Speech perception of hearing aid users versus cochlear implantees

SYDNEY '97

XVI World
Congress of
Otorhinolaryngology
Head and
Neck Surgery

Sydney, Australia
2-7 March 1997

M. FLYNN, R. DOWELL and G. CLARK

Department of Otolaryngology, The University of Melbourne (AUS)

SUMMARY

Recent improvements in speech recognition abilities for profoundly deaf cochlear implantees suggests that some adults with a severe hearing impairment might benefit from a cochlear implant. Unfortunately, no studies have directly compared the speech perception abilities of the severely hearing impaired with those of cochlear implant users. An investigation of the speech perception performance of people with a severe hearing loss, who use hearing aids, was conducted in the Department of Otolaryngology at The University of Melbourne. Each participant (n=35) took part in a series of speech perception tests which included 11 vowel recognition tests, CNC words, CUNY sentences, and the Connected Speech Test. The results from these severely hearing impaired persons were compared to results from cochlear implant users. The group of severely hearing impaired adults performed better on tests of vowel and word perception but poorer on tests of open set sentence perception in comparison to a group of cochlear implant users.

INTRODUCTION

Multiple channel intracochlear implants were initially devised for providing auditory cues to assist lip-reading for persons who were postlingually deafened. For almost two decades researchers from around the world have been rapidly improving the speech processing strategies of the so that cochlear implants are now far more than just an aid to lip reading. They now allow many cochlear implant candidates to understand conversational speech using audition alone. By the mid 1990s many users of the Nucleus 22 channel cochlear implant, employing the SPEAK processing strategy, were obtaining

good open set speech perception scores by using audition alone (Skinner et al., 1994). These reports of excellent open set speech perception have led some researchers to suggest that adults with a severe hearing loss may receive better speech perception information by using a cochlear implant than with a hearing aid (Shalloo, Arndt & Turncliff, 1992). Unfortunately, studies such as these have focused on poor performing hearing aid users. No previous study has looked at the broad range of speech perception abilities of adults with a severe hearing impairment.

Hence, the aim of the current study is to examine the speech perception of a sample of people with a severe hearing loss in order to compare their performance with users of multiple channel cochlear implants.

MATERIALS AND METHODS

Thirty-five adults with a severe hearing loss agreed to participate in this study. The subjects had a pure tone average (500, 1000 & 2000 Hz) of between 61 dB HL and 100 dB HL in the better ear. The subjects were current hearing aid wearers, had an oral education, and had no additional handicaps that might affect their speech perception abilities. The average pure tone hearing loss was 78 dB HL in the better ear.

All of the subjects had a comprehensive audiological evaluation and a full hearing aid evaluation to determine whether their hearing aids were optimally configured for their hearing loss. If optimal amplification could not be ensured then the subject was withdrawn from the study.

All of the speech perception tests were administered free field at 70 dB SPL in a sound proof audiometric test booth. The participants listened to the materials whilst using their hearing aids. The materials were recorded on compact discs at a sampling rate of 44 kHz to ensure optimum presentation of speech materials.

Figure 1: Comparisons between cochlear implant users and the severely hearing impaired on a closed set vowel test, open set CNC word test (scored phonemically), and CUNY open set sentence test in quiet conditions and in +10 dB SNR of multiple talker speech babble.

A set of 11 vowels in /h/ - vowel - /d/ context were used to provide data on closed set vowel perception. Four lists were used, each list containing four random presentations of each vowel or consonant. For each item the participant was required to select from a list of the 11 vowels, that is, this was a closed set test, to eliminate the influence of linguistic cues.

The CNC word test consists of ten lists of 50 words of consonant-vowel-consonant structure. The lists were devised so that each list contained approximately the same set of phonemes. The actual stimuli selected for this test were also chosen so that the words used were in frequent American English usage. An equal proportion of phonemes in spoken American English were included in each list.

The CUNY sentence test was used in this investigation to provide a measure of open set sentence perception. Although the CUNY sentences were originally designed with the sentences being topic related, in this study the sentences were randomised to make the test open-set. To reflect Australian English usage some of the sentences were modified, but the grammatical and semantic structure of the sentence was left intact. Each list contained 12 sentences and was scored as the number of words correct out of a total of 102 words per list. Consequently, all words are scored and a percentage correct score was obtained. Each subject listened to two lists.

