Poster #T35b

Investigating Binaural Sensitivity with Clinical Processors by Analyzing Eye Gaze Behavior

Z. Ellen Peng, Alan Kan, Ruth Litovsky
University of Wisconsin-Madison, USA
e-mail: z.ellen.peng@wisc.edu

Binaural Hearing and Speech Laboratory

Conference on Implantable Auditory Prostheses
Lake Tahoe, CA
July 16-21, 2017

INTRODUCTION

- ❖ Sensitivity to **interaural time and level differences** (**ITD** and **ILD**, respectively) is typically estimated as the just-noticeable-difference (JND) at a specific performance level (e.g., 70.7% correct) without information on the decision-making process. Listeners with bilateral cochlear implants (BiCI) typically have much higher JNDs than normal-hearing (NH) listeners as measured using clinical processors. [1]
- ❖ A novel method is introduced by providing acoustic stimuli through **clinical processors** that capitalize on the *Advanced Combinational Encoder (ACE)* strategy to provide ILD and envelope ITD in a conventional left/right discrimination task, while simultaneously recording **eye gaze behavior**
- ❖ Previous work has shown that eye gaze on screen in time-course trajectories can provide inferences on NH listeners' decision-making process prior to providing responses [2,3]
- ❖ The present study attempts to explore subtle differences between BiCI and NH listeners in sensitivity to ITD/ILD, beyond JNDs as revealed by eye gaze patterns

Study Aims

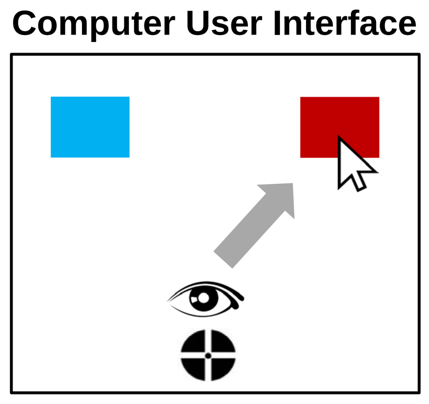
(1) Measure sensitivity to ITD and ILD in BiCI listeners using clinical processors with the ACE strategy
(2) Investigate eye gaze behavior in BiCI and NH listeners, using stimuli with increasing saliency in binaural cues (ITD and ILD)

METHODS

Task: Left/Right Discrimination

- ❖ 2-Interval, 2-alternative forced-choice
- ❖ Method of constant stimuli (30~40 repetitions per cue level)
- ❖ ITD: Whole waveform shift in either ear, available in the envelope
- ❖ ILD: Half-intensity offset between ears up to +3 dB, then full-intensity attenuation in one ear

Computer User Interface



METHODS (Cont.)

Stimulus: Complex of 8 transposed tones designed to provide high fidelity envelope ITD cues through the ACE strategy on Cochlear N5 processors [4]

- ❖ BiCI: Complex targeting N5 electrodes No. 4-11 with everyday clinical maps; Playback via auxiliary input ports at listeners' chosen comfortable level
- ❖ NH: Complex targeting similar places of stimulation along the cochlea as BiCI listeners [5]; Playback via Sennheiser HD600 headphones at 60 dBA sound pressure level (re 20 µPa)

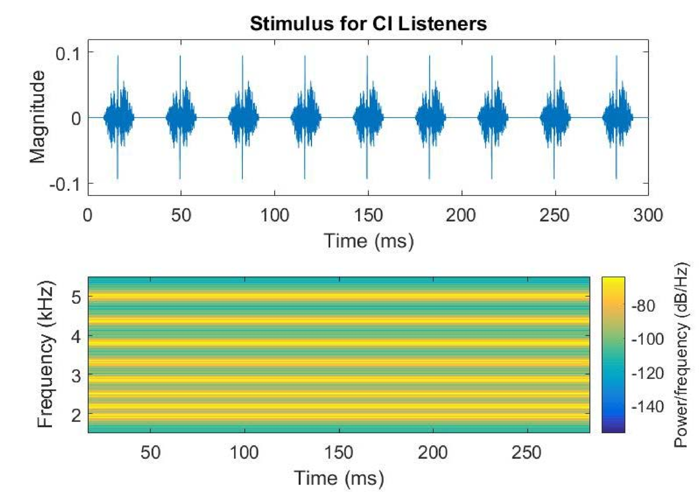


Figure 1. Waveform (upper panel) and spectrogram (lower panel) of an example transposed tone complex created with 8 center frequencies (f_c) matching those of electrodes No. 4-11 in the default 22-channel frequency allocation table (FAT) for Cochlear N5 processor. Each transposed tone was modulated at 30 Hz before summing in the time domain to create a tone complex. Individual BiCI listeners' transposed tone complexes were created based on actual FATs from their clinical processors.

