Open-Set Word Recognition With the 3M/Vienna Single-Channel Cochlear Implant

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• The author visited Innsbruck (Austria) to evaluate the performance of nine of the better patients implanted in Europe with the 3M/Vienna single-channel cochlear implant. Word- and sentence-level speech recognition tests recorded in German by two speakers from Austria were presented. Performance varied from 15% to 86% correct word recognition on the sentence material, 11% to 57% correct word recognition with word lists, and 21% and 66% correct phoneme recognition on the word tests. These results confirm earlier studies indicating that high levels of open-set word recognition without visual cues can be obtained with the 3M/Vienna single-channel cochlear implant.

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Many patients around the world are now receiving significant benefit with their cochlear implants. The benefit can range from understanding everyday sounds, improvements in lipreading, and in some cases, recognizing words and sentences. Patients using the single-channel device developed by Hochmair and Hochmair-Desoyer[1,2] have been reported to understand some words without lipreading. However, three patients tested with this device at the University of Iowa (Iowa City)[3,4] and two in England[5] have not been able to obtain open-set word recognition. In this investigation the author visited Innsbruck (Austria) and was allowed to test nine of the better patients with the 3M/Vienna device.

This implant activates a single unipolar electrode pair with a broadband analogue signal (150 to 6000 Hz). The analogue waveform is compressed and then frequency-dependent amplification is provided.[1] The intracochlear version of this typically has four electrode pairs on the electrode carrier. The best (largest dynamic range) of these four electrodes is chosen to stimulate with the wearable single-channel device. The extracochlear version uses monopolar stimulation with the active electrode in the round-window niche. The speech processing is exactly the same for the extracochlear and intracochlear implant.

PATIENTS AND METHODS

Nine patients were tested, a group of four and a group of five. Preimplant audiograms[6] in the test ear indicated a profound hearing loss. Thresholds at 250 Hz were 105-dB hearing level (HL) or worse for all patients except V8. The patient with the best hearing was V8, who had thresholds of 75-, 85-, and 95-dB HL at 125, 250, and 500 Hz with no measurable hearing at higher audiometric frequencies. Patients V1, V3, and V8 used an extracochlear device, with the others using an intracochlear device. The patients identified V1 through V9 have been designated by MB, MW, HH, SO, HZ, GR, RW, MK, and JF by the Vienna/Innsbruck team in previous publications.

All the speech material was in the German language. The author selected the words and sentences the night before testing. Thus the patients were unaware of the materials. The words were simple, everyday words, one or two syllables in length. The sentences were all statements, ranging from three to six words per sentence. The same material was used by Tyler[7] although a different speaker was used.

The author requested a male and female speaker who were unfamiliar to the patients. However, it was discovered afterward that the patients had some familiarity with the male speaker.

The stimuli were recorded on a tape recorder (Marantz PMD 430) using a dBX noise-reduction system. The talkers were asked to produce materials at a typical rate. Both spoke very clearly, but at a rate slower than normal. The speaking rate was quantified by measuring the sentence duration (from the onset of the first word to the offset of the last word) and dividing by the number of words in the sentence. This method provides a score that is artificially lower than conversational speech because the silent intervals between sentences are not considered. The male spoke at 93 words per minute and the female at 105 words per minute. This is considerably less than the 170 words per minute rate spoken by two German speakers under

