Error-detection in Cochlear Implant and Normal Hearing Listeners
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**Background**
- Individuals with normal hearing are known to be sensitive to acoustic variability and will self-correct subphonemic variation while talking (Niziolek et al. 2013).
- The ability to detect and self-correct errors in one’s own productions is crucial for the production of clear, intelligible speech.
- Cochlear implants (CIs) reduce the spectral resolution, potentially masking variability in the signal.
- Are cochlear implant (CI) users able to hear subphonemic variability in their own speech?
- Do CI users use this auditory feedback to guide speech production?

**Hypothesis**
CI users will only be able to detect small acoustic differences between multiple repetitions of their own speech productions if those differences occur across filters of the implant. Similarly, normal hearing listeners may only be able to hear such differences in vocoded speech if they span across filter bands.

**Method**
- Recorded subjects’ own “Ed” and “oh”; one token of each was chosen as a base stimulus from which all other stimuli were generated.
- F1 shifted up/down in “Ed”; F2 shifted up/down in “oh” using Audapter (Cai et al. 2008; stimulus from which all other stimuli were generated).
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- F1 shifted up/down in “Ed”; F2 shifted up/down in “oh” using Audapter (Cai et al. 2008; stimulus from which all other stimuli were generated).
- Subject discrimination curves, left 2: discrimination over all trials from one subject. X-axis shows trial number, and y-axis shows interval tested on that trial. Peaks or valleys indicate reversals. After correct trials, the interval between the base stimulus and the test stimulus decreased; after incorrect trials, the interval increased. Lower intervals indicate greater sensitivity.

**Results**
- **Discrimination in F1 for Subject ICC**
  - **Simulated electrodograms**
  - **Discrimination in F2 for Subject ICC**
- **Electrograms, left 4**: Simulated electrodograms for one subject showing difference in stimulation between base stimulus and the altered stimulus at the perception threshold. Results shown for one participant in all four conditions. Orange shows stimulation pattern of just the base stimulus; grey shows stimulation of just the threshold stimulus. Overlay indicates stimulation pattern common to both stimuli.

**Discussion**
- Greater sensitivity to subphonemic differences in self-produced speech than expected for both populations, though large within- and across-individual threshold variability.
- Some subjects surprisingly sensitive to differences in two acoustic items that produce very similar stimulation.
- F2 thresholds are higher than F1 for CI users (p = 0.03), consistent with hypothesis that wider filters, which may have wider band widths in the F2 range, yield a decrease in sensitivity.
- Within-filter thresholds tend to occur near boundary between two filters: role of formant bandwidth?
- Experiment manipulates one spectral peak, but signal is time-varying: longer time windows (i.e. entire vowel) may provide enough information for some speakers.

**Conclusions**
- For some speakers and frequency bands, implant provides enough spectral resolution to hear small-between-utterance deviations in their own speech.
- CI users may be able to use their auditory feedback to detect errors and update motor plans while speaking.

**Future directions**
- Ongoing study with real-time altered auditory feedback suggests that some CI users do rely on feedback (and not entirely on feed-forward mechanisms) while speaking.

Selected references: