Frequency-place mismatch and speech intelligibility in simulated cochlear implant processing

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Abstract

Listeners with normal hearing show a large release from masking in multiple-talker environments, but these advantages are limited for cochlear implant users. One reason for this disparity is the mismatch between frequency and place of stimulation that arises because surgical limitations preclude stimulation of the most apical regions of the auditory nerve by the most apical electrodes, and because standard clinical practice is to extend analysis bands downward to cover the entire frequency region known to be important for speech reception, despite the fact that there are no available electrodes to stimulate the corresponding place. The idiosyncrasies of surgery also make it very likely that there is an interaural place mismatch for bilateral CI users as well, which has implications for binaural hearing because binaural processing requires good interaural fusion across frequency. The goal of the current study was to examine the possible benefits of various approaches to manipulate the frequency position of the cochlear implant analysis bands to mitigate the negative effects of these mismatches. Cochlear implant processing was simulated using a vocoder which implemented a high number of pure-tone carriers, all in random phase, to control for the contribution of temporal fine-structure cues. In Experiment 1, the control condition was the standard clinical practice of extending analysis bands downward to cover the full usable frequency region of speech, which introduces frequency-place mismatch. One test strategy aligned all analysis bands with their respective electrodes, which resulted in no frequency-place mismatch but which discarded low-frequency energy. Another strategy was to align the majority of analysis bands, but to extend only the most apical analysis bands downward as a compromise, wherein all but a few channels had no mismatch, yet no information was discarded. The results showed significant improvements to speech intelligibility when analysis bands are aligned in frequency with their respective electrodes, even though this means discarding low-frequency information. There was only a small decline in benefit when the lowest-frequency analysis bands were extended downward, which introduced frequency-place mismatches on these electrodes, but which also avoided discarding energy in the lowest frequencies. Experiment 2 confirmed this pattern of results in the presence of a distractor talker presented at various signal-to-noise ratios. Experiment 3 simulated a bilateral CI configuration, and used non-individualized head-related impulse responses to simulate a spatial configuration in which the target talker was at the midline, and two symmetrical distractors were either co-located with the target, or at +/-30 degrees. Results showed that when simulated insertion depths were interaurally asymmetrical, there was no spatial release from

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masking using the standard clinical approach, while aligning all analysis bands with their respective electrodes resulted in a significant benefit over the standard clinical approach in the co-located condition, as well as an addition spatial-release from masking.