Error-detection in Cochlear Implant and Normal Hearing Listeners

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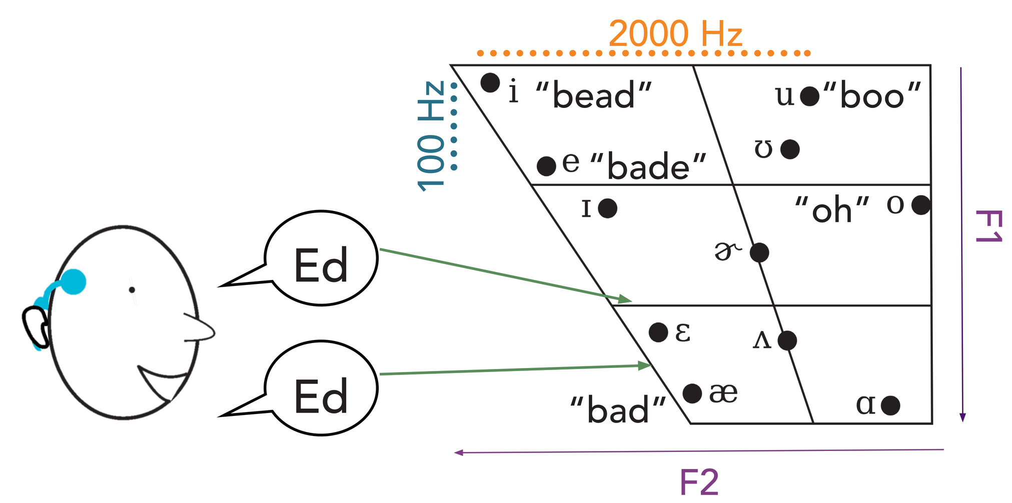
Background

- 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

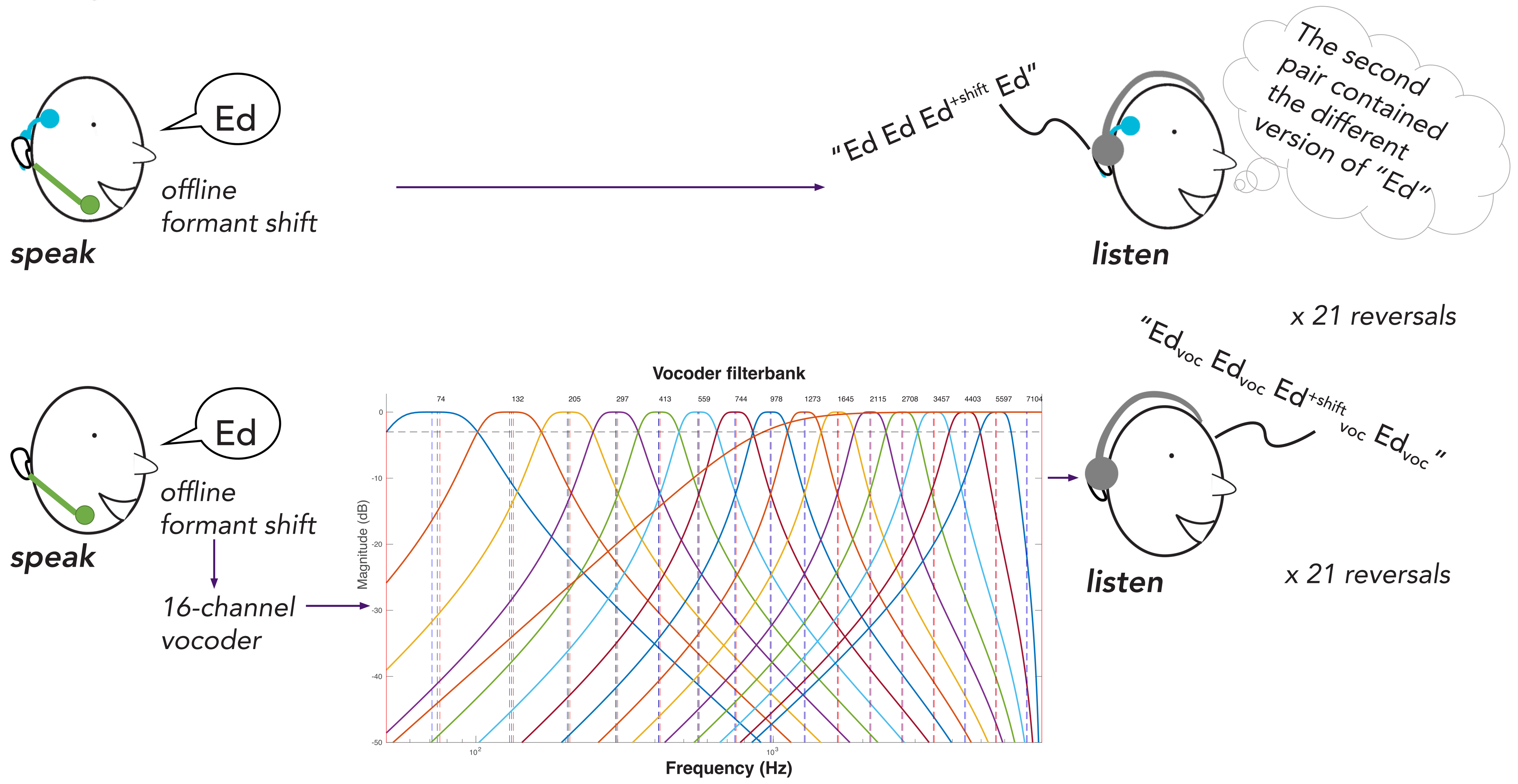
CI users will only be able to detect small acoustic differences between multiple repetetitions of their own speech productions if those differences occur *across* filters of the implant. Similarly, normal hearing listeners may only be able to hear such differences in vocoded speech if they span across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



