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Introduction

- Many patients with **bilateral cochlear implants (BiCIs)** experience **asymmetric hearing outcomes in each ear** [1-3].
- Asymmetric hearing outcomes are **associated with**:
 - Poorer sensitivity to binaural cues [4-5]
 - Poorer sound source localization [2-3]
 - Abnormal vowel perception/fusion [6-7]
 - Poorer speech understanding [2-3, 8-10]
- Thus, asymmetric hearing outcomes yield **less sensitivity** to segregation cues and **poorer overall outcomes**.
- Poorer speech outcomes could be due to **failure to allocate attention** [8,11], **maladaptive integration** of sounds [6-7], or both.
 - "Missing link" between segregation cues and speech
- Question:** Do asymmetric hearing outcomes lead to poor segregation of speech sounds?

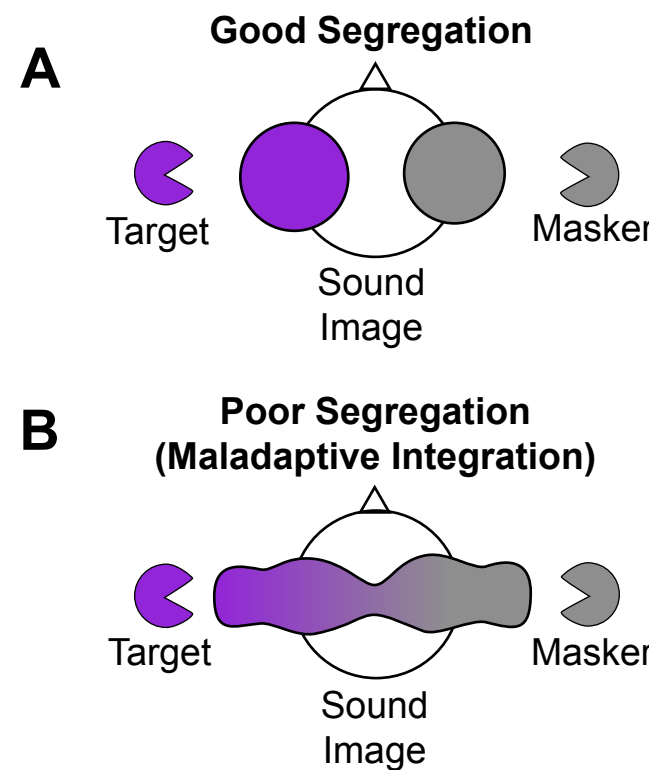


Fig. 1. A. When speech is accurately segregated across the ears, listeners report two punctate sound images. B. When segregation is poor, listeners hear unclear sound images that may be maladaptively "fused" integrated into one image.

Goal: Investigate the speech perception of words presented across the ears where one ear provides a degraded signal (i.e., interaural asymmetry), or both ears provide degraded signals.

Methods

- Two groups of listeners participated:
 - 4 normal-hearing (NH):** with unprocessed and noise-vocoded (Fig. 2) speech via circumaural headphones
 - 5 BiCI:** unprocessed speech via direct connect (Cochlear) or circumaural headphones (Advanced Bionics T-mic) at a comfortable level
- Speech stimuli were **closed-set, monosyllabic words** (Fig. 3) from Cutting [12-13] spoken by one male talker.

Bed	Led	Red	Bled	Bread
Pay	Lay	Ray	Play	Pray
Go	Low	Row	Glow	Grow

Fig. 3. Responses were recorded on a graphical user interface identical to the one above. Listeners chose one- or two-word responses.

