Poster # T4

Sensitivity to binaural cues in normal hearing children and children who use cochlear implants

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Introduction

•Binaural hearing provides a listener with cues that aid in sound localization, namely inter-aural time and level differences (ITDs and ILDs). In addition, ITDs in the envelopes of modulated high frequency carriers may also be important.
•Although patients with bilateral cochlear implants (BiCIs) are known to have improved sound localization abilities compared to single CI-use, children with BiCIs still perform notably poorer than their normal hearing (NH) peers (Grieco-Calub and Litovsky, 2010).
•One reason for this gap in performance is that CI speech processing alogrithims discard the detailed temporal structure of the original sound, making it difficult to gain access to ITD cues.
•A second reason is that pre-lingually deafened children also lack early access to acoustic binaural input during particularly important developmental years, therefore their auditory system may be insensitive to binaural cues.
•The aim of this study was to investigate the sensitivity of children who use BiCIs to ITDs and ILDs and to compare their sensitivities to NH children participating in a CI simulation.

Methods

Participants

•Eight children with bilateral Cochlear Nucleus devices (Nucleus 24, Freedom, N5) participated in three experiments.
•Eleven NH children (ages 8-10 yrs) participated in similar tasks while listening to CI simulations using vocoders.

Table 1: BiCI Information

BiCI Subjects (n=8)	Sex	Age (yrs)	Early Acoustic Hearing (mos)	Age at 1st implant (mos)	Bilateral Experience (yrs, mos)
CIAG	M	12	--	21	9, 3
CIAW	M	11	--	15	6, 5
CIAY	M	12	42	62	6, 9
CIDJ	F	10	--	19	5, 1
CIEB	F	11	19	43	7, 3
CIEC	M	9	--	28	7, 2
CIEU	F	13	Progressive	51	3, 9
CIFF	M	10	--	13	4, 7

Stimuli

•A 300 ms, constant amplitude, 100 pulses per sec (pps) pulse train with a 25µs pulse width was presented at a self-reported comfortable loudness level.
•Stimuli were presented via a bilaterally synchronized pair of Nucleus Implant Communicators (NICs)
•NH children listened to a Gaussian Enveloped Pulse Train (4kHz center frequency, 100pps) via Etymotic ER-2 headphones.

Procedure

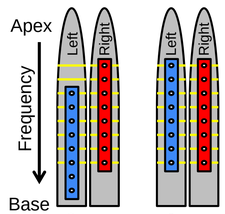
•Subjects' threshold, comfortable, and most comfortable levels were measured through the NICs.
•A pitch-matched pair was found via pitch magnitude estimation and direct pitch comparison.
•NH subjects and subjects with BiCIs both completed lateralization and discrimination tasks. Children with BiCIs completed the tasks using the pitch-matched pair.

Table 2: Electrode pairs tested for each subject (Left/Right)

CIAG	CIAW	CIAY	CIDJ	CIEB	CIEC	CIEU	CIFF
12/10	14/16	12/12	12/12	12/12	12/14	14/14	14/14

Experiment 1: Pitch Matched Pairs

Methods



•Selection of pitch-matched pairs was a two step process.
  •Pitch Magnitude Estimation: subjects were asked to rank pitch of interaural electrodes along a scale of 1-100.
  •Direct Pitch Comparison: subjects were asked to compare pitch of interaural electrodes for Δ 0, Δ 2, and Δ 4. Subjects had to report whether the second sound was the same, higher, much higher, lower, or much lower in pitch than the first sound.
•Electrode pairs were chosen based off the best pitch matched pairs in order to attempt to control for interaural mismatch.

Figure 1: Diagram showing interaural mismatch. Electrode locations on unrolled cochleae shows mismatched spectral shifts.

