SPEECH PERCEPTION ABILITIES OF PATIENTS USING COCHLEAR IMPLANTS, VIBROTACTILE AIDS AND HEARING AIDS

Eva Agelfors and Arne Risberg

Department of Speech Communication and Music Acoustics,
Royal Institute of Technology (KTH), Box 70014,
S-100 44 Stockholm, Sweden

ABSTRACT

The speech perception ability reported from profound hearing impaired persons using different technical aids: hearing aids, cochlear implants or tactile aids, varies widely. A test-battery was constructed that consisted of segmental and suprasegmental tasks and speech tracking. Two presentation modalities were used, vision only and visual information supplemented with the assistive device. Three groups of subjects participated, deafened adults, subjects with profound postlingual hearing loss and normally hearing subjects artificially deafened. The results indicated that use of a hearing aid by listener with some residual hearing provided more information than the other assistive devices.

1. INTRODUCTION

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 many profoundly hearing impaired and deaf persons. This has been carried out by more sophisticated and powerful hearing aids or by cochlear implants, which directly stimulate the auditory nerve or by tactile aids, which employ the cutaneous sense and its pathways for transferring information.

The aim of this study was to develop a simple test battery and to compare the effectiveness of tactile aids, hearing aids and cochlear implants. It is recognized that the comparison between results obtained by different teams or devices in tests with the postlingually deaf is difficult. To get an uniform selection of patients is more or less impossibly. The performance among individuals shows often great variations, not only as a result of what they hear or feel with their device, but also as a result of their varying ability to lip-read or make use of small linguistic and paralinguistic cues. A standardized test material does not exist in any language and the phonological characteristics from one language to another make the interlingual comparisons complicated.

During the last years, research groups have reported that prosodic features, such as syllable length, stress pattern and vowel length, as well as segmental features such as voicing and manner of articulation may be transmitted through the tactual modality [6]. A few studies have also reported good tactual support during speechreading of normal speech [8].

Great variations among patients using the same type of cochlear implant have been reported, but results from both single-channel users and multichannel users show that the devices can provide important cues to intonation, manner and voicing that are significant to lip-reading [1].

In some patients very good speech understanding with or without support of lip-reading has been reported from cochlear implanted patients using either single-channel [7] devices or multichannel devices. Dowell et al [3] have reported that 50% of the patients using (Nucleus) multichannel cochlear implants have demonstrated ability to understand connected discourse with auditory input only.

2. SUBJECTS, MATERIALS AND METHODS

Four different groups of subjects participated voluntarily in the testing. In the vibrotactile group eight subjects participated (Vt:1-Vt:8). Three deafened adults (Vt:1-Vt:3) had varying experience of tactile aids. Five normally hearing subjects were artificially deafened and had experience of about 100 hrs of training with vibrotactile aids. Two vibrotactile single-channel aids were used, an ordinary bone-conductor coupled to an amplifier (6 subjects) and the Minivib (2 subjects). The processor in the Minivib gives amplitude modulated pulses at a fixed frequency of 220 Hz. The acoustic energy at the frequencies between 700 and 1500 Hz is extracted. During testing the subjects held the vibrator in their left hand.

In the cochlear-implanted group, six subjects participated (Ci:1-Ci:6). Two subjects, Ci:1 and Ci:2, were implanted with a single-channel extra cochlear implant (Wien/3M) and four subjects were implanted with a multichannel intracochlear implant (Nucleus). Subjects ranged in age from 36-65 years and they represented an average sample of adults, who had received cochlear implants in Sweden. The cochlear implant users had a daily experience of their devices from 6 months up to 5 years.

In the hearing aid users group, eleven subjects participated (H1:1-H1:4) and (H2:1-H2:7). Subjects ranged in age from 38-75 years and they were all profoundly hearing-impaired since many years. During testing they wore their own hearing aid. Although all subjects were profoundly impaired, the subjects were not equivalent audiometrically. For that reason they were divided into two groups: group H1 with mean hearing-loss at frequencies 500, 1000 and 2000 Hz of 104 dBm, sd 13.1 dB and group H2 with mean hearing losses of 82 dBm, sd 16.1 dB.

