the subjective evaluation questionnaire could not give a consistent estimate of changes in the speech rate. Rather, they commented that these subjects got clearer and more intelligible speech post-implant, indicating that the rate of articulation measure more reflects the intelligibility than the perceived speech rate.
**PERCEPTUAL VOICE EVALUATION (S5)**

- Preimplant
- Postimplant

**VOICE QUALITY**

<table>
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<tr>
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<tr>
<td>Grating</td>
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**MEAN RATING OF DEVIANCE**

**WAVEFORM PERTURBATION**

- Preimplant: Mean 1.0, St. dev. 14.2
- Postimplant: Mean 0.3, St. dev. 6.7

**Fig. 4.** Results of the perceptual voice evaluation and the waveform perturbation analyses of a female subject (S5) preimplant and postimplant.

**PERCEPTUAL VOICE EVALUATION (S7)**

- Preimplant
- Postimplant

**VOICE QUALITY**

<table>
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<tbody>
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<td>Grating</td>
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**MEAN RATING OF DEVIANCE**

**WAVEFORM PERTURBATION**

- Preimplant: Mean 0.1, St. dev. 13.3
- Postimplant: Mean 0.2, St. dev. 4.1

**Fig. 5.** Results of the perceptual voice evaluation and the waveform perturbation analyses of a male subject (S7) preimplant and postimplant.
Voice quality

Some of the patients' voice quality can be described as tense, harsh, creaky, and strained before operation. This deviant voice quality implies variations of loudness, high subglottal pressure, high tension in the vocal folds, and irregular vocal fold vibrations due to the lack of auditory control. After some use of the implant, these patients' voice quality improved considerably which is shown both in the acoustic and the perceptual analysis. Figs. 4 and 5 show the results of the perceptual voice evaluation and of the waveform perturbation analysis of two subjects, one female (S5) and one male (S7). There are correlations for both subjects between perceived ratings of deviants concerning the parameters creaky, grating, hyperfunctional, strangled, and tight and large waveform irregularities. The pre-implant voices show a greater amount of perturbations with large magnitudes than do the post-implant voices. Also the peaked-ness of the distributions reveals more stable and solid voices after implantation.

Questionnaire

A subjective questionnaire was used for assessing the benefits of the implant on speech and voice, as viewed by the patients and their families. The inquiry was answered by nine patients and eight relatives. All patients felt more relaxed when communicating after implantation... "It is easier nowadays to speak with people." When asking the patients if their control of the voice has changed after operation, seven of nine were positive and found that the improved modulation, especially of the speech volume, led to increased self confidence. When asking the families if they thought that the speech of their relatives had improved by the use of the implant, five of eight answered that the intelligibility had improved but only one thought that the speech rate had been modified.

Direct feed-back effect of the implant

To eliminate training effects, we studied the direct effect of the implant by recording two of the subjects' (S1, S2) readings with and without the implant. The subjects came on the morning of the day of recording without their implants on. They read the standard text and an unfamiliar text without implants before they put them on and adjusted them to appropriate levels. After half an hour the "aided" reading was recorded. The results of these recordings are shown in Tables 2 and 3. The pitch decreased when both subjects read the texts with their implants on. It is therefore reasonable to assume that the observed improvements in F0 were due to the low-frequency feed-back from the implant.

Experiment with delayed auditory feed-back

The subjects were exposed to delayed auditory feed-back (DAF) of 200-600 ms in order to investigate what sort of feed-back the implant provided. The effects of DAF on normal-hearing speakers are a slow irregular rate, repetition of words or parts of words, higher intensity, and a rise in pitch. None of these effects occurred to the implant wearers. Possible explanations can be that the patients have learned to rely on tactile feedback during many years of total deafness, or that the feedback from the implant, that is, the fundamental frequency and the time information, is perceived as background noise by the patients and does not affect the articulation.
5. Conclusion

The results of the instrumental analyses conducted in this study show some individual changes in the subjects' speech production pre- and post-implant. The changes that have occurred post-implant are, in every case, improvements. Those patients who pre-implant diverged most in pitch, voice quality, and in an unnatural fast rate of articulation improved these speech parameters to a great degree.

The results of the subjective evaluation show that the achieved control of the speech volume was the most important change for the patients because the improved modulation led to increased self-confidence. The general opinion of the patients' families was that the speech production of their relatives had become more intelligible and distinct after implantation.

In this study, the patients were given speech- and voice-training. It is therefore difficult to say if the observed effects are due to the implant, to the training, or to a combination of both. The experiment with direct feedback showed that the device obviously enables the speaker to monitor and control his pitch and loudness. The improvements in voice quality, on the other hand, are probably an effect of the speech- and voice-training.

References


