PS 735

Does rate or place affect interaural timing difference sensitivity in children who use bilateral cochlear implants?

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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) there is little evidence suggesting ITDs are utilized in spatial hearing tasks.
• An initial experiment was conducted in children with BiCIs to examine whether they were sensitive to ITDs (Ehlers et al., 2015). Testing was conducted using synchronized research processors with low-rate, 100 pulses per second (pps), pulsatile stimulation on pitch-matched electrode pairs. Pitch-matched electrode pairs were used because prior work with adults has shown that pitch-matched electrode pairs typically yielded the best ITD sensitivity (Kan et al, 2013).

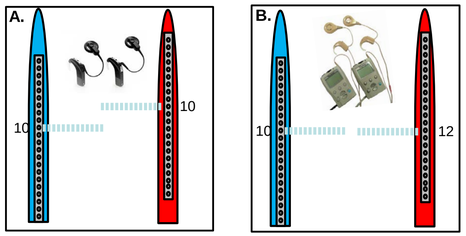

Figure 1A: Electrode arrays inserted at different depths between the ears, causing interaural frequency mismatch when using clinical processors.
Figure 1B: Electrodes at the same insertion depth, matched for pitch when using research processors.

•Ehlers et al., (2015) measured just noticeable differences (JNDs) for pitch-matched electrode pairs located at the base, middle, and apex of the electrode array. Results suggest that all children with BiCIs have sensitivity to ILDs, but sensitivity to ITDs is weak or absent in the majority of subjects (see Fig. 2).
• Another notable result from Ehlers et al., (2015) was that the majority of subjects identified the same numbered electrodes across the ears as being identical in pitch (see Table 2). This suggests that congenitally deaf children may have learned to judge pitch through their everyday listening with clinically mapped speech processors (c.f. Reiss et al., 2008). Thus, pitch-matching methods may not be a useful measure for identifying electrode pairs that would yield the best ITD sensitivity.
• Alternatively, the lack of measurable ITD sensitivity may be due to the stimuli used in Ehlers et al., (2015), which are much lower in pulse rate than current clinical processing strategies. It may be possible that stimuli presented at a pulse rate that is more similar to the children's every day listening environments may produce better ITD sensitivity.
• The experiments in this presentation were conducted to examine these hypotheses.

Table 2

Subject	Chosen Electrode Pairs
CIAQ	4/4, 12/13, 20/19
CIAY	12/12, 20/18
CIDX	12/12
CIAP	4/4, 12/12, 20/16
CIBO	4/4, 12/12, 20/18
CIEB	12/12
CIAG	12/10, 4/4, 12/12, 20/18
CIEU	14/14, 4/4, 12/12, 18/18
CIBK	4/4, 12/12, 20/18
CIDQ	4/4, 12/12, 20/20
CIEH	4/6, 12/14, 20/20
CIDJ	6/6, 12/12, 20/16
CIEV	14/14
CIFF	14/14
CIEC	12/14
CIAW	14/16

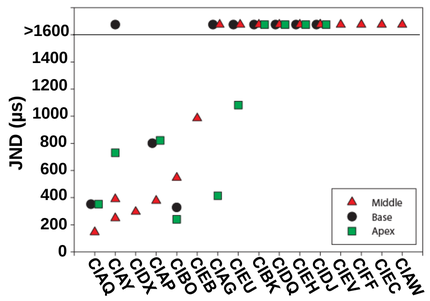

Figure 2: Individual ITD JNDs for all subjects from Ehlers et al (2015).

Aims

Experiment I: Relationship between pitch matching and ITD sensitivity:

• The aim of the first experiment was to determine whether pitch-matching tasks can identify the best electrode pair for ITD sensitivity in children with BiCIs.
• It was hypothesized that children who did not previously show ITD sensitivity at a pitch matched pair will show ITD sensitivity at another electrode pair better matched for anatomical stimulation.

Experiment II: Relationship between stimulation rate and ITD sensitivity:

• The aim of the second experiment was to determine whether the rate of stimulation affects ITD sensitivity.
• It was hypothesized that subjects who do not demonstrate ITD sensitivity to low-rate stimulation (100pps) may demonstrate ITD sensitivity to high-rate (1000 pps) amplitude modulated (AM) stimuli because this is more similar to their clinical processor rate.

General Methods

Participants

•10 children with bilateral Cochlear Nucleus © devices participated in these experiments.

