PS-234

Sensitivity to Interaural Level Differences is More Prevalent Than Interaural Timing Differences in Children Who Use Bilateral Cochlear Implants

Erica Ehlers*, Shelly Godar, Alan Kan, Ann Todd, & Ruth Litovsky
University of Wisconsin-Madison, USA
e-mail: eehlers@wisc.edu

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Introduction

•Spatial hearing tasks depend on access to binaural cues, such as interaural time and level differences (ITDs and ILDs). Binaural hearing provides reliable access to these cues in normal hearing (NH) listeners. However, for people who use bilateral cochlear implants (BiCIs) these cues are mostly inaccessible, even when they are fit bilaterally.
•Due to the nature of cochlear implant sound processing, children with BiCIs are not exposed to ITDs on a daily basis and ILDs are present but less salient than in a NH system.
•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.
•Finally, to optimize binaural sensitivity, pitch-matched electrode pairs should be used in order to stimulate the same anatomical region on the cochlea (Kan et al, 2013), something that is not taken into account in clinical mappings.
•As little is known about binaural abilities in this population, the aim of this study was to investigate pitch matching abilities and ITD/ILD sensitivity in children with BiCIs.

Methods

Participants

•16 children with bilateral Cochlear Nucleus devices (CI24, CI512) participated in three experimental tasks.
•6 were tested on only a single pair, 7 were tested on multiple pairs (base, middle, and apex) and 4 were tested twice, on both a single pair and multiple pairs.

Table 1: Participant Characteristics

Subjects	Sex	Age at first test (yrs)	Age of ID (mos)	Age at 1st implant (mos)	BiCI Exp. (yrs, mos)	Single Pair (L/R)	Multi. Pairs Base, Mid, Apex
CIAW	M	12	2	15	6,5	14/16	N/A
CIEB	F	11	19	43	7,3	12/12	N/A
CIDX	M	10	birth	29	8,2	12/12	N/A
CIEV	F	11	birth	32	2,0	14/14	N/A
CIFF	M	10	1	13	4,7	14/14	N/A
CIEC	M	9	birth	28	7,2	12/14	N/A
CIEU	F	13	6	51	3,9	14/14	4/4, 12/12, 18/18
CIAG	M	12	birth	21	9,3	12/10	4/4, 12/12, 20/18
CIAY	M	12	36	62	6,9	12/12	DNT, 12/12, 20/18
CIDJ	F	10	12	19	5,1	12/12	6/6, 12/12, 20/16
CIAP	F	14	16	42	9,7	N/A	4/4, 12/12, 20/16
CIBK	M	15	17	26	8,1	N/A	4/4, 12/12, 20/18
CIBO	F	14	25	34	10,4	N/A	4/4, 12/12, 20/18
CIDQ	F	12	birth	46	7,11	N/A	4/4, 12/12, 20/20
CIEH	M	9	birth	13	8,0	N/A	4/6, 12/14, 20/20
CIAQ	M	17	14	48	9,4	N/A	4/4, 12/13*, 20/19*

Stimuli

•A 300 ms, constant amplitude, 100 pulses per second (pps) pulse train with a 25 µs pulse width was presented at a self-reported comfortable loudness level.
•Stimuli were presented via a bilaterally synchronized pair of L34 Speech Processors (Cochlear Ltd).

Procedure

•Subjects' threshold, comfortable, and most comfortable levels were measured through the research processors for even numbered electrodes.
•Pitch-matched pairs were found via pitch magnitude estimation and pitch comparison. The pairs were then used, one at a time, for the discrimination task.

Experiment 1: Pitch Magnitude Estimation

Methods

•Subjects were asked to rank pitch of interaural electrodes along an arbitrary scale of 1-100. This was completed in order to estimate the degree of perceived interaural pitch mismatch occurring.

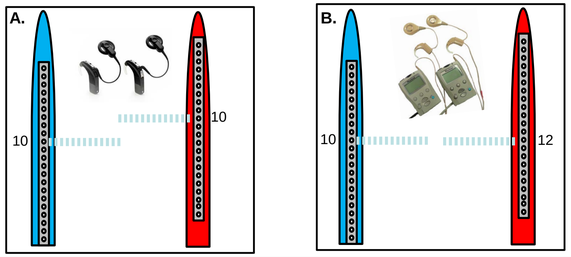


Figure 1A: Electrode arrays inserted at different depths between the ears, causing interaural frequency mismatch when using clinical processors. Figure 1B: Electrodes at the same insertion depth, matched for pitch when using research processors.

Results

Figure 2: Individual pitch magnitude estimation data

•Most 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 on average. Results from the pitch magnitude estimation task guided the selection of which pairs to use for the direct pitch comparison task.

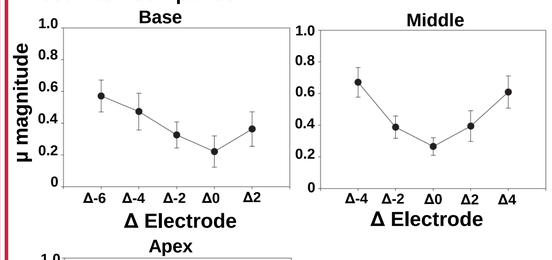
Experiment 2: Pitch Comparison

Methods

•Subjects were asked to compare pitch of interaural electrodes for Δ0, Δ2, and Δ4, where Δ0 is defined as stimulation of the same numbered electrode in each ear. Negative numbers represent electrodes closer to the apex. For example, Δ-2 would be 12 (left)/14 (right).
•An electrode from each ear was stimulated sequentially. The subject had to report whether the second sound was the "same", "higher", "much higher", "lower", or "much" lower in pitch than the first sound.
•The metric, µ, was calculated by giving the above responses values of 2, 1, 0, -1, and -2, respectively and summing together (Kan et al, 2015).

