M12a

Across-Electrode Sensitivity to Differences in the Envelope and its Relation to Electrode-Neuron Interface

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Introduction

- **Across-electrode temporal comparisons** change based on **electrode-neuron interface** (Fig. 1) in **cochlear implant (CI)** users [1].
- Comparison of **envelope shape** across-electrodes is one perceptual mechanism **normal-hearing (NH)** listeners use to **segregate sound sources**, and whose signal is preserved in CI signal processing.
- This study investigated sensitivity to differences in **amplitude modulation rate (AMR),** or frequency of amplitude modulation, for stimuli presented simultaneously across pairs of electrodes.

1: Depiction of Poor Electrode-Neuron Interface

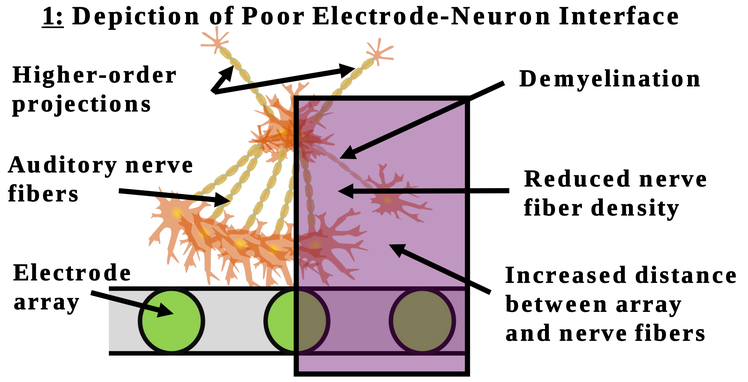


Fig. 1: Poor electrode-neuron interface is shown in the purple box, and results in reduced temporal sensitivity at specific electrode sites [2,3,4].

Hypothesis: If, given two pairs of electrodes, one pair has the **electrode with least amplitude modulation sensitivity**, then it will be **less sensitive** to differences in amplitude modulation rate presented **across-electrodes**.

Stimuli & Procedures

- Listeners: 7 bilateral CI users
- 600 ms duration
- Presented via direct stimulation
- 3000 pulse per second pulse train; presented to electrodes 4 and 16

2: AMR Sensitivity Assessment

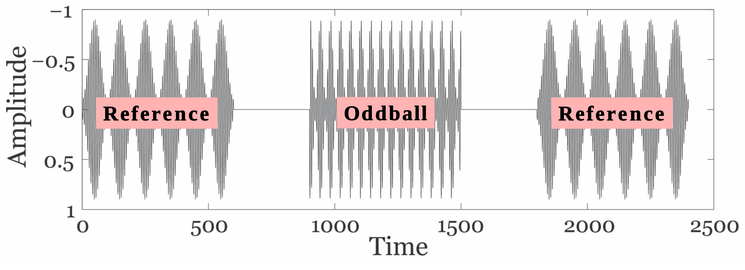


Fig. 2: Stimuli were sinusoidally amplitude modulated (50% modulation depth). AMR of the oddball was adaptively varied to find 71.7% threshold.

3: Across-Electrode AMR Comparisons

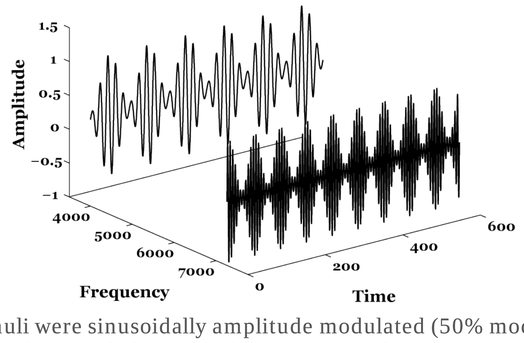


Fig. 3: Stimuli were sinusoidally amplitude modulated (50% modulation depth). Example provided is normal-hearing stimulus; the CI stimulus had a pulse train carrier played to different electrodes.