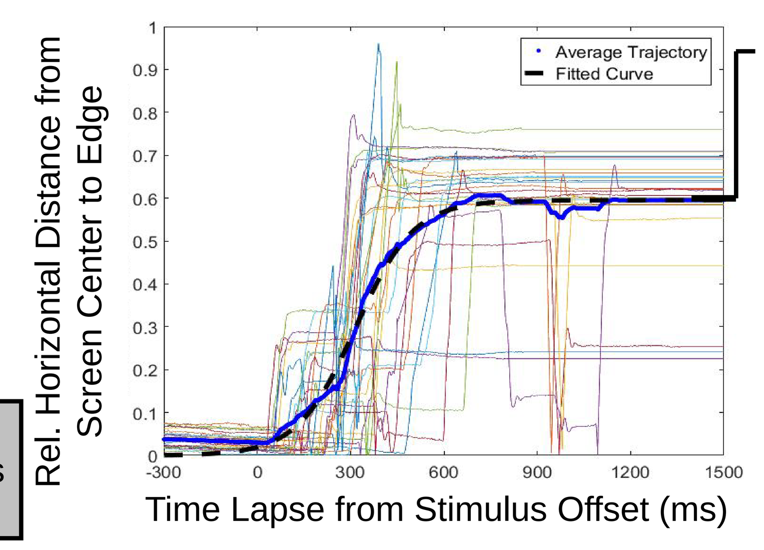
Participants

- ❖ BiCI: 5 listeners, most had measured ITD JNDs in the past with pitch-matched single-pair electrodes through direct stimulation at 100 pulses/second (pps)
- ❖ NH: 3 listeners, aged 19-22 years

BiCI Listener ID	Age (Yr)	Age at Onset of Hearing Loss (Yr)	BiCI Use (Yr)	Etiology	Pulse Rate (pps), Pulse Width (µs)	ITD JND (µs) measured from single-electrode pair at100 pps
IAU	68	Birth	11	Hereditary	900 pps, 25 µs	(no data)
ICB	66	9	11.5	Hereditary	1800 pps, 25 µs	L4-R4: 199 µs L12-R12: 193 µs
ICP	54	3	5.2	Nerve damage	500 pps, 25-75 µs	L4-R8: 129 µs L12-R14: 134 µs
IDD	19	Birth	9	Hereditary	1200 pps, 25 µs	L4-R2: > 2500 µs L12-R11: 1351 µs
CIEV	16	Birth	5	Hereditary	1200 pps, 25 µs	L12-R14: 962 µs

Behavioral Data Collected Simultaneously

- ❖ *Left/Right Response*: Provided by listeners with mouse-click; To obtain JND by calculating performance in varying cue levels and fitting psychometric function
- ❖ *Eye Gaze Data*: Time-course eye gaze position during individual trials prior to listener response (correct only); To infer listeners' looking behavior in responding to varying cue levels (Example fit in Figure 2)



Fitting Equation [6]

$$\frac{Maximum}{1+e^{-\left(\frac{Time-\alpha}{\beta}\right)}}$$

α: Linear offset at 75%
β: Inversed slope of linear rise

Figure 2. Example curve fitted to a participant's gaze trajectories, who was tested at an ITD (60 µs) nearest JND. Only correct trials are included to perform model fit. All model fits $R^2 > 0.9$.