Results

Pitch Magnitude Estimation:

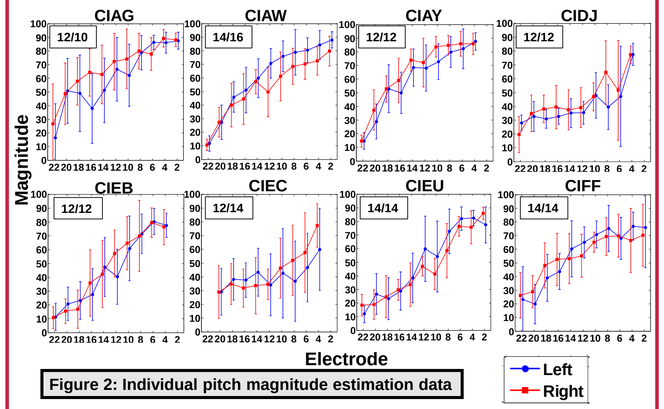


Figure 2: Individual pitch magnitude estimation data

•Subjects were able to rank pitch along the full scale of 1-100, as seen in Fig. 2. However, there was a large variability within and between subjects. For example, subject **CIAW** is able to use the full scale, whereas subject **CIEC** only uses 30-78. Pitch matched electrodes were chosen based off of the electrode numbers that were ranked closest in pitch between ears.

Direct Pitch Comparison:

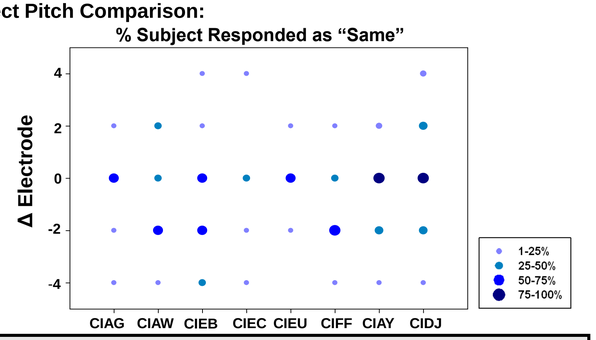
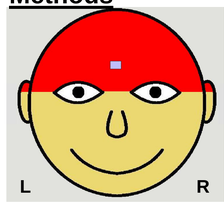


Figure 3: Percent the subject responded to interaural electrodes as "same"

•Δ 0 is defined as stimulation of the same electrode in each ear. For example, for a subject with a chosen pair of 12/14, Δ 0 would be 12/12. Negative numbers represent electrodes closer to the apex.

Experiment 2: Lateralization

Methods



•Subjects were asked to report the perceived lateral position of the stimuli by clicking a position in the red zone of Fig. 4. Testing was completed using the pitch-matched pair found in Exp. 1.
•Subjects were given 20 repetitions of the following conditions for all three stimuli.
  •ITD Conditions
    •0, ± 50 100, 200, 400, 800, 1600 µs
  •ILD Conditions
    •0, ± 1, 2, 5, 10, 20 current units (CU)

Figure 4: Graphical user interface used to capture the perceived lateral position of the stimuli.

BiCI Results

ILDs:

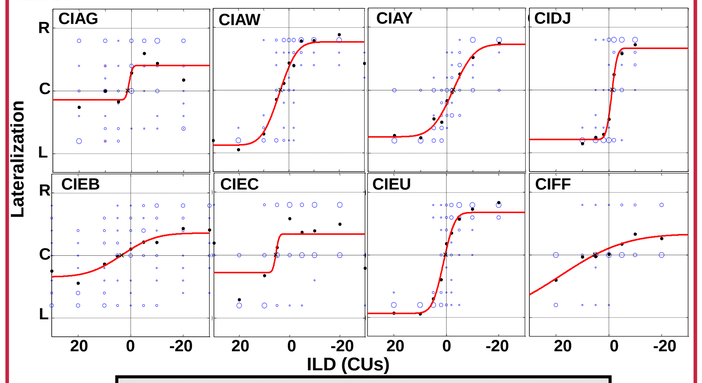


Figure 5: Individual ILD Lateralization Data for subjects with BiCIs

ITDs:

