Channels interactions have less impact on temporal-pitch than ITD sensitivity in dual-electrode cochlear implant stimulation

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Abstract

Timing cues, i.e., interaural time differences (ITDs) and temporal pitch, are pivotal for sound localization and source segregation, but perception is impaired in cochlear-implant (CI) listeners compared to normal-hearing listeners. Interactions between channels (i.e., electrodes) are assumed to be an important limiting factor, being responsible for pronounced differences in performance between single- and multi-electrode stimulation. To unveil the origin of these performance differences and the role of channel interactions, dual-electrode monaural temporal-pitch and ITD sensitivity was measured in five CI listeners each. The use of matched experimental setups enabled us to directly compare the effects of between-electrode delay, tonotopic separation of electrodes, and stimulus type.
Our stimuli consisted of a target electrode paired with a flanker electrode. For ITD, target and flanker pairs were interaurally ITD-matched. Two tonotopic separations were tested: To create maximal channel interactions, 'narrow' flankers were selected to be adjacent to the target on either side. To create minimal channel interactions with the smallest possible target-flanker separation, 'wide' flankers were selected based on individually measured forward-masked spatial tuning curves. Three stimulus types were tested: Per electrode, stimuli were either unmodulated low-rate pulse trains (LR; 100 pulses/s; high sensitivity and low intrinsic channel interaction potential expected), amplitude-modulated (AM) high-rate pulse trains (HR; 1000 pulses/s with 100-Hz AM at a depth of 0.3; low sensitivity and high channel interaction potential expected), and AM high-rate pulse trains with additional short inter-pulse interval pulses (SIPI; LR-like sensitivity and HR-like channel interaction potential expected). The between-electrode delay was varied within the pulse or AM period, respectively. Furthermore, single-electrode conditions for all electrodes were tested.

For LR, both pitch and ITD results indicate systematic effects of between-electrode delay and tonotopic separation, with best performance for short delays and wide separations. Adding a second electrode lowered sensitivity for narrow separations, but did not affect sensitivity for wide separations. For both HR and SIPI, ITD performance approached chance level. In contrast, for pitch, the between-electrode delay had a similar effect for the three tested stimulus types, despite lower overall sensitivity for HR and SIPI. Adding a second electrode improved HR and SIPI pitch sensitivity for wide electrode separations, regardless of the between-electrode delay.
Our results demonstrate the important role of channel interactions in timing-cue sensitivity for both temporal pitch and ITD. For pitch, the lack of a delay effect for wide tonotopic

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separations suggests perceptual independence of electrodes approximately 12 mm apart, regardless of the stimulus type (i.e., of its intrinsic potential for channel interaction). For ITD, a pitch-like effect of tonotopic spacing was only found for low-rate stimulation (i.e., conditions having a low channel interaction potential). Taken together, the impact of channel interactions appears to be distinct in monaural vs binaural processing. In particular, pitch seems to be less susceptible to channel interactions than ITD.