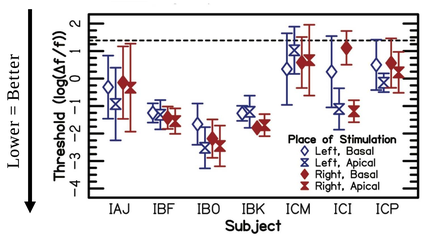
- One or two AMRs presented simultaneously (Fig. 3)
  - One electrode fixed to 10 or 90 Hz
- Subjects responded **same or different** (1-interval, 2-alternative forced-choice)
  - Method of constant stimuli

AMR Conditions:
Cochlear Place

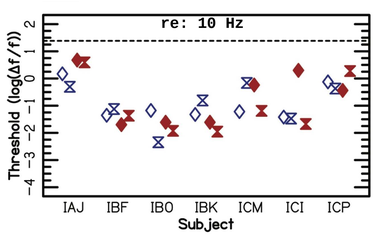
Ear	Same Place Within Ears	Different Place Within Ears
	Same Place Across Ears	Different Place Across Ears

Amplitude Modulation Sensitivity in Each Electrode

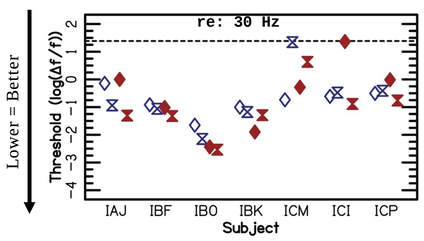
4A: Mean Threshold



4B: Threshold re: 10 Hz



4C: Threshold re: 30 Hz



4D: Threshold re: 90 Hz

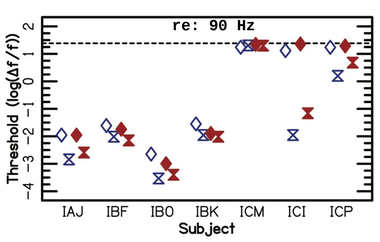
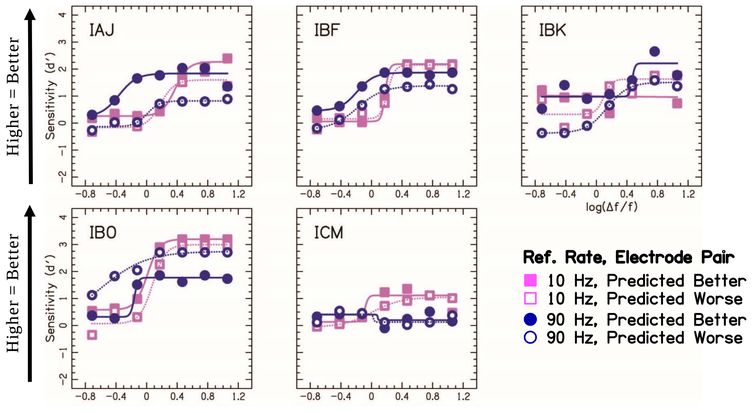


Fig. 4: Thresholds for changes in AMR at each electrode site are shown with respect to ear and place. 4A shows results averaged across reference AMRs. B-D show results for each AMR.

- Thresholds for 70.7% correct in the AM sensitivity assessment task vary depending upon place of stimulation at all reference AMRs (Fig. 4B-4D).
  - No consistent relationship across subjects is supported by previous literature [2,3,4].
  - Higher thresholds at specific electrode sites suggest poorer temporal sensitivity.
- Thresholds vary according to AMR, but are inconsistent across listeners (Fig. 4B-4D).

Binaural Comparisons of AMR

5A: Same Place, Across-Ears



5B: Different Place, Across-Ears

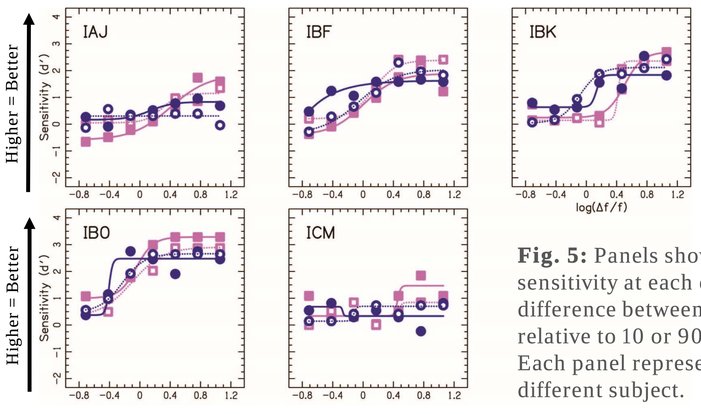


Fig. 5: Panels show the sensitivity at each degree of difference between AMRs relative to 10 or 90 Hz AMR. Each panel represents a different subject.

