Poster #T3

The Ability to Understand Interaural Alternating Speech is Intact in Some Bilateral Cochlear-Implant Listeners

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INTRODUCTION

- Speech perception for cochlear-implant (CI) users is compromised by degraded auditory input from CIs. As CI listeners age, declines in executive function such as attention and working memory add to the challenge, where central processing may be slower for understanding degraded speech.
- Cherry & Taylor (1954) first showed that when a single speech stream is continuously switching between two ears at varying rates, normal-hearing (NH) listeners' intelligibility demonstrated a V-shape function. That is, low and high interaural switch rates resulted best accuracy and mid-range rates poorer performances, with the worst at ~4 Hz. Stewart et al. (2008) showed that the rate at which performance dipped was not different for older adults, because there was no significant age × switch rate interaction.
- One working hypothesis suggests that interaural switch rate at ~4-5 Hz marks the boundary where listeners no longer selectively attend to a single ear, and beyond which they begin to fuse and form the percept of a single auditory stream (Culling & Mansell, 2013; Hauth & Brand, 2018).
- In this study, we used the interaural switch paradigm to explore factors that include peripheral degradation, aging, and executive functions in bilateral CI (BiCI) listeners and NH listeners.
- **Hypothesis & Predictions**: If either peripheral degradation or decline in executive functions slows down the processing of interaurally switching speech and limits the ability to attend to a single ear, the performance dip in BiCI listeners will be at a lower switch rate than NH listeners.

METHODS

Experimental Conditions

Dichotic: Auditory stream *alternated* between two ears at different switch rates 1, 2, 4, 6, 8, 12, 16, and 32 Hz, and a control condition of continuous stream in both ears ("no-switch")
Monotic: Auditory stream *interrupted* in one ear (silence in the other ear) at the same switch rates

Speech Stimulus & Tasks

- In each switch rate condition, verbally repeated 10 IEEE sentences. All stimuli low passed at 4000 Hz
- 8-channel log-spaced noise vocoder (200 to 4000 Hz)
- Cognitive measures
  - Screening: Montreal Cognitive Assessment (MoCA)
  - Executive functions (NIH Toolbox): Attention Switching, Working Memory, Inhibition and Processing Speed

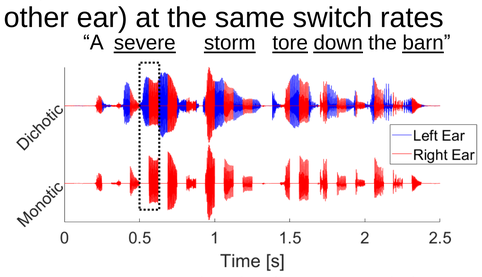

FIGURE 1. Sample stimuli at 8 Hz switch rate. Dashed box highlights a single switch cycle between ears (top) or within one ear (bottom).

Participants

- 17 BiCI users
- Listeners with NH (≤25 dB HL between 125 to 4000 Hz)
  - 18 Younger NH
  - 6 Older NH (all passed MoCA)

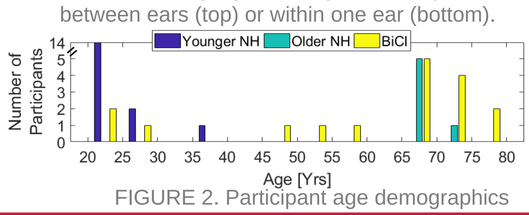

FIGURE 2. Participant age demographics

RESULT 1: Intelligibility vs. Switching Rate

FIGURE 3. Group average of intelligibility (RAU score) when a single auditory stream switched between two ears (a) and on/off in one ear. ∞ denotes no switching. For NH listeners, only right ear was measured in monotic listening. Error bar = ±1 standard error (SE).