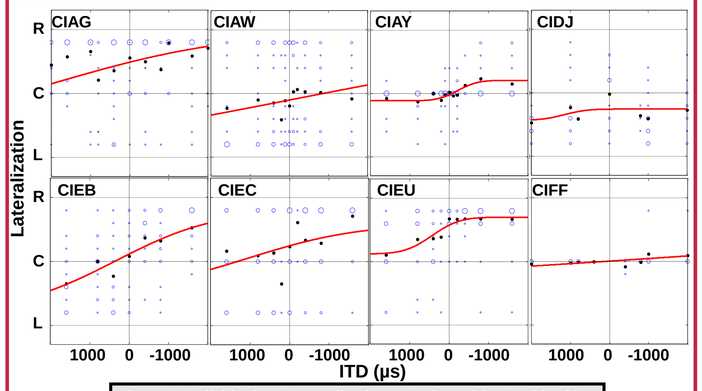
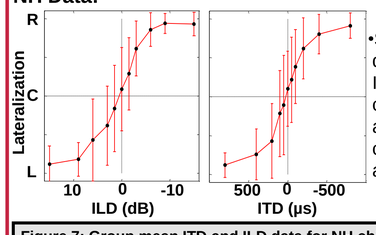


Figure 6: Individual ITD Lateralization Data for subjects with BiCIs

NH Data:



•Some children with BiCIs are able to distinguish lateral positions when given ILDs, similar to that observed for NH children. However, children with BiCIs are unable to perceive a systematic change in the lateral location of an auditory image as a function of ITD.

Figure 7: Group mean ITD and ILD data for NH children

Experiment 3: Discrimination

Methods

•Subjects were asked to report whether the the sound moved to the right or to the left.
•An adaptive two down, one up track was used, where the last of 6 reversals were averaged to determine the subjects' just noticeable difference (JND) for ITDs and ILDs.

ILDs:

•JNDs were measurable for all children who use BiCIs. NH children showed lower JNDs than the children who use BiCIs.

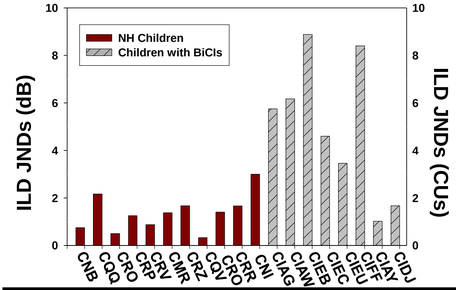


Figure 9: ILD JNDs for NH subjects and subjects with BiCIs

ITDs:

•JND measurement was attempted with all children who use BiCIs but **CIEU** and **CIAY** were the only subjects with measurable JNDs. **CIEU** and **CIAY** had higher JNDs than their NH peers. For both ITD and ILD cues, NH children performed similarly to adults (Kan et al., 2011).

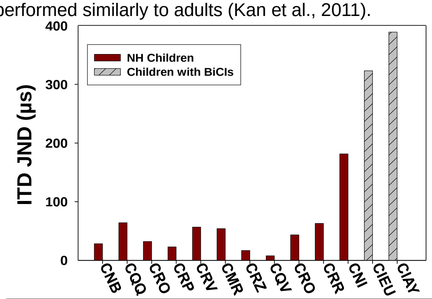


Figure 10: ITD JNDs for NH subjects and subjects with BiCIs

Conclusions

•Using research processors on a pair of pitch-matched electrodes, children with BiCIs show some ability to differentiate lateral positions using ILDs. In contrast, their ability to use ITDs is not well developed.
•Children with BiCIs show sensitivity to ILDs on tasks of discrimination with all subjects having measurable JNDs. ITD sensitivity was measurable in only two subjects that both had early exposure to normal acoustic hearing.
•In NH children, with stimuli that mimic the processing of cochlear implants, performance was comparable to NH adults.
•This suggests that the lack of ITD sensitivity in pre-lingually deafened children who use BiCIs may be due to the lack of access to fine binaural timing information that is necessary during the early years of life.

ACKNOWLEDGEMENTS

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Grieco-Calub, T.M., &Litovsky, R.Y. (2010). Sound localization skills in children who use bilateral cochlear implants and in children with normal acoustic hearing. Ear Hear. 31(5): 645-656.
Kan, A., Stoelb, C., Goupell, M.J., Litovsky, R.Y. "*Effect of Mismatched Place-of-Stimulation on Binaural Sensitivity in Bilateral Cochlear Implant Users*", Presented at the Conference on Implantable Auditory Prostheses, CIAP 2011, Pacific Grove, CA, July 2011.