Sensitivity to Spectral Peaks and Notches in Cochlear Implant Listeners

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INTRODUCTION

To localize sounds in the vertical plane, spectral peaks and notches are necessary. The necessary frequency range is typically accepted to be 4-16 kHz. This could be problematic for cochlear implant (CI) users because the frequency range is typically limited to approximately 10 kHz, thus omitting half of the relevant frequency range.

Particularly important spectral features for sound localization may include:

- Front: 1-oct. notch with lower cutoff from 4-10 kHz
- Back: small peak from 10-12 kHz
- Increasing frontal elevation: increasing lower cutoff of 1-oct. notch

However, broadband rather than narrowband cues are most relevant (Møller and Middlebrooks, 2005). Given the crude spectral resolution of CIs, this is a promising and necessary result for implementing a CI sound localization strategy.

This study measures CI listeners’ sensitivity to spectral peaks and notches in a “flat” background with different bandwidths and at different tonotopic places. The results will be compared to the normal hearing (NH) thresholds (Moore et al., 1989).

LOUDNESS BALANCING

All 12 electrodes are balanced to an equal loudness using an iterative loudness balancing procedure.

1. Determine a comfortable level (CL) for each electrode separately.
2. Present all electrodes simultaneously at CL, reduce level to an overall comfortable level (OCL)
3. Balance level of individual electrodes at CL, adjusted by the offset found from the OCL
4. Present all electrodes simultaneously at new levels, reduce level to an overall comfortable loudness (OCL)
5. Repeat steps 3 and 4 and all electrodes are presented at an equal loudness, and can be presented simultaneously at a comfortable loudness

Listeners needed 2-4 iterations to reach an overall equal-comfortable level. The levels at all twelve electrodes were balanced to the same overall loudness.

METHODS

1. Listeners
   - 6 Med-El C40+ Pulsear Implants
   - 1513 pps stimulation rate per electrode (direct stimulation research interface)

2. Procedures
   - 32-240% duty cycle
   - 2 down – 1 up staircase
   - 16 turnarounds (first 4 omitted from calculation of mean and stand. dev.)
   - Frequency stimuli were presented in a down-up staircase paradigm

EXPERIMENT 1: AMPLITUDE DETECTION

EXPERIMENT 2: AMPLITUDE DISCRIMINATION

EXPERIMENT 3: FREQUENCY DISCRIMINATION

CONCLUSIONS

Three types of spectral sensitivity were tested in CI listeners. Specific results are:

- Peak sensitivity without roving (2-3 electrodes) is less than 8% DR (≈ 7.8 µA)
- Level roving increased peak thresholds by 7% DR (∼ 4.5 µA)
- Frequency discrimination thresholds were approximately 1 electrode

Conditions

- Tonotopic place
  - low = electrodes 4-6
  - Bandwidth = 1, 2, 3 electrodes
  - Peaks and notches

All peaks could be determined, but only 50% of notches were determined. The reason for this is that the wideband, equal-loudness stimuli were presented at levels lower than the thresholds for the CI listeners.

The necessary frequency range is typically accepted to be 4-16 kHz. To localize sounds in the vertical plane, spectral peaks and notches can be presented simultaneously at a comfortable loudness.

The results will be compared to the normal hearing (NH) thresholds (Moore et al., 1989). Given the crude spectral resolution of CIs, this is a promising and necessary result for implementing a CI sound localization strategy.

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