Results

Direct Pitch Comparison:



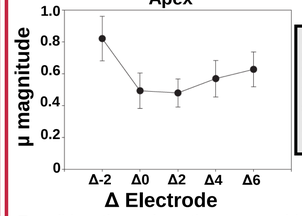


Figure 3: Average change in the metric, µ as a function of mismatch is shown. A value of 0 indicates that the pitch was perceived as the same across ears. Larger values of µ imply that the pitch was perceived as increasingly different.

•For all locations along the array, subjects most frequently reported Δ0 as sounding the same. However, there was high variability on this task between subjects.

Chosen Electrode Pairs:

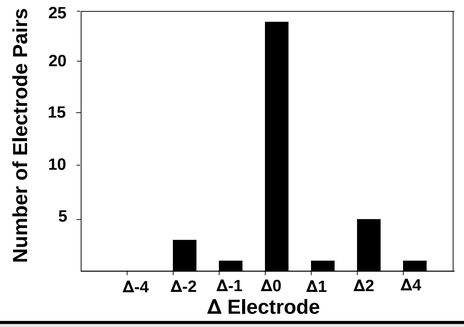


Figure 4: Amount of interaural mismatch for chosen electrode pairs.

•The results of the pitch comparison task are reflected in the chosen electrode pairs.
•The majority of subjects had small or no amounts of interaural mismatch as indicated by the higher number of electrode pairs with Δ0.
•The two pairs with Δ-1 and Δ1 were from the same subject. For this subject odd-numbered electrodes were used as the subject required several even-numbered electrodes be turned off (pairs indicated with a * in Table 1).

Experiment 3: ITD/ILD Discrimination

Methods

•Discrimination Just Noticeable Differences (JNDs) were measured using a method of constant stimuli. ITD values tested were ± 100, ± 200, ± 400, and ± 800 µs and ILD values were ± 2, ± 5, ± 10, and ± 15 CUs, although these varied for some subjects depending on their sensitivity to these cues.
•Subjects were asked to report whether the sound moved to the right or to the left.

ILDs:

•Although the JNDs were highly variable, all subjects tested showed measureable ILDs.

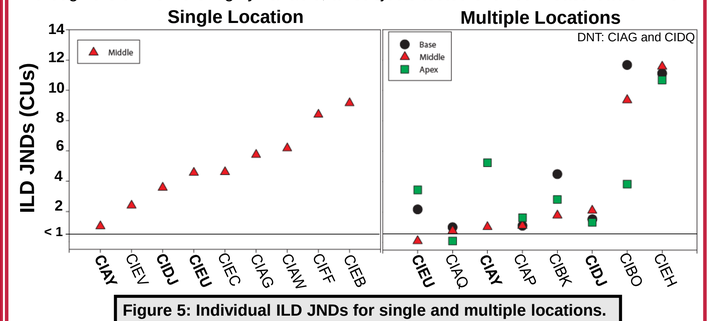


Figure 5: Individual ILD JNDs for single and multiple locations. Subjects in bold completed both visits.

ITDs:

•An ITD JND of >1,600 µs was deemed unmeasurable. Contrary to ILD sensitivity, the majority of subjects did not have measureable ITD JNDs. Additionally, some subjects only demonstrated ITD sensitivity at one place along the electrode array (e.g. CIEU and CIAG).

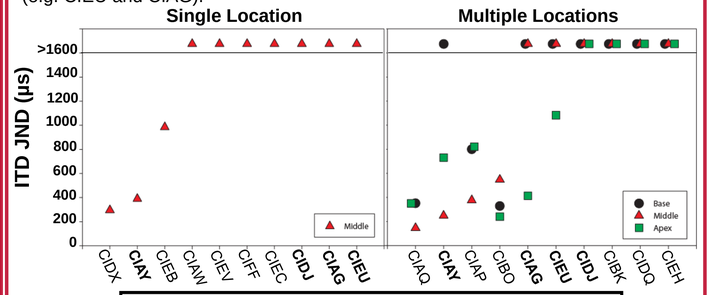


Figure 6: Individual ITD JNDs for single and multiple locations. Subjects in bold completed both visits.

Conclusions

•Lack of interaural pitch mismatch in pre-lingually deafened children could be due to pitch perception learned through clinical maps (c.f. Reiss et al., 2008). Therefore, pitch-matching tasks may not be a reliable way to identify anatomical mismatch in this population
•Lack of measurable ITD JNDs may be due to a persistent underlying anatomical mismatch, which was not identified via the pitch matching tasks. However, ILD JNDs were still measureable because ILDs are less susceptible to interaural mismatch (Kan et al., 2013).
•A more systematic investigation of ITD sensitivity on different interaural electrode pairings needs to be conducted to determine if pre-lingually deafened children are indeed sensitive to ITDs, and whether pitch-matching is a useful task for aligning BiCIs in children.

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