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Dichotic speech recognition by bilateral cochlear implant users

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Abstract. A series of experiments was run to assess bilateral cochlear implant users' ability to fuse information presented dichotically. Two different methods of splitting the spectral information were investigated. In the first method, the odd-index channels were presented to one ear and the even-index channels to the other ear. In the second method, the lower frequency channels were presented to one ear and the high-frequency channels to the other ear. Results from word recognition tests indicated that in quiet, the bilateral implant users were able to fuse the information presented dichotically as accurately as when presented diotically. In contrast, subjects were not able to fuse the information presented dichotically in noise as accurately as when presented diotically.

Keywords: Dichotic speech presentation; Bilateral cochlear implants; Diotic summation; Dichotic fusion

1. Introduction

Several studies had demonstrated that bilateral cochlear implants can provide significant benefit in terms of sound localization and speech recognition in noise (e.g., Hoesel and Tyler [1]). Not much had been done, however, to examine possible benefits of dichotic electrical stimulation. Potential benefits of dichotic electrical stimulation include reduction in channel interaction since the stimulation could be alternated between the two ears and reduction in power consumption since only a subset of electrodes within each ear needed to be stimulated. In order for the bilateral implant users to receive these benefits,

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however, they must be able to spectrally fuse the information presented to the two ears. The ability of bilateral cochlear implant users to fuse spectral information presented dichotically was investigated in this study.

2. Methods

2.1. Subjects

Eight bilateral Nucleus-24 implant users participated in this study.

2.2. Speech material

Sentences from the HINT database (Nilsson et al. [2]) were used for the experiments in quiet. Sentences from the TIMIT database were used for the experiments in noise. Speech shaped noise was added at +10 dB signal to noise ratio. A total of 30 sentences were used for each condition.

2.3. Procedure

Two different dichotic conditions were considered. In the first condition, which we refer to as low–high dichotic condition, the low-frequency information (consisting of half of the total number of channels) was presented to one ear, and the high-frequency information (consisting of the remaining half high-frequency channels) was presented to the opposite ear. In the second dichotic condition, which we call odd–even (or interleaved) dichotic condition, the odd-index frequency channels were presented to one ear, while the even-index channels were presented to the opposite ear. For comparative purposes, we included a diotic condition where all the channels were presented to both ears. For comparison with the odd–even stimuli presented dichotically, two additional conditions were created. In the first condition, the odd-index channels were presented to the left ear alone, and in the second condition, the even-index channels were presented to the right ear alone. Similarly, for comparison with the low–high stimuli presented dichotically, the low-frequency channels (lower half number of channels) were presented to the left ear alone and the high-frequency channels were presented to the right ear alone. Similarly, for comparison with the diotic stimuli, all the channels were presented to the left ear alone and all the channels were presented to the right ear alone. Presentation order of each condition was counterbalanced across subjects.

All the experiments were conducted using the SPEAR3 research processor, which is capable of delivering dichotic electrical stimulation. Subjects were first fitted with a 12-channel CIS strategy (1200 pulses/s, 25 μs/phase) as opposed to the SPEAK or ACE strategy commonly used in the Nucleus device. This was done to ensure that a fixed number of electrodes were stimulated in each cycle. Speech was processed through the SPEAR3 research processor and presented to the subjects via the auxiliary input jack at a comfortable level.

