Interaural Place-Mismatch Estimation With Two-Formant Vowels in Unilateral Cochlear-Implant Users

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Interaural Place-Mismatch Estimation with Two-Formant Vowels in Unilateral Cochlear-Implant Users

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Introduction

For cochlear implant (CI) users with residual hearing in the contralateral ear, usually a default frequency-to-electrode map is used in the CI. This assumes that the human brain can adapt to interauralplace-pitch mismatches. This "one-size-fits-all" method might be partly responsible for the large variability of the individual binaural benefit. Therefore, knowledge about the location of the electrode array is an important prerequisite for optimal fitting. Theoretically, the electrode location can be determined from CT-scans. However, these are often not available in audiological practice. Behavioral pitch matching between the two ears has also been suggested, but has been shown to be tedious and unreliable (Carlyon et al., 2010). Here, an alternative method using two-formant vowels was developed and tested.

Research question: Can we use the second formant (F2) of a two-formant vowel as a pitch matching stimulus by presenting it either on the aid/normal side or on the implanted side?

Results: NH listeners

- Monaural, No-Voc: F1 and F2 => Left Channel
  - Dichotic, Voc1: F1 => Left, F2 => Right, vocoded with no shift
  - Dichotic, Voc2: F1 => Left, F2 => Right, vocoded with ±0.45 oct shift
  - Dichotic, Voc3: F1 => Left, F2 => Right, vocoded with ±0.85 oct shift

- Monaural, No-Voc: F1 and F2 => Left Channel
  - Dichotic, Voc1: F1 => Left, F2 => Right, vocoded with no shift
  - Dichotic, Voc2: F1 => Left, F2 => Right, vocoded with ±0.45 oct shift
  - Dichotic, Voc3: F1 => Left, F2 => Right, vocoded with ±0.85 oct shift

Main results:

- NH listeners were able to fuse formants, even when one is vocoded.
- Large individual differences were observed for the dichotic acoustic-electric stimulus (poor vowel discrimination). Difficulty to fuse electric and acoustic percepts might be an explanation, as suggested by the speech perception results.

Discussion, conclusions

- NH listeners' results suggest that this new procedure could be a tool to indicate the existence of a mismatch. However, quantitative estimation of the mismatch remains challenging.
- CI listeners could perform the task within a reasonable amount of time (30 minutes), and reliably for the acoustic monaural condition.
- Large individual differences were observed for the dichotic acoustic-electric stimulus (poor vowel discrimination). Difficulty to fuse electric and acoustic perceptions might be an explanation, as suggested by the speech perception results.

Overall, these results suggest that place mismatches can be identified from such vowel spaces, but the method remains limited by the individual variability and the difficulty to achieve spectral fusion.

References:

- Carlyon et al. (2010). With comparisons between electrical stimulation of a cochlear implant and acoustic input presented to a normal-hearing contralateral ear, JASA, 128(3):458-466
pants with the resynthesized voices in a phonemic restoration paradigm.

Results
Data show, as expected, an overall decrease of intelligibility as the spectral resolution is reduced. However, the effect of pitch presence or absence does not follow exactly our expectations. The addition of pitch showed improvement of restoration only at 8- and 6-bands spectral resolution, which is fully due to improvement of intelligibility when the interruptions are filled with noise.

Conclusion
With the addition of pitch, NH listeners may be better able to discriminate the speech from the noise, and may therefore avoid interpreting the latter as (spurious) speech cues, thus yielding fewer errors. Moreover, the addition of pitch to the spectrally degraded speech also provides more bottom-up cues that seem to trigger the top-down repair of the missing segments (especially at 8- and 6-bands). When the speech is intelligible enough, adding new speech features does not enhance restoration any further. When the speech is too degraded, adding pitch is not sufficient to improve intelligibility. The present results suggest that phonemic restoration also depends on the amount of speech features available in the speech segments. Adding pitch information to CIs could lead to the improvement of top-down repairs in noisy listening situation.

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Background
For patients with one cochlear implant (CI) and residual hearing in the opposite ear, a default frequency-to-electrode map is typically used despite large individual differences in electrode-array insertion depth. This non-individualized fitting rationale might partly explain the variability in long-term speech-reception benefit among CI users. Knowledge about the electrode-array location is thus crucial for adequate fitting. Although electrode location can theoretically be determined from CT scans, these are often unavailable in audiological practice. Moreover, existing behavioral procedures such as interaural pitch-matching are rather tedious and time-consuming. Here, an alternative method using two-formant vowels was developed and tested.

Methods
Eight normal-hearing (NH) listeners were presented synthesized two-formant vowels embedded between consonants /t/ and /k/, with first-formant frequencies (F1) at 250 and 400 Hz and second-formant frequencies (F2) between 600 and 2200 Hz. F1 was presented unaltered to the left ear, while F2 was presented to the right ear via a vocoder system simulating 3 different CI insertion depths. In each condition, the listeners indicated in a forced-choice task which of 6 vowels they perceived for different [F1, F2] combinations. Ten CI users (5 bimodal and 5 single-sided deaf) performed the same task for F1 presented acoustically to the non-CI ear and F2 presented either acoustically to the same ear or electrically to the CI ear.

Results
After some training, all NH listeners were able to fuse the unaltered F1 and vocoded F2 into a single vowel percept, and vowel distributions could be reliably derived in 7 listeners. Vocoder simulations of reduced CI insertion depth led to clear vowel-distribution shifts in these listeners. However, these shifts were overall smaller than their theoretical value, with high across-subject variability. Vowel distributions could be derived for all CI users in the monaural acoustic condition, indicating an ability to perform the task reliably. Despite this, large individual differences were observed for dichotic bimodal stimulation, with listeners showing either basal or apical shifts, or generally-poor vowel discrimination.

Conclusion
The two-formant-vowel method is a fast and clinic-friendly candidate to derive interaural place mismatches from a simple vowel-recognition task. However, it remains unclear whether the measured “vowel spaces” in CI users are directly related to insertion depth, and whether they are influenced by the ability to fuse acoustic and electric stimuli or habituation to the CI. The comparison of the present results to CT-scan and speech-intelligibility data in the same listeners will shed light on the validity of the proposed method.

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The Effect of Spectral Resolution on Temporal Processing Abilities in Simulated Electric Hearing
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Background
Gap detection threshold (GDT, the shortest intervals a person can perceive) is a commonly used measure of temporal processing resolution. Normal GDT is critical for speech encoding. It has been reported that the large variability in cochlear implant users’ speech perception may be related to the temporal processing deficits in some cochlear implant (CI) users (Muchnik et al., 1994; Fu et al., 2002). Unlike the GDT measured using direct electric stimulation through the electrode, the GDT measured via clinical processors may also reflect additional limitations imposed by limited spectral resolution due to CI processing. The purpose of this study is to determine how spectral resolution may affect GDTs in normal hearing (NH) subjects listening to acoustic simulation of CI processing. Additionally, the neural correlates of gap detection were examined using the late auditory evoked potential (LAEP). If a correlation between behavioral and LAEP measures exists, a clinically useful outcome would be to use the