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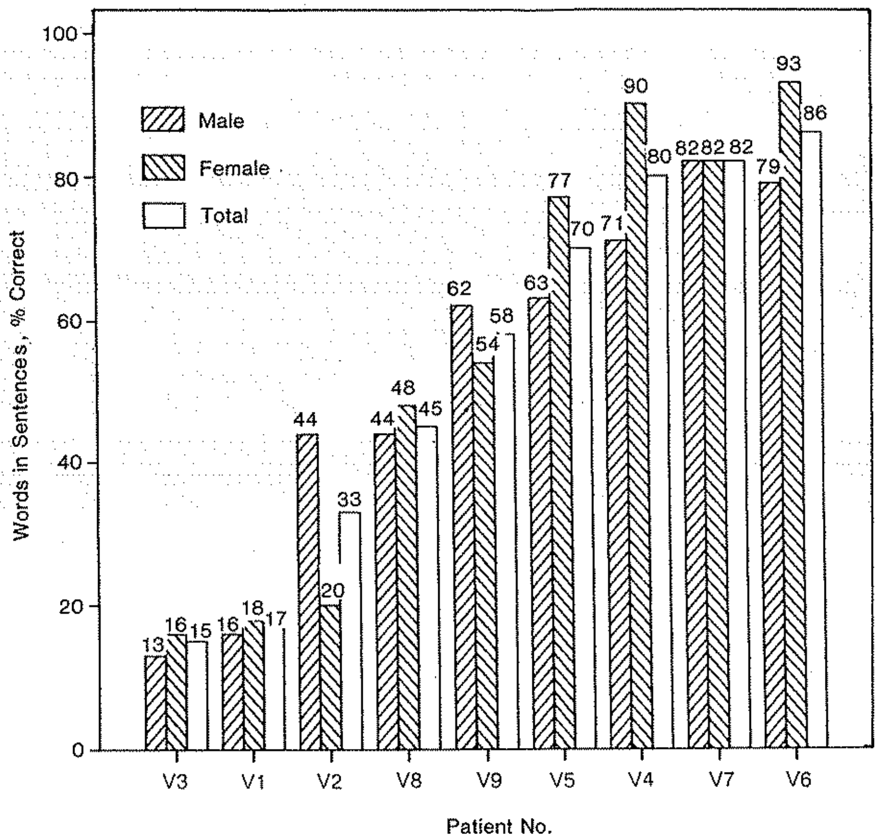

Fig 1.—Words identified correctly on sentence test. Results are shown separately for male and female speakers and for total score.

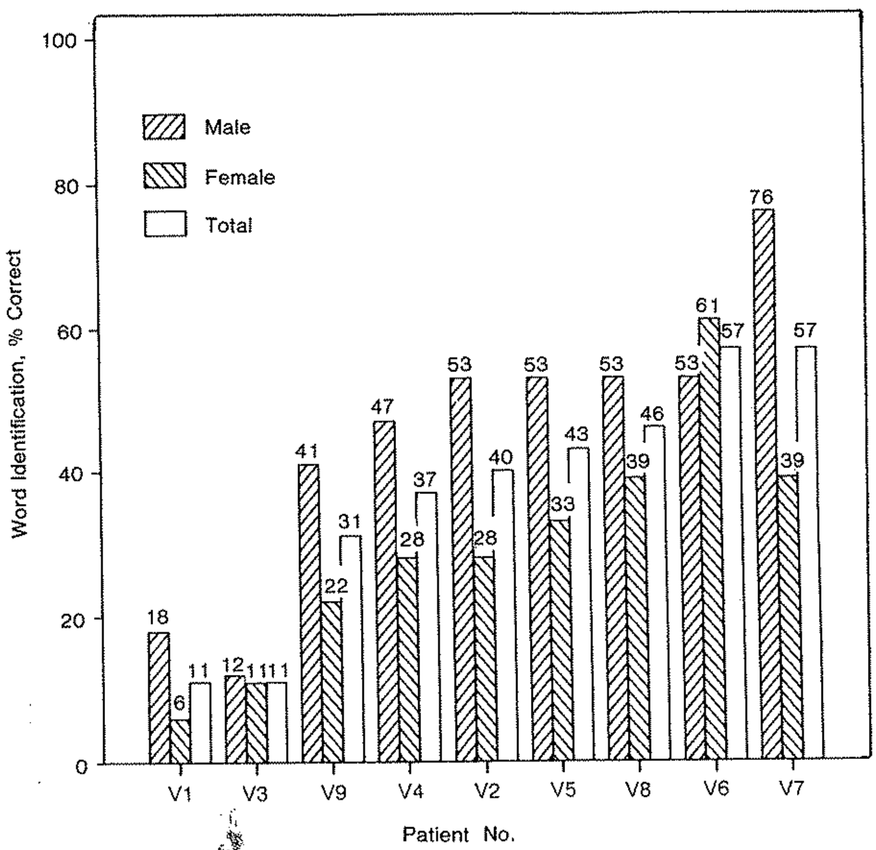

Fig 2.—Words identified correctly in word test. Results are shown separately for male and female speakers and for total score.

similar circumstances (R.S.T., unpublished observation). The stimuli were played back through the same tape recorder, a Sony amplifier, and a speaker (Pioneer S510).