- The task indexed **accuracy** and **interaural integration** (Fig. 4).
- One third of trials included:
 - The same word in both ears
 - Two words differing in the first consonant (stop + liquid pair; Fig. 4A)
 - Two words differing in vowels
- Responses were sorted into categories (Fig. 4B).
 - * Bias = correct for only one side

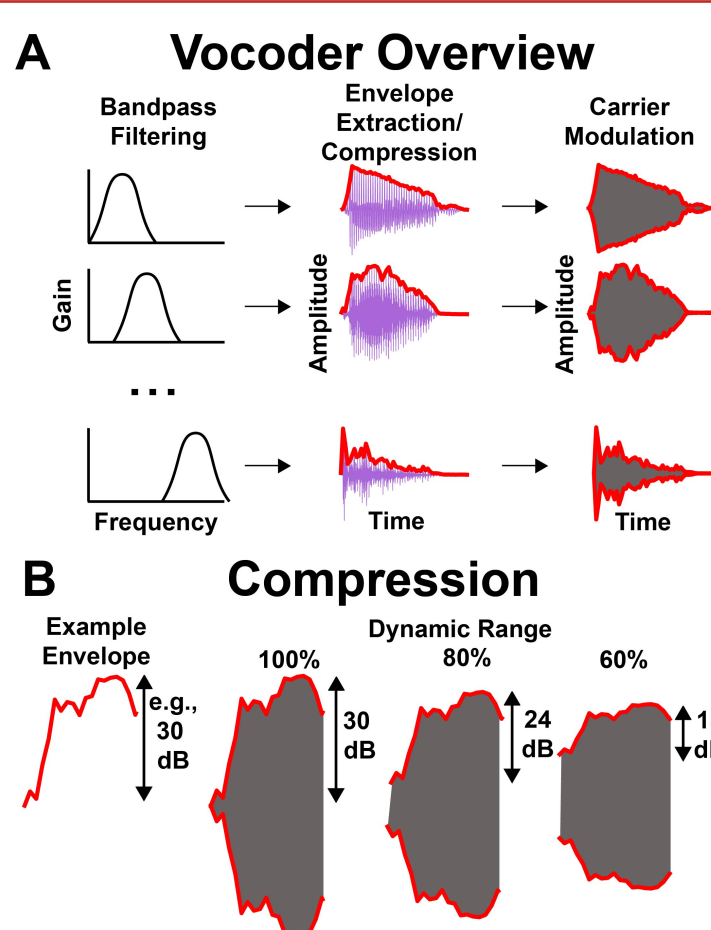
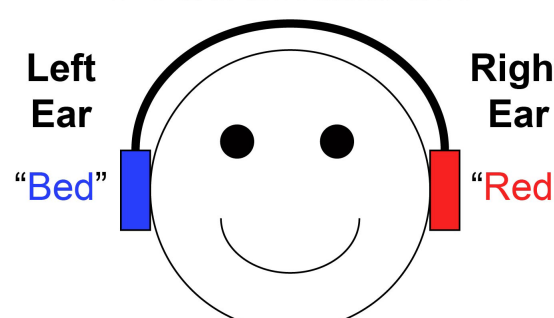


Fig. 2. A. Sixteen channel vocoding [14] was completed with low-noise noise carriers. B. The dynamic range was manipulated to elicit changes in speech understanding. RMS level remained 65 dB(A).

Presentation



Possible Responses

Ideal: "Bed + Red"
Fused: "Bred"
Biased left: "Bed"
Biased right: "Led + Red"
Interference: "Led"

Fig. 4. A. One word was presented to each ear. Listeners responded with the word(s) they heard. Listeners did not indicate the side from which words were presented. B. Responses were sorted into categories based upon listening strategy.

Hypothesis: If one or both ears yield poor speech understanding, then speech perception will result in: (1) poorer accuracy, and (2) maladaptive integration.