RESULTS

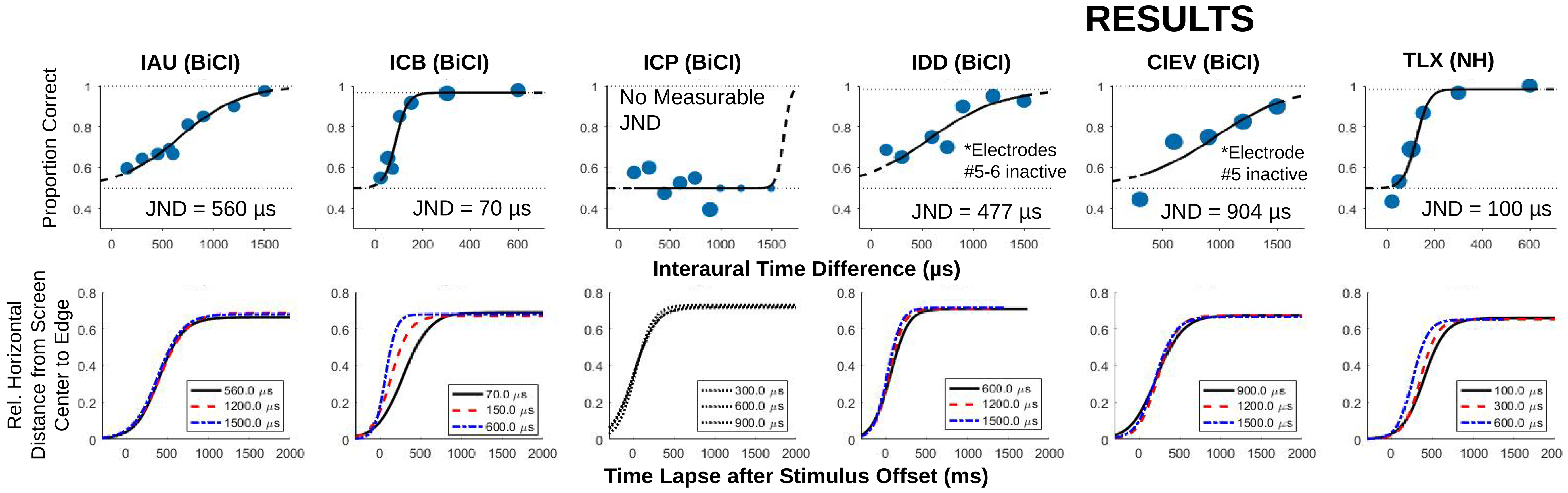


Figure 3. Individual listener data showing proportion correct (upper panels) from L/R responses in the ITD discrimination task. Individual listener's average gaze trajectories are plotted (lower panels) for ITD JND and two ITDs with proportion correct above 0.9. Only correct responses are included to perform model fit. NH listeners showed similar psychometric functions and gaze trajectories; only one typical NH listener (TLX) data is shown. ITD JNDs for TLP and TLW (NH listeners) were 47 µs and 48 µs, respectively.

- ❖ ITD JNDs were measured in 4 of 5 BiCI listeners using clinical processors. One BiCI listener (ICB) showed ITD JND within the range of measured JNDs from NH listeners (Figure 3).
- ❖ As the ITD became more salient, a general trend of decreasing α and increasing slope (1/β) occurred in NH and some BiCI listeners (Figure 4)