The patients sat in a sound-treated chamber. Their individual microphones were placed on a specially-designed foam rack located approximately one meter from the speaker. This eliminates the body baffle effect. Normally with a microphone worn on the chest the low-frequency (around 500 Hz) sounds are enhanced by 5 to 8 dB and mid-frequency sounds (around 1500 Hz) are decreased by 5 to 20 dB relative to a free-field microphone location.[8] Therefore, the artificial situation in the present test would result in a speech spectrum that was different from what the patients would normally receive in typical situations with a body-worn microphone. However, the Innsbruck investigators requested this microphone arrangement because they felt it was important to achieve the exact sound field for all the patients tested simultaneously. The material was played back at a level of approximately 70-dB sound pressure level. The patients were required to write all the words or parts of the words that they heard.

RESULTS

Figure 1 shows the percentage correct for words in sentences. Scores averaged across the male and female speakers ranged from 15% to 86% correct ($X = 54$, SD = 28). Performance was slightly better for the male speaker for subjects V2 and V9, whereas it was better for the female speaker for patients V4, V5, and V6.

Figure 2 shows the results for word recognition when presented as single words. Scores averaged across the male and female speakers ranged from 6% to 61% correct ($X = 31$, SD = 17). Scores were higher for the male speaker for V1, V2, V4, V5, V7, V8, and V9. Several patients did better with the male speaker on the word test, but three did better with the female speaker on the sentence test. Only patient V2 did better with the male speaker on both tests. However, with only one male and one female speaker, differences in performance may be related to individual speaker differences as much as gender.

Figure 3 shows the results obtained from the phoneme scoring of the same word-recognition test. Scores averaged across the male and female speakers ranged from 21% to 66% correct ($\bar{X} = 54$, SD = 15).

Figure 4 shows the relationship between word recognition in single-word lists and in sentence level material. The Pearson correlation is $r = .82$ ($P < .01$). The linear regression equation $Y = 4.37 + 1.34X$ suggests that the scores on the sentence test are about 1.3 times higher than the scores on the word test. However, a wide range of performance is observed on the words in sentence score for patients with about the same word identification score. This suggests that additional skills are required to process speech at near-normal rates of presentation compared with single-word presentations.[6]

COMMENT

Clearly, the 3M/Vienna single-channel cochlear implant can provide sufficient information both in intracochlear and extracochlear stimulation to result in open-set word recognition without lipreading. These results corroborate the previous findings of Hochmair-Desoyer et al.[9]

It is unclear why patients in the United States and England have been unable to reach this level of performance. It may be related to (1) effectiveness of setting the device, (2) language differences or (3) insufficient number of patients to make a valid comparison. The Hochmairs[1] visited Iowa City to set the devices of the three patients tested there, so it is unlikely that these devices were not set appropriately.

There are some differences between the English and German languages. For example, German has three vowels /y, Y, and O/ not found in English, and English has one vowel (3ʳ) not found in German. There are differences in formant frequencies and duration. For example, vowel-duration differences between short and long vowel counterparts are more pronounced in German than in English.[10] There are four consonants in German not present in English and five consonants in English not present in German.[10] The frequency of occurrence of even the similar consonants and vowels is different in both languages.[10] However, it is not clear how these language differences could have had a major impact on speech recognition. In both languages, speech features of voicing, duration, formant frequency, formant transitions, and frication are thought to be important.

A likely explanation of the differences between the English and German results is that an insufficient number of patients have been implanted in the United States and the United Kingdom for a valid comparison to be made with those in Innsbruck. Not all patients implanted in Austria achieve open-set word recognition. We expect that eventually some of the patients implanted in the United States or the United Kingdom will achieve the level of performance described here.