NH Results

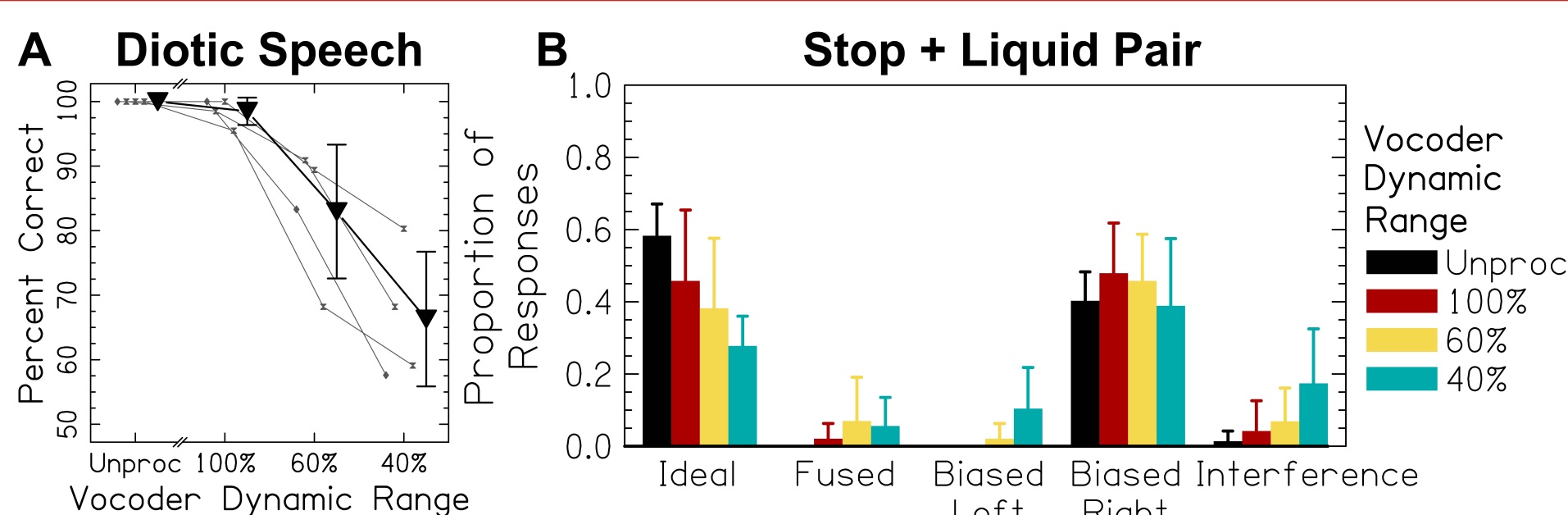


Fig. 5. Mean results from for NH listeners. Error bars represent ±1 standard deviation. A. Mean results are shown in black. Individual listeners are shown in grey. B. Response categories (see Fig. 4) are shown by vocoder condition.

- Symmetric, smaller dynamic range resulted in poorer speech understanding when the same word was presented to both ears (Fig. 5A).
- Accuracy decreased as dynamic range decreased symmetrically (Fig. 5B).
 - Trade-off: As ideal responses decreased, interference increased