Dichotic (Figure 3a): Auditory stream *alternated* between ears

- In NH listeners, both groups of NH adults reached ceiling performance when listening to unprocessed stimuli switching between two ears
- However, when listening to vocoded speech switching between ears, intelligibility showed a U-shape function with poorest performance at switch rate = 4 Hz. Overall, younger NH listeners performed better than older NH listeners. Interaction between age × switch rate was not significant ($p > .05$)
- BiCI listeners had similar intelligibility trend as NH listeners along different switch rates

Monotic (Figure 3b): Auditory stream *interrupted* in one ear

- BiCI users showed generally better intelligibility in the *right* ear at switch rate ≥ 12 Hz
- BiCI listeners shared similar trend as younger NH adults (when listening to vocoded speech) along various switch rates. Shallower U-shape function than in the dichotic conditions (a) than monotic conditions (b) for all three groups

RESULT 2: Binaural Benefits

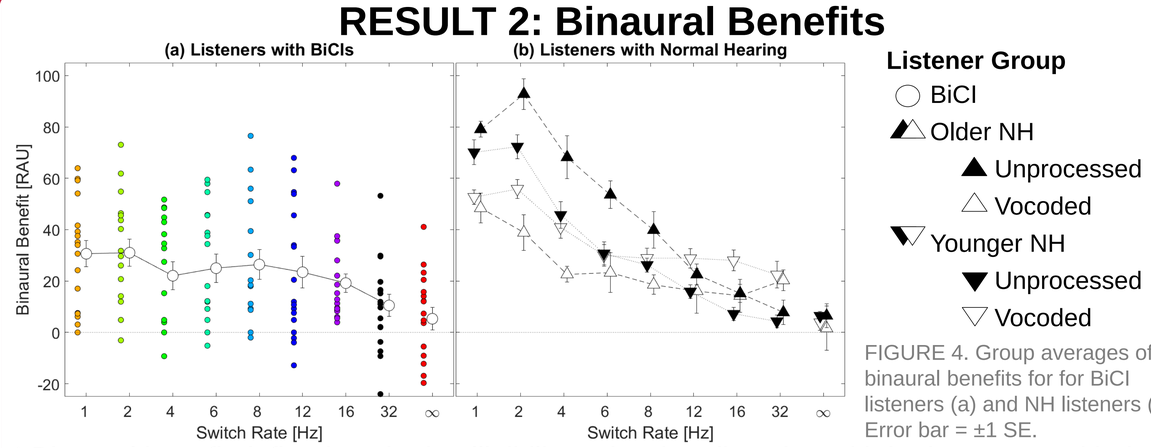

FIGURE 4. Group averages of binaural benefits for for BiCI listeners (a) and NH listeners (b). Error bar = ±1 SE.

- Binaural benefit defined as the intelligibility gain when listening with both ears vs. with the better ear only for BiCI users (Figure 4a) and with right ear only for NH listeners (Figure 4b)
- Benefit decreased as switch rate increased for BiCI listeners [b=-.61, t(119)=-4.5, p<.001] and for NH listeners when listening to vocoded speech [b=-.59, t(425)=-7.0, p<.001]
- Older NH listeners received larger binaural benefits than the younger NH group in unprocessed speech, but smaller benefits when listening to vocoded speech (Figure 4b)

RESULT 3: Individual Variability in BiCI Listeners

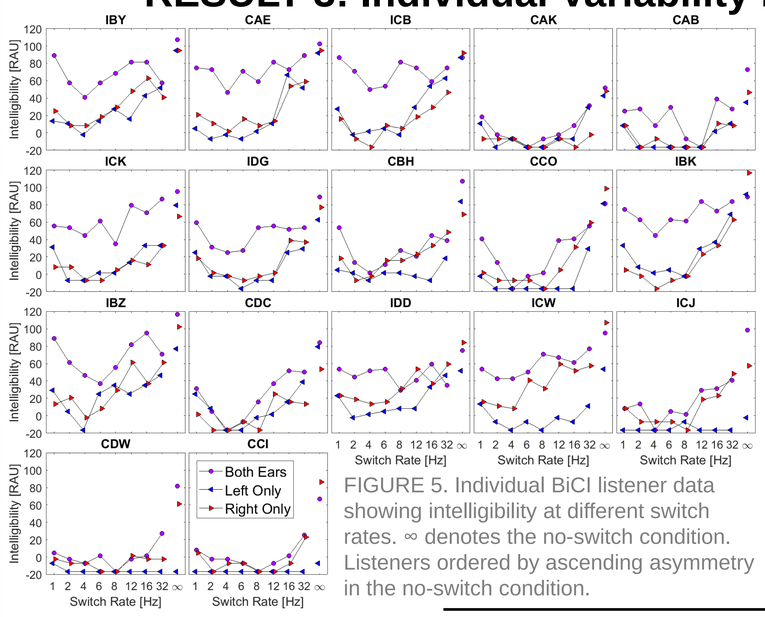

FIGURE 5. Individual BiCI listener data showing intelligibility at different switch rates. ∞ denotes the no-switch condition. Listeners ordered by ascending asymmetry in the no-switch condition.