Left: Vowel space showing acoustic distance between vowels along F1/F2 dimensions. Some phonetic categories are separated by acoustic differences that may be smaller than the spectral resolution provided by a CI. Low spectral resolution may prevent detection of important subphonemic differences

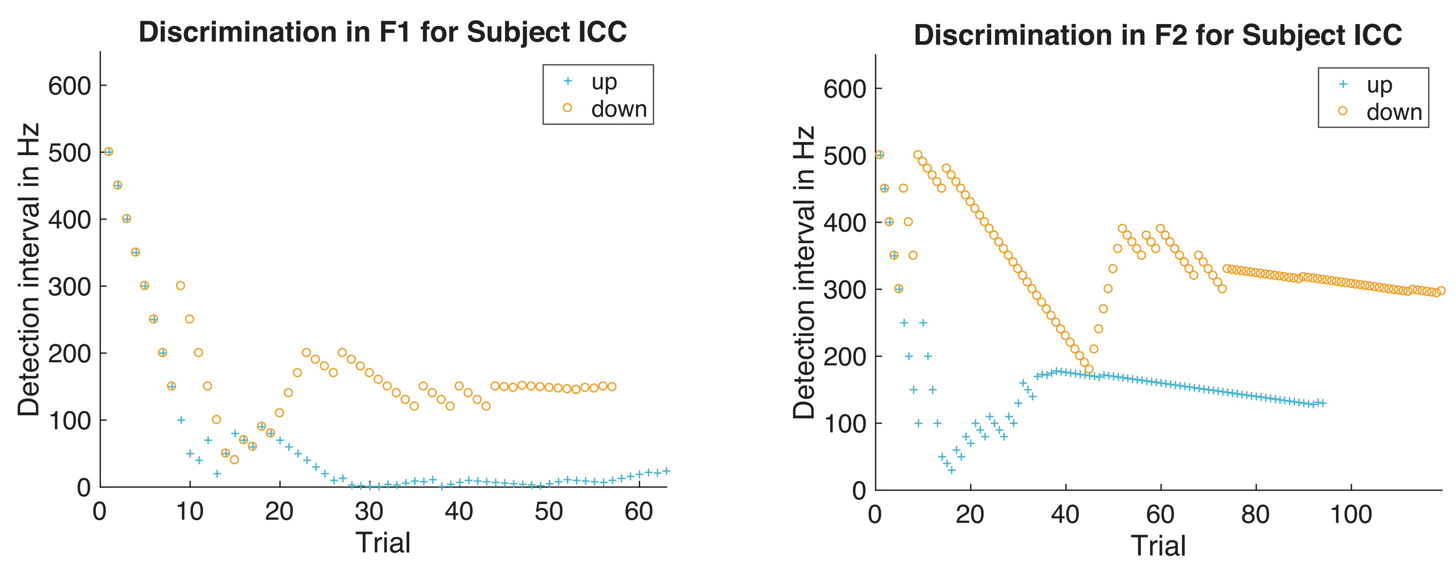
Method

- 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; Tourville et al. 2013), 1 Hz increments.
- 4-interval 2-alternative forced choice adaptive discrimination task
- Direction of shifts (up/down) interleaved
- Interval increases by 3 steps after incorrect response, decreases 1 step after correct
- Choice indicated with button press
- For NH: 16-channel vocoded to mimic bandwidths of implant; sine carrier (same task)
- Just noticeable difference (JND) obtained by averaging final six reversals
- 14 CI listeners: 13 bilaterally (1 unilaterally) implanted with Cochlear® CIs
- 4 age-matched NH listeners