BiCI Results

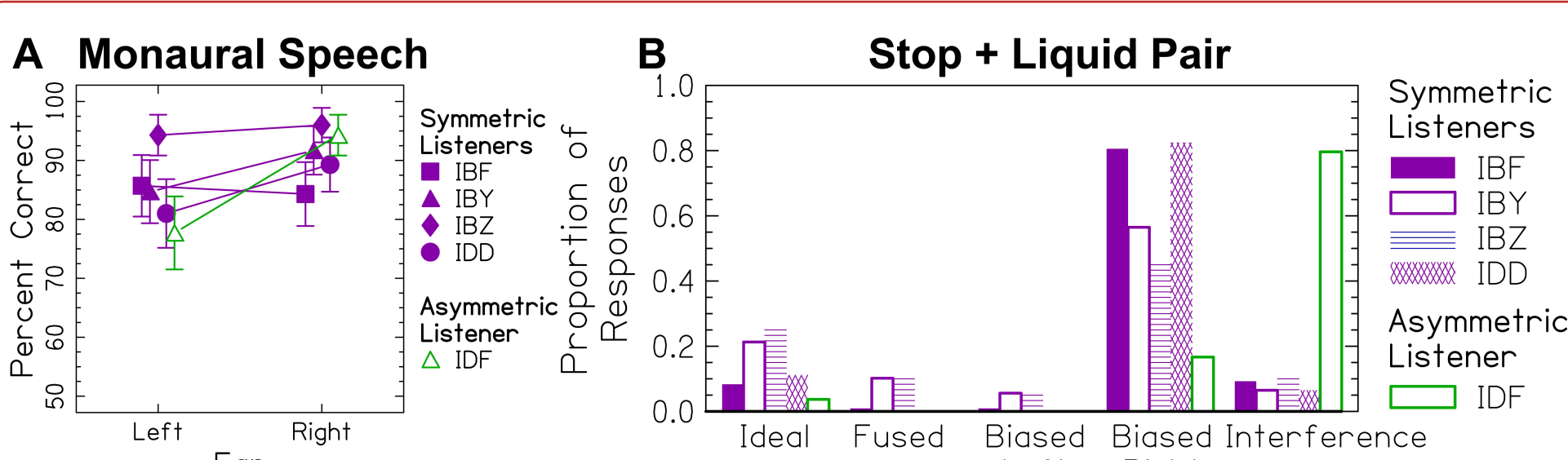


Fig. 6. Individual data from BiCI listeners, with symmetric or asymmetric speech understanding shown in purple and green, respectively. A. Error bars represent 99% confidence intervals. Listener IDF's confidence intervals did not overlap for the left and right ear. B. Response categories (see Fig. 4) shown by listener.

- One listener showed asymmetric speech understanding (Fig. 6A).
- Listeners with symmetric speech understanding were most likely to exhibit bias toward their right ear (Fig. 6B). This was the first-implanted ear for all listeners except IBY.
- Listener IDF with asymmetric speech understanding showed substantially more frequent interference (Fig. 6B).

Next Steps: Remote Testing

- Remote testing will be conducted with younger and older NH listeners.
 - Additional cognitive measures: list sorting working memory, pattern comparison processing speed, and flanker inhibitory control
- Experiments will be conducted in MATLAB in a quiet room in the lab or at the listener's home (Fig. 7).
- Experimenter is available in-person or for remote conference.

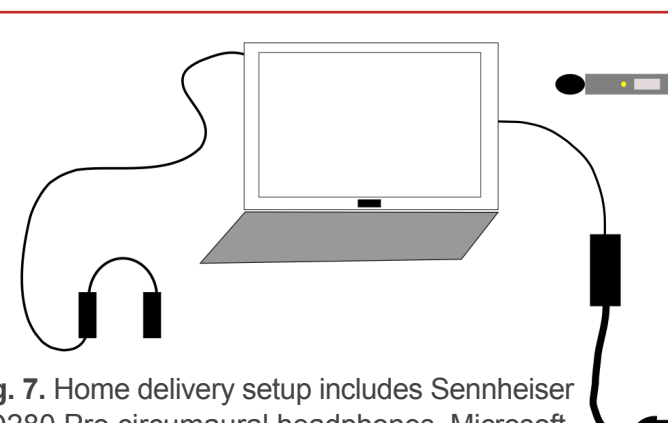


Fig. 7. Home delivery setup includes Sennheiser HD280 Pro circumaural headphones, Microsoft Surface, and dosimeter (to monitor background sound level).

Summary

- Asymmetric hearing outcomes result in poorer overall hearing outcomes, which could be due to poor segregation of sounds across the ears.
- Smaller dynamic range of vocoders in NH listeners, simulating poorer temporal resolution, resulted slightly worse speech understanding (Fig. 5A) and greater amounts of speech perception interference (Fig. 5B).
- BiCI listeners with symmetric speech understanding tend to show bias toward the right ear. The listener with asymmetric speech understanding experienced substantial speech perception interference (Fig. 6B).
- Together, results suggest that when speech understanding decreases slightly in one or both ears, listeners may experience poor segregation of speech across the ears.

References

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