- Thresholds from Fig. 4A were used to predict the better pair (see hypothesis).
- For several subjects, especially relative to 90 Hz, the predicted worse pair:
  - Was less sensitive on average
  - Required larger differences in AMR to achieve the same sensitivity as the predicted better pair (rightward shift).

Monaural Comparisons of AMR

6: Different Place, Within-Ears

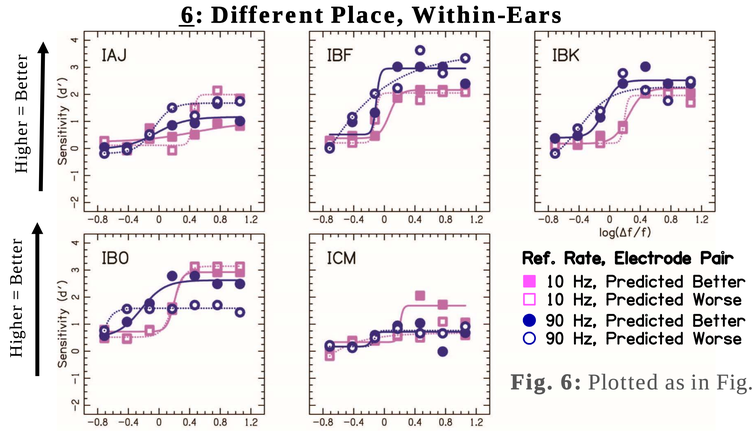
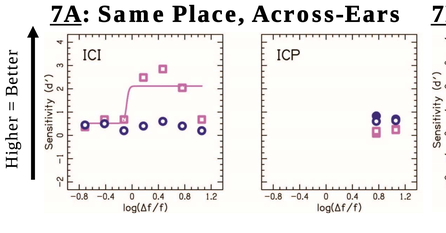


Fig. 6: Plotted as in Fig. 5.

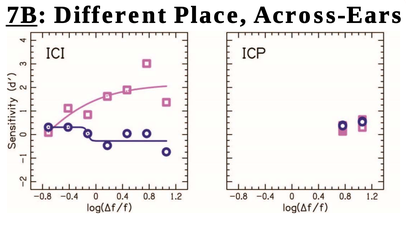
- As in Fig. 5, for many subjects, the predicted better pair reached peak sensitivity earlier than the predicted worse pair in monaural conditions (Fig. 6).

Listeners

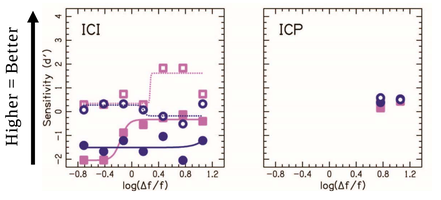
7A: Same Place, Across-Ears



7B: Different Place, Across-Ears



7C: Different Place, Within-Ears



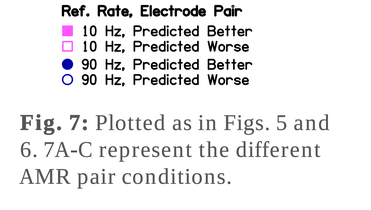


Fig. 7: Plotted as in Figs. 5 and 6. 7A-C represent the different AMR pair conditions.

- Subjects ICI and ICP were not able to achieve above 70% correct in the most AMR conditions (Fig. 7).

Subject	Age	Etiology	Experience (Years L/R)
IAJ	68	Unknown	17/10
IBF	62	Hereditary	6/8
IBK	73	Noise-induced	9/3
IBO	48	Otosclerosis	2/5
ICI	55	Unknown	5/4
ICM	62	Progressive	5/4
ICP	52	Unknown	8/5

Summary

- **Amplitude modulation sensitivity appears to change** depending upon the electrode site, not consistent with ear or place across subjects (Fig. 4B-D).
  - May be an appropriate proxy to electrode-neuron interface
- Performance judging differences in **AMR across electrodes** (Fig 5-6):
  - Varied highly between subjects.
  - **Depended on reference AMR.**
  - Appears to be **related to amplitude modulation sensitivity** at individual electrode sites.
- Ability to segregate between sound sources may be mediated by temporal sensitivity at each electrode.

References

1. Ihlefeld, A., Carlyon, R. P., Kan, A., Churchill, T. Y., & Litovsky, R. Y. (2015). Limitations on monaural and binaural temporal processing in cochlear implant listeners. *Journal of the Association for Research in Otolaryngology*. doi: 10.1007/s10162-015-0527-7.
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Acknowledgements

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