In the normally hearing group four subjects with simulated hearing-loss participated (Lp1-Lp4). They listened to low-pass filtered speech at cutoff frequencies .250, .5 and 1 kHz. The filter had a damping of more than 80 dB/oct. White noise was added, S/N = 20 dB. The subjects ranged in age from 25-45 years.

The test material consisted of three parts: Intervocalic consonants, prosodic contrasts and speech tracking. The segmental test used a set of 16 vCv utterances with a carrier phrase in which the vowel was always /a/. Consonants were chosen to sample a variety of distinctions in voicing, place of articulation and manner of articulation.

The suprasegmental test used is a closed-set test battery, presented as a two alternative forced-choice task. The specific prosodic features tested were: number of syllables, vowel-length, juncture, tone and emphasis.

Speech tracking was introduced by De Filippo and Scott [4] and has been used to train and evaluate the reception of connected speech via lip-reading combined with different assistive devices. The speaker reads, at a normal rate, sentence by sentence from a book, and the speech-reader (the subject) is required to repeat the information verbatimly. If the sentence is not correctly repeated the speaker employs a hierarchy of strategies to assist the subject in repeating every word correctly. The speech material used was taken from a book by a famous Swedish author. This material was chosen because it has a relatively consistent level of reading difficulty from session to session. During each test session, tracking was performed for a total of ten minutes under each of two conditions: (a) lip-reading plus aid and (b) lip-reading alone. The result of the test in words per minute (wpm) was calculated by dividing the number of words correctly repeated by 10 for each ten-minute tracking period. The tracking rate achieved by normally hearing subjects (unmasked) using the same method with the same speaker and the same text material was 88 wpm.

The consonant and prosodic tests were videotaped and the speech tracking was presented live. The same speaker, a woman, was used in all test situations. Each subject was tested individually. The test order was the same for all subjects: vCv-syllables, prosody and speech tracking. Each test started with the combined situation.

The normally hearing subjects (Vt-group) were masked by earplugs and pink noise in the test situation with lip-reading and aid. During the speech tracking situation they were sitting in a sound-attenuating test-room and viewed the speaker through a window. The cochlear-implanted subjects and the hearing aided subjects were tested in free

field at the most comfortable level, adjusted by themselves, in condition lip-reading plus aid. In the situation lip-reading alone the hearing aided subjects were unaided and sitting in the test room under the same condition as the normally hearing subjects.

3. RESULTS AND DISCUSSION

Confusion matrixes were constructed for each individual and for each situation. An information transfer measure [5] was calculated for each feature. Three major articulatory and phonetic categories were used: manner (stop, frication and nasality), place and voicing.

The results obtained from the segmental test, expressed as mean percent transmitted information of vCv-syllables displayed for each group of subjects in the two conditions are shown in figure 1.

aid". The recognition of distinctive features was improved with the aid especially by groups of subjects Lp-500, H2 and Ci. The subjects received very little information about voicing when they were only lip-reading, but the high proportion of information transferred about voicing in the combined situation shows that the devices provided strong cues of low-fundamental frequency for all subjects.

Results obtained from the suprasegmental test show that mean score of 78.2% correct, (sd. 5,6%), is greater than chance level (50%) for all groups in condition "vision only". In the condition "vision plus aid", the vibrotactile aid transmitted no added information to visual cues. Suprasegmental features were very well perceived by all hearing aid users and by normally hearing subjects.