3. Results

Fig. 1 gives the mean performance, in terms of percent words identified correctly, obtained in the various conditions. For the testing in quiet, one-way ANOVA (repeated

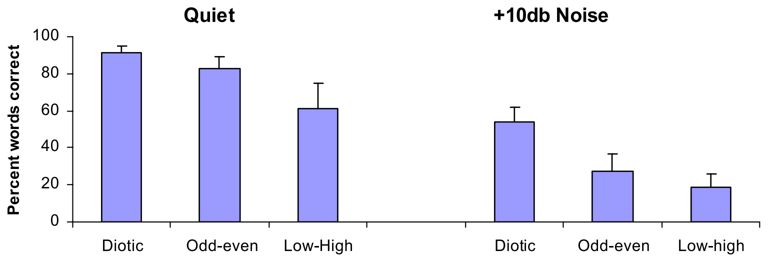

Fig. 1. Mean word recognition scores obtained in the various dichotic conditions by eight bilateral implant users.

measures) showed a significant effect [$F(2,12)=6.2$, $p=0.014$] of presentation mode (diotic vs. odd–even, low–high). Post hoc tests, however, according to Fisher's LSD showed no significant ($p>0.05$) difference between the diotic and odd–even dichotic condition, and a nearly nonsignificant ($p=0.04$) difference between the diotic and low–high condition. This suggests that subjects were able to spectrally fuse the information presented dichotically very accurately.

For the testing in noise, one-way ANOVA (repeated measures) showed a highly significant effect [$F(2,12)=41.4$, $p<0.0005$] of presentation mode (diotic vs. odd–even, low–high). Subjects performed significantly worse ($p<0.05$) in the dichotic conditions compared to the diotic condition. Subjects were not able to spectrally fuse the information presented dichotically as accurately as in the diotic condition.

4. Discussion

For the low–high dichotic condition, scores obtained dichotically were significantly higher (Fisher's LSD test, $p<0.05$) than either ear alone suggesting that subjects were indeed integrating the information presented to the two ears. Fig. 2 shows the comparison between the low–high dichotic condition and the condition in which low-frequency information was presented to the left ear alone and high-frequency information was presented to the right ear alone.

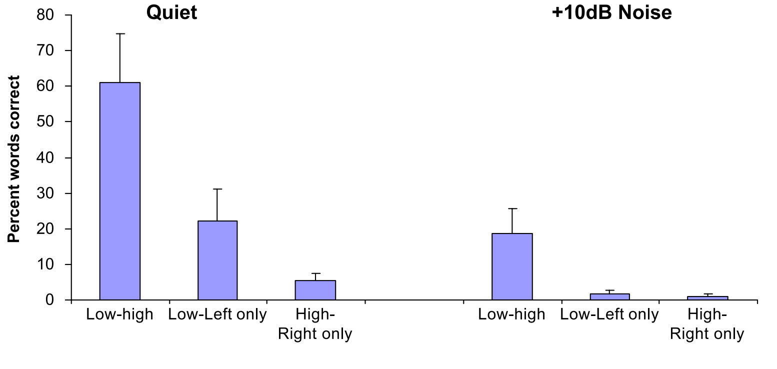

Fig. 2. Mean word recognition scores obtained in the low–high, low left-ear only and high right-ear only conditions in quiet and in noise.

For the odd–even dichotic condition, scores obtained dichotically were not significantly higher (Fisher's LSD test, $p>0.05$) than either ear alone. This suggests that presenting either the even or odd channels alone is sufficient for understanding speech. Bilateral subjects were able to fill in the spectral gaps. This outcome extends previous findings on the perception of speech with spectral holes (e.g., Kasturi et al. [3]). For three subjects, the diotic performance was significantly higher (Fisher's LSD, $p<0.05$) than either ear alone suggesting a *diotic summation benefit* in the absence of binaural cues (identical signals were presented to the two ears). This indicates that some subjects are receiving complementary rather than overlapping information by the two implants.

5. Conclusions

Bilateral subject's ability to fuse spectral information presented dichotically is better in quiet than in noise. This finding is not surprising given that normal-hearing listeners have difficulty fusing spectral information in noise (Loizou et al. [4]) when presented with sentences processed through a small number (6) of channels. This suggests that bilateral subjects are not fusing spectral information as accurately in noise because of the small number of channels of information they receive in each ear. Some subjects received a diotic summation benefit suggesting that the information presented to the implants was complimentary, perhaps due to differences in insertion depth.

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