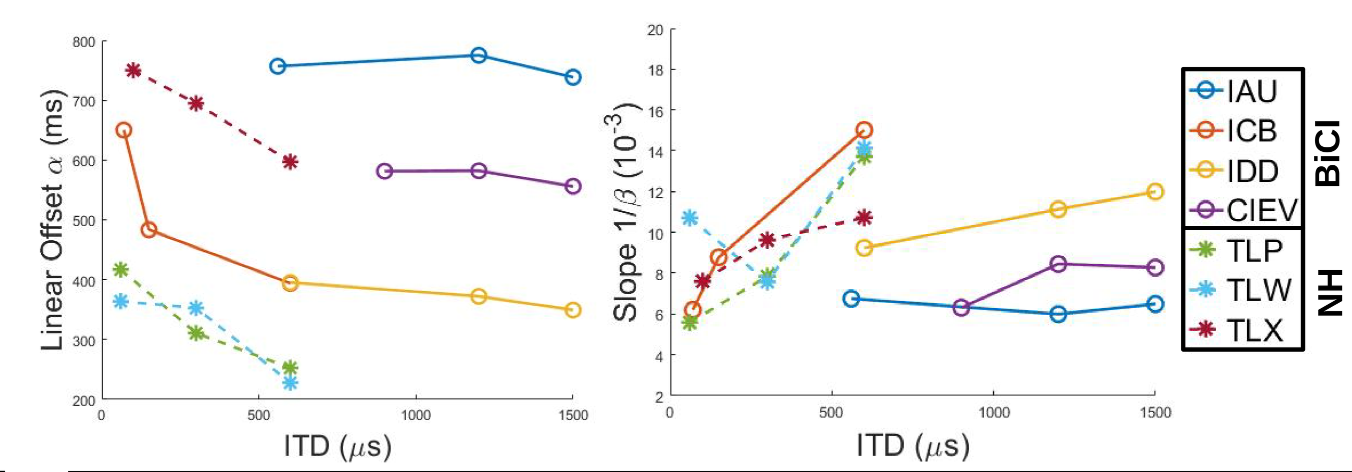


Figure 4. Fitted curve parameter estimates α & 1/β as a function of increasing magnitude in ITD from JND to the two ITDs above 0.9 proportion correct for individual listeners. BiCI listeners in solid lines; NH listeners in dash lines.

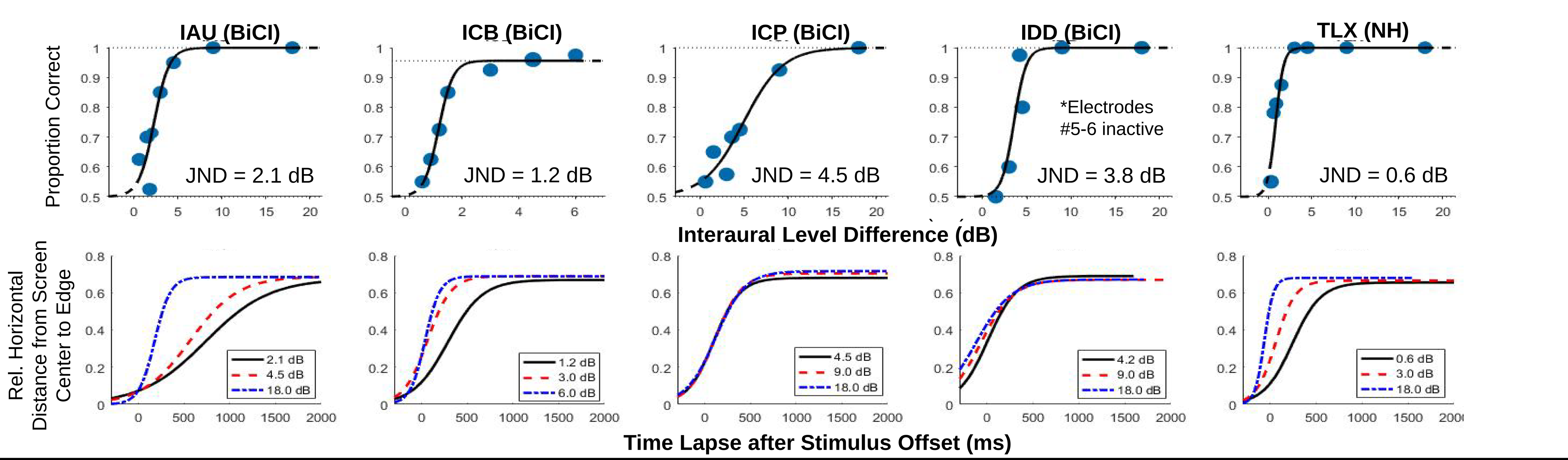


Figure 5. Individual listener data showing proportion correct (upper panels) from L/R responses in the ILD discrimination task. Individual listener's average gaze trajectories are plotted (lower panels) for ILD JND and two ILDs with proportion correct above 0.9. Only correct responses are included to perform model fit. One typical NH listener's (TLX) data is shown; ILD JNDs for TLP and TLW (NH listeners) were 0.4 dB and 0.5 dB, respectively.