The Connected Speech Test v2 (CST) (Cox, Alexander, Gilmore & Pusakulich, 1988). consists of 24 pairs of passages (paragraphs), 48 passages in all. Each passage is about a familiar topic (e.g. lions) and contains 25 key words embedded in 10 sentences. A word describing the passage is shown to the participant prior to presentation of the passage. Although the passages are interrelated they are presented one at a time and are repeated by the participant. While the original recording of the CST used a female American speaker the version in this investigation used a male speaker with an Australian accent.

RESULTS AND CONCLUSIONS

Perception of vowels (mean = 89%, s.d. = 15%, range = 56%-100%) indicated that vowel perception is relatively intact within the severely hearing impaired population. Twelve subjects scored at the 100% level. Scores for open set words (scored phonemically) (mean = 74%, s.d. = 20%, range = 25%-98%) indicated more variability between the subjects. Sentence tests provide the most information regarding the difficulties that a severely hearing impaired person may have in their everyday communicative exchanges. Results for CUNY sentences in quiet conditions (mean = 70%, s.d. = 28%, range = 4%-98%), show that while some subjects performed exceptionally well, others had difficulty perceiving the sentences. To better simulate real life conditions background noise (+10 dB SNR) was added which resulted in the subjects' level of performance decreasing significantly (mean = 55%, s.d. = 34%, range = 0%-98%). None of the subjects with a severe hearing loss was able to score at the 100% level on any tests of open set speech perception, and a number of subjects performed at less than 40%.

In order to further understand why some people with a similar audiogram and/or similar speech perception results often report different speech perception abilities in their daily lives, the Connected Speech Test (CST) was conducted. This speech test examines the effect contextual information on speech perception. When the results for the CST were compared with CUNY

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sentences it was found that the subjects performed significantly better on the CST ($p < 0.01$). This indicates the potential advantages that contextual information provides. Not all subjects, however, showed equivalent use of context. For, example there were many subjects who had equivalent CUNY sentence test results but significantly different results once the effects of context were added. It may be that the CST demonstrates differences between subjects that have not previously been detected with conventional speech perception tests. These differences may become important when deciding if a severely hearing impaired person who has a reasonable level of open set speech perception would have better speech perception with their hearing aid or with a cochlear implant.

For comparison purposes, published data from cochlear implant users were evaluated. Only those studies in which cochlear implant users had the SPEAK processing strategy with the Nucleus 22 Channel Cochlear Implant System were considered for this analysis. The Skinner et al. (1994) study provided the most appropriate comparison data, and speech perception test scores for individual participants were provided by Skinner et al (1994) for these analyses. The mean scores for the Skinner et al (1994) participants were 81% ($n=52$) for CUNY sentences in quiet and 68% ($n=46$) for CUNY sentences presented with a 10 dB SNR. The results for medial vowel identification (mean = 74%), and CNC phoneme score (mean = 60%) were also considered.

Figure 1 shows the mean scores for vowel perception, word perception (phoneme score) and open set sentence perception in quiet and in the presence of four talker speech babble (+10 dB SNR), for the severely hearing impaired group tested in Melbourne and for the cochlear implant users tested by Skinner et al (1994). Results showed that the group of severely hearing impaired perceived vowel information ($p < 0.001$) and open set words ($p < 0.001$) significantly better than the group of cochlear implant users. For open set sentences, however, the cochlear implant users perceived the words in sentences significantly better than the severely hearing impaired in quiet conditions ($p < 0.05$) and in noise ($p < 0.05$).

These data demonstrate that many people with a severe hearing loss have poorer open set sentence perception scores in comparison to published results from cochlear implant users. Thus, the data support the argument that some severely hearing impaired adults should be provided with information regarding cochlear implant as a treatment option. While test performance differences were statistically significant, within the group of cochlear implant users and the group of severely hearing impaired there was large variability between the best performers and the worst. Because of this variability, and the many social, medical and psychological issues that pertain to implantation, therefore, recommendations for cochlear implantation to the severely hearing impaired should be made on an individual basis.

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Author/s:

Flynn, Mark C.;Dowell, Richard, C.;Clark, Graeme M.

Title:

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Date:

1997

Citation:

Flynn, M. C., Dowell, R., & Clark, G. M. (1997). Speech perception of hearing aid users versus cochlear implantees. In Cochlear Implants: XVI World Congress of Otolaryngology Head and Neck Surgery, Sydney, N.S.W.

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