- Large individual variability among BiCI users when speech stream switching between ears; many listeners had binaural benefit and R/L asymmetry (defined as |R-L| in RAU score)
- Some listeners (e.g., CAK, CCI, CDW) scored <10% across different switching rates, but with good intelligibility when no switching occurred
- Binaural benefit negatively predicted by both *poorer ear performance* [b=-.37, t(143)= -7.2, p<.0001] and *asymmetry* [b=-.27, t(143)=-3.2, p=.0017]

FIGURE 6. Descriptive statistics for cognitive measures in YNH and BiCI groups. Error bar = +1 standard deviation (SD). Normative mean = 100, SD = 15.

Dependent Measure	Cognitive Measure	Listener Group: BiCI	Listener Group: Younger NH (Vocoded)
Dichotic Intelligibility (Switch Rate < ∞)	Attention Switching	n.s.	***p* = .032**
	Working Memory	n.s.	n.s. (p = .051)
	Inhibition	n.s.	n.s.
	Processing Speed	n.s.	n.s.
Binaural Benefit (Switch Rate < ∞)	Attention Switching	n.s.	***p* = .0095**
	Working Memory	n.s.	n.s.
	Inhibition	n.s.	***p* = .029**
	Processing Speed	n.s.	n.s.

TABLE 1. Effect of executive functions on intelligibility and binaural benefits for younger NH and BiCI listeners. Each cognitive measure was entered individually as a fixed effect in addition to switch rate (fixed effect) and listeners (random effect) to predict the dependent measure. n.s. = p>.05.

- BiCI listeners scored similarly on cognitive measures as younger NH adults (older NH adults cognitive data to be analyzed)
- Executive functions did not seem to explain BiCI listeners' accuracy or binaural benefit in understanding interaurally alternating speech
- In younger NH listeners, attention switching predicted both intelligibility and binaural benefit. It suggests that peripheral degradation (vocoded vs. unprocessed speech) may involve more executive functions during processing

CONCLUSIONS

- Peripheral degradation did not seem to slow down the processing of interaurally switching speech. Performance dip always at 4 Hz in all three groups of listeners (Figure 3a)
- BiCI users share similar trend of intelligibility and binaural benefit in different switch rates as NH listeners when listening to vocoded speech (Figures 3 & 4)
- Peripheral degradation seemed to involve more selective attention among younger NH listeners, but such effect of executive functions was not found among CI users (Table 1)

REFERENCES

1. Cherry, E. C., & Taylor, W. K. (1954). Some further experiments upon the recognition of speech, with one and with two ears. *The Journal of the Acoustical Society of America*, *26*(4), 554-559.
2. Stewart, R., Yetton, E., & Wingfield, A. (2008). Perception of alternated speech operates similarly in young and older adults with age-normal hearing. *Perception & psychophysics*, *70*(2), 337-345.
3. Culling, J. F., & Mansell, E. R. (2013). Speech intelligibility among modulated and spatially distributed noise sources. *The Journal of the Acoustical Society of America*, *133*(4), 2254-2261.
4. Hauth, C. F., & Brand, T. (2018). Modeling sluggishness in binaural unmasking of speech for maskers with time-varying interaural phase differences. *Trends in hearing*, *22*, 2331216517753547.
5. Rossetti, H. C., Lacritz, L. H., Cullum, C. M., & Weiner, M. F. (2011). Normative data for the Montreal Cognitive Assessment (MoCA) in a population-based sample. *Neurology*, *77*(13), 1272-1275.
6. Zelazo, P. D., Anderson, J. E., Richler, J., Wallner-Allen, K., Beaumont, J. L., & Weintraub, S. (2013). II. NIH Toolbox Cognition Battery (CB): Measuring executive function and attention. *Monographs of the Society for Research in Child Development*, *78*(4), 16-33.

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