Lateralization of Interaural Level Differences in Multi-Channel Electrical Stimulation
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Background
Improved sound localization is one of the benefits associated with use of bilateral cochlear implants (CIs). Modern speech processors cannot reliably encode all of the localization cues available to normal-hearing listeners. Therefore, CI listeners rely mostly on interaural level differences (ILDs) to produce a spatial impression of the surrounding environment. The thresholds (T) and the "most-comfortable" (C) levels obtained during the mapping procedures often differ across the electrodes within the ear and across the ears, resulting in a different spread of excitation at different cochlear locations. Moreover, real world sounds can activate multiple electrodes simultaneously. It is unclear if multi-electrode stimulation with current spread can produce a centered and punctate auditory image in a CI user's head, which could be used as a baseline to create a consistent spatial map across frequencies.

Methods
We investigated the perceived intracranial location of direct electrical stimulation in a group of bilateral CI listeners. For five electrodes in each ear, T and C levels were obtained. Stimuli were monopolar, 1000 pulse/sec pulse trains that were 500 ms in duration. They were presented bilaterally at 70-80% of the dynamic range using single-electrode pairs and several multi-electrode combinations, including three widely-spaced pairs, three closely-spaced pairs, and five-electrode pairs. Listeners reported the position of the perceived intracranial image at ILDs of 0, ±2, ±5, and ±10 current units (cus). Lateralization ability with inconsistent ILDs across frequencies was studied in normal-hearing listeners to simulate lateralization with multi-electrode stimulation in CI listeners.

Results
The shape of the lateralization curves was highly variable for single- and multi-electrode stimulation, both within and across listeners. This often resulted in an offset in the perception of a centered image for 0-cu ILD. Adjusting the levels of individual electrode-pairs within a multi-electrode combination with the offsets measured in the single-electrode pairs shifted the location of the perceived sound at 0-cu ILD. This shift resulted in a more centered image for 7/10 multi-electrode combinations in 4 listeners.

Conclusion
The results suggest that auditory spatial maps are distorted for single- and multi-electrode stimulation in bilateral CI users. The perception of a centered image for 0-cu ILD can be improved by adjusting the levels of individual electrodes within a multi-electrode combination based on the single-electrode data. These data have implications for bilateral clinical mapping strategies.