- ❖ ILD JNDs were measured in all BiCI listeners (Figure 5)
- ❖ As the ILD became more salient, a general trend observed in decreasing α and increasing slope (1/β) in NH and some BiCI listeners (Figure 6)

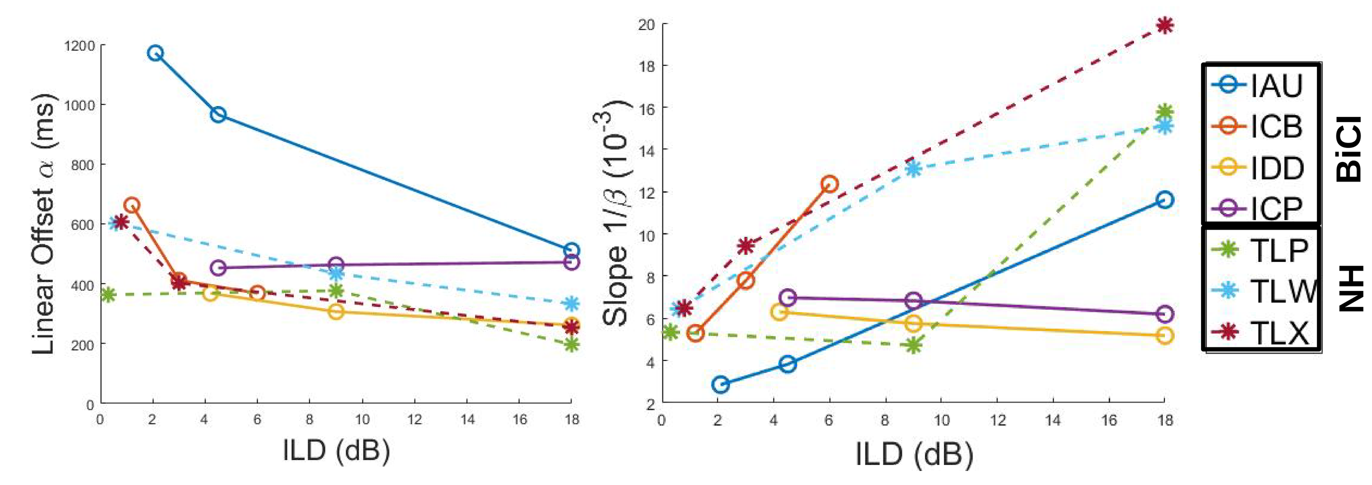


Figure 6. Fitted curve parameter estimates α & 1/β as a function of increasing magnitude in ILD from JND to the two ILDs above 0.9 proportion correct for individual listeners. BiCI listeners in solid lines; NH listeners in dash lines.

CONCLUSION, DISCUSSION & FUTURE WORK

- ❖ ITD JNDs were measured in BiCI listeners using clinical processors with a typical clinical stimulation rate (e.g., ≥ 900 pps), when a matched set of electrodes across ears were activated
- ❖ As binaural cue saliency improves, even beyond the magnitudes of JND, an emerging trend is observed that both NH and some BiCI listeners show steeper slope in the eye gaze trajectories and are faster at reaching the 75% location to the final gaze position
- ❖ The difference in eye gaze patterns between BiCI and NH listeners is not yet clear; ongoing data collection

REFERENCES

1. Laback, B., Pok, S. M., Baumgartner, W. D., Deutsch, W. A., & Schmid, K., "Sensitivity to interaural level and envelope time differences of two bilateral cochlear implant listeners using clinical sound processors," Ear and hearing, **25,** 488-500 (2004).
2. Winn M. B., A., Litovsky, R. Y., "Temporal dynamics and uncertainty in binaural hearing," in preparation.
3. Peng, Z. E., Fields, T., & Litovsky, R., "Investigating processing delay in interaural time difference discrimination by normal-hearing children," J. Acoust. Soc. Am. **141**, 3634-3634 (2017).
4. Kan, A., Bergal, J., Peng, Z. E., Moua, K., & Litovsky, R. Y., "Measuring the ability of clinical processors to encode binaural cues in the signal envelope," 2017 Conference on Implantable Auditory Prostheses, Lake Tahoe, CA.
5. Greenwood, D. D., "A cochlear frequency-position function for several species—29 years later," J. Acoust. Soc. Am. **87**, 2592-2605 (1990).
6. Wichmann, F. A., & Hill, N. J., "The psychometric function: I. Fitting, sampling, and goodness of fit," Attention, Perception, & Psychophysics, **63**, 1293-1313 (2001).

ACKNOWLEDGEMENTS

The authors thank Shelly Godar for audiological assistance on this study and Dr. Matt Winn for feedback. Work supported by NIH-NIDCD (R01DC003083 & R01DC008365 to RYL; R03DC015321 to AK) and in part by NIH-NICHD (U54HD090256) to the Waisman Center

Printing courtesy of the Friends of the Waisman Center