The proportion of patients with this device who can obtain open-set word recognition is unknown. The Austrian teams have implanted approximately 85 patients with their device, 51 postlingually-deafened adults, 24 prelingually-deafened adults, and ten children below the age of 14 years. Thus, we might expect the level of perfor-

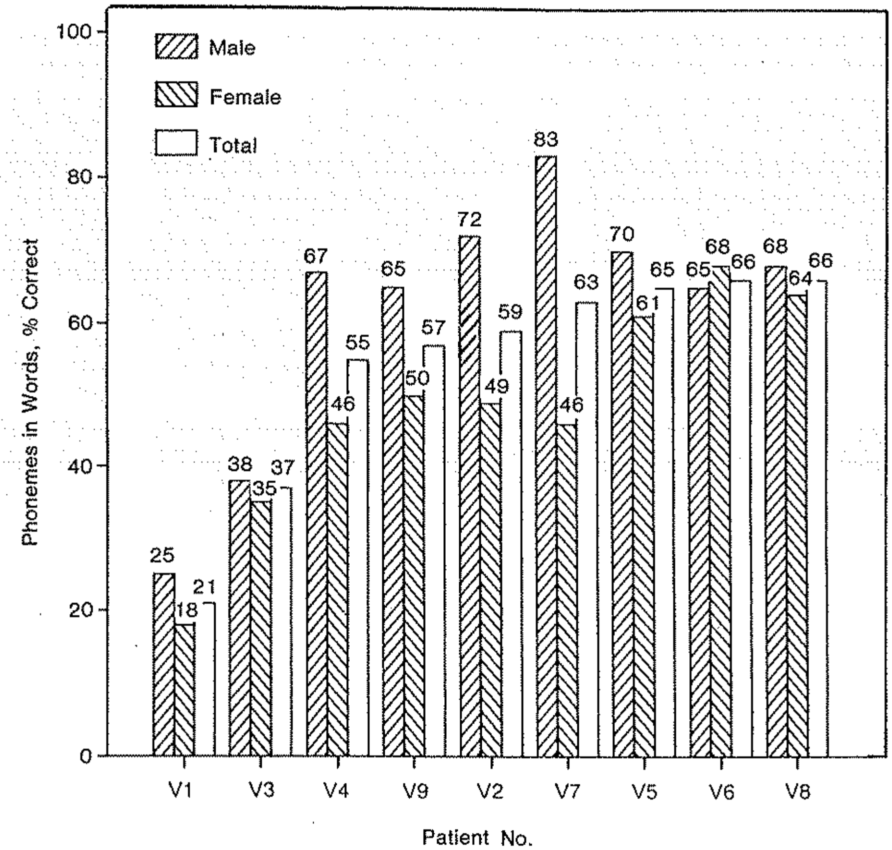

Fig 3.—Phonemes identified correctly on word test. Results are shown separately for male and female speakers and for total score.

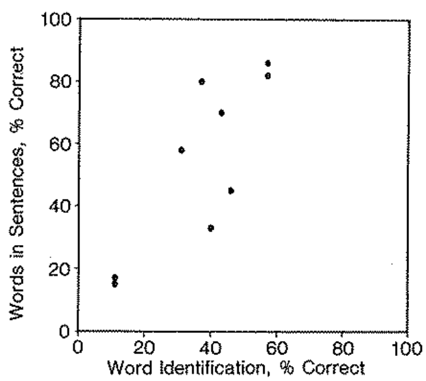

Fig 4.—Relationship between word recognition in sentences and word recognition in single word lists. Pearson correlation $r = .82$ ($P < .01$).

mance observed in this group to be achieved by at least nine (18%) of 51 of the postlingually deafened adults. The Viennese group claims that approximately 60% of their postlingually deafened patients obtain open-set speech understanding.[11]

This high level of performance, particularly with the extracochlear version of this device, indicates that this may be an appropriate device for trials on young children.[12,13]

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