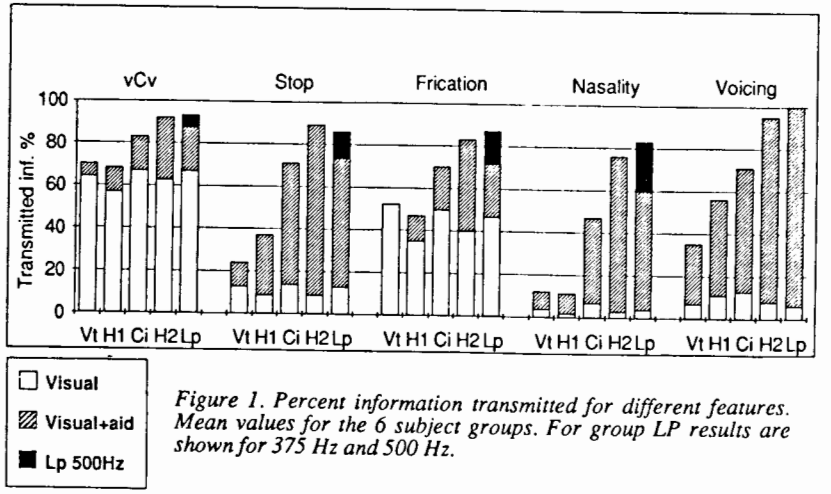

Figure 1. Percent information transmitted for different features. Mean values for the 6 subject groups. For group LP results are shown for 375 Hz and 500 Hz.

All subjects performed comparably in the "vision only" condition. There is no difference between normally hearing and hearing impaired subjects in this test condition. Two of the subjects, Ci:1 and Vt:1, are excellent lipreaders with more than 40 words/min in the speech tracking test. In spite of this, they did not achieve better results on the "visual only" consonant test. As expected, in "vision only" condition, the place feature was correct most often followed by frication. All groups of subjects, have got some improvement in the condition "visual plus

The cochlear implant group was helped by transmitted information concerning the features tone and juncture. These features are among the most difficult to lip-read.

Results obtained from speech tracking are shown in figure 2. The enhancement of lip-reading with the single-channel vibrotactile aid is close to 5 wpm, and about 10 wpm for the group H1. The mean score enhancement for the cochlear implant users is about 25 wpm and about 55 wpm for the group H2. The speech tracking score for the Lp-1000

group reaches the ceiling rate in this particular situation. Data obtained with the speech tracking procedure, clearly show the difference between communication with the vibrotactile aid, cochlear implant and hearing aids.

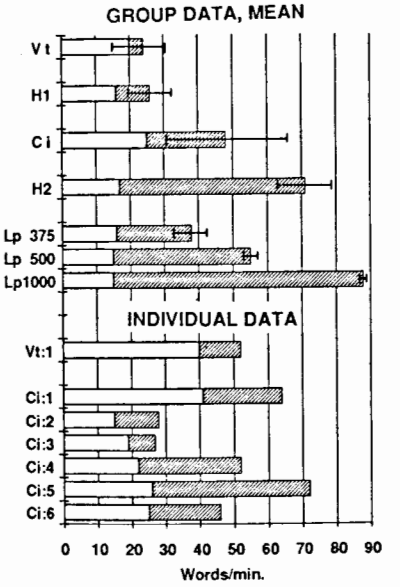

Figure 2. Results from speech tracking. Mean values for the different groups and individual values for the best tactile subject and the 6 cochlear implant subjects.

The individual data (Ci:1) in fig.2 shows that speechunderstanding performance for one single-channel cochlear implant subject can be as good as those obtained with multichannel cochlear implants. The difference between better and poorer patients is the detection/resolution of high-frequency components is reported by Dorman [2]. Responses of the subjects with hearing aids and with residual hearing (H2) were consistently superior to those subjects with implants or vibrotactile aids. The wide variation in responses of the cochlear implant users indicates the necessity of carefully evaluating each implant user.

4. CONCLUSION

The results in fig. 1 and 2 show that the hearing aid using group with a profound loss get very little benefit from their hearing. They might therefore be considered as candidates for a cochlear implant operation. On the other hand, the results also show a large variation in results on all tests for the cochlear implant group. By the use of diagnostic tests of the type presented here, it might be possible to understand the reason for these variation. The results can also be used in patient selection for implantation.

5. ACKNOWLEDGEMENTS

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