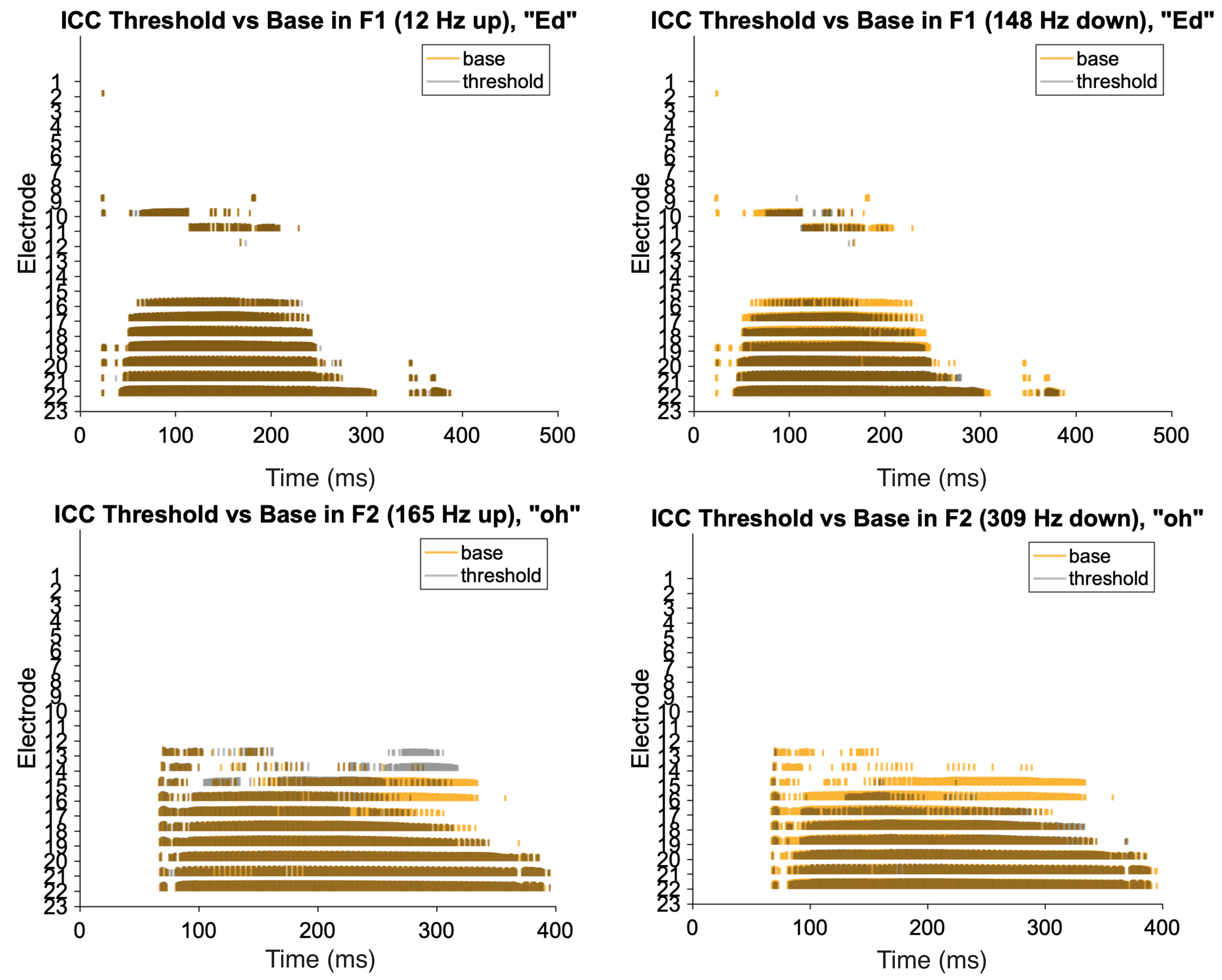
Results

Discrimination curves



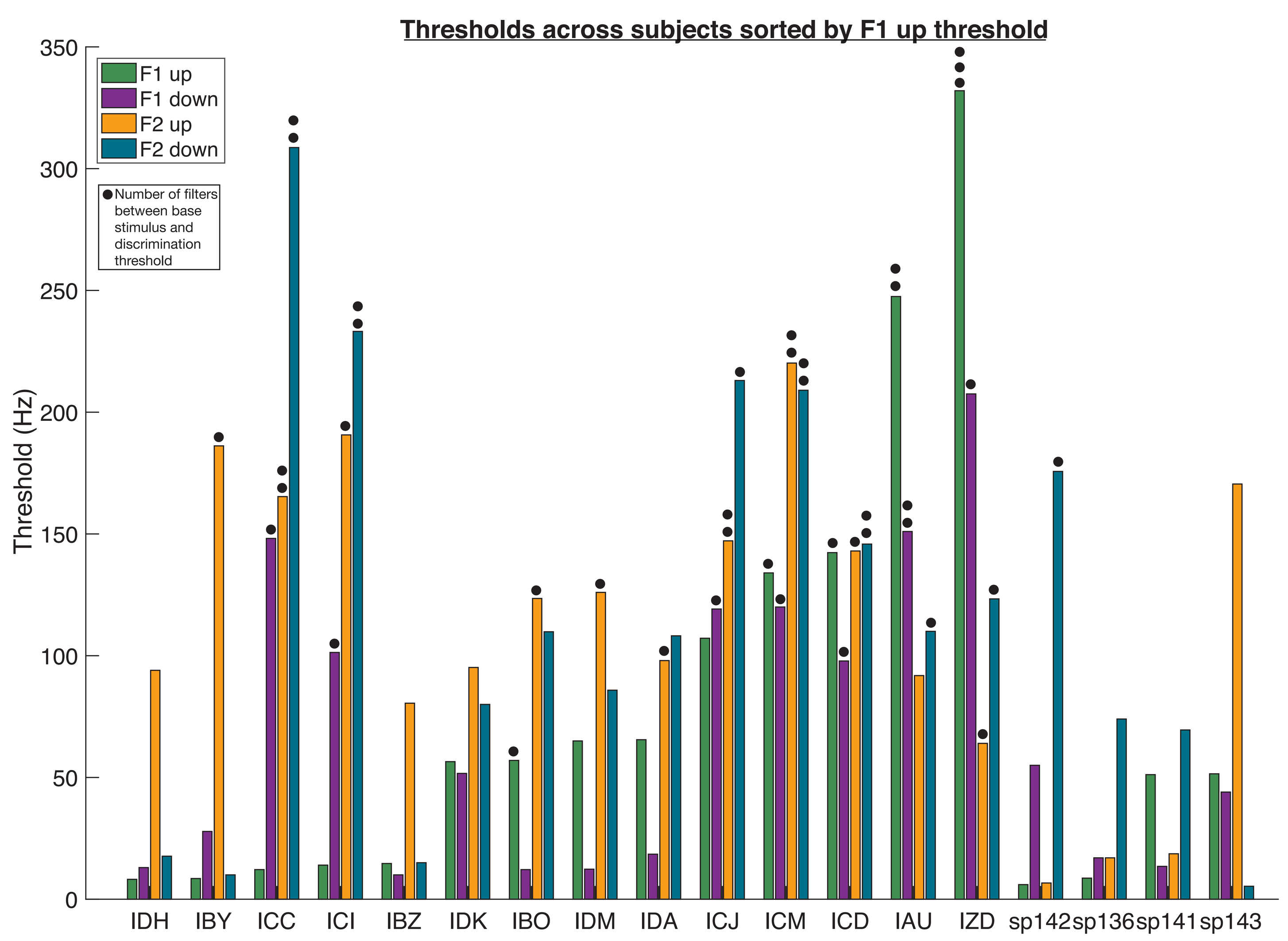
Subject discrimination curves, left 2: discrimination over all trials from one subject. X-axis shows trial number, and y-axis shows interval tested on that trial. Peaks or valleys indicate reversals. After correct trials, the interval between the base stimulus and the test stimulus decreased; after incorrect trials, the interval increased. Lower intervals indicate greater sensitivity.

Simulated electrodograms



Electrodograms, 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. Overlap indicates stimulation pattern common to both stimuli.

Below: thresholds for all subjects in Hz. Subject IDs beginning with "sp" indicate normal hearing participants listening to vocoded speech.
Circles **:** above bars indicate number of filters between the base stimulus and stimulus representing threshold (0 circles = within-filter sensitivity).
Lower threshold = greater sensitivity.



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

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