Subject	Sex	Age	Early Acoustic Hearing Experience (mos)	Age at 1st implant (mos)	Inter-implantation Delay (yrs, mos)	BiCI Exp. (yrs, mos)
CIAY	M	15	42	62	0,10	9,12
CIBO	F	16	ID at 25, fluctuating	34	1,1	10,4
CIAP	F	16	ID at 16, progressive	42	1,8	9,7
CIAW	M	15	None	15	4,3	9,9
CIBI	F	13	None	13	1,9	10,10
CIEV	F	14	ID at birth, progressive	32	8,3	2,0
CIDJ	F	14	None	19	3,5	9,0
CIAG	M	14	ID at birth, progressive	21	1,5	11,10
CIEU	F	17	ID at 6, progressive	51	6,2	3,9
CIEH	M	10	None	13	0	9,0

Stimuli

• 300 ms, constant amplitude pulse train
• 25 µs pulse width
Experiment I: 100 pps
Experiment II:
100 pps
1000 pps
1000 pps with 100 Hz AM
• Stimuli were presented via a pair of bilaterally synchronized L34 Speech processors (Cochlear Ltd.) at a self-reported comfortable level.

Mapping Procedure

• Threshold (T), comfortable (C), and maximum comfortable (MC) levels were measured through the L34 Speech processors for each stimulus separately.
• C levels were loudness-balanced between ears and also for the different maps.

Tasks

Direct Pitch Comparison (DPC):

• Subjects were asked to compare pitch of interaural electrodes for Δ0, Δ±2, and Δ±4, where Δ0 is defined as stimulation of the same numbered electrode in each ear. Negative numbers imply electrodes in the right ear were closer to the apex. For example, Δ-2 would be electrode 12 (left)/14 (right).
• An electrode from each ear was stimulated sequentially. The subject reported whether the second sound was the "much higher", "higher", "same", "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 (Litovsky et al., 2012).
•$\mu = (2)N_{\text{much higher}} + (1)N_{\text{higher}} + (0)N_{\text{same}} + (-1)N_{\text{lower}} + (-2)N_{\text{much lower}}$, where N is the number of times a particular response was chosen.

ITD Discrimination:

• ITD sensitivity was tested on a range of interaural electrode pairs in Experiment I (Δ0, Δ±2, Δ±4, Δ±6) or on a pitch-matched pair in Experiment II.
• ITD just noticeable differences (JNDs) were measured using a method of constant stimuli in a two interval, two alternative forced choice task. Subjects were asked to report whether the sound moved to the right or to the left.
• ITDs tested were ±100, ±200, ±400, and ±800 µs, although these were varied based on individual performance.

Experiment I: Relationship of pitch matching and ITD sensitivity

Results:

• Three of the four subjects showed ITD sensitivity, and the pitch-matched pair typically yielded the best ITD JND. Subject CIAP had a pitch-matched pair for electrodes L12/R12 but had the best JND at electrodes L12/R16.
•For the remaining subjects, a pitch-matched pair was identified but no ITD sensitivity was found for any electrode pairs tested.

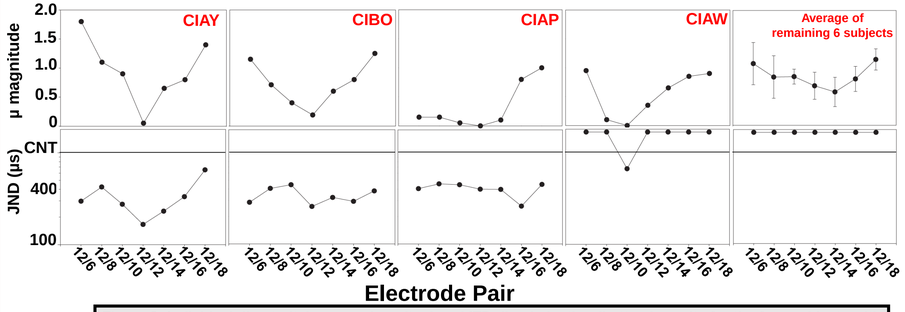

Figure 3: Individual direct pitch comparison (top) and ITD discrimination (bottom) results for the four subjects with ITD sensitivity. The last panel shows the group average for all subjects that did not have ITD sensitivity.

Summary

• Subjects that demonstrated ITD sensitivity in previous experiments continued to show ITD sensitivity to low-rate stimuli (100 pps) in the current experiment.
• Subject CIAW did not show ITD sensitivity at a pitch matched pair of L14/R16 in Ehlers et al, 2015, but did show ITD sensitivity to low-rate stimuli at a pitch matched pair of L12/R12.
• The remaining subjects that did not show ITD sensitivity in the previous experiment were still not sensitive to ITDs regardless of rate or place of stimulation.

Subject	Ehlers et al, 2015: Pitch- matched electrode pair	Ehlers et al, 2015: 100 pps JND	Current Exp: Pitch- matched electrode pair	100 pps JND	1000 pps with 100 Hz AM JND	1000 pps	ITD sensitivity at pairs other than pitch-matched pair?
CIAY	12/12	389.47	12/12	165.83	212.51	754.52	Yes
CIBO	12/12	546.93	12/12	257.54	No Sensitivity	DNT	Yes
CIAP	12/12	376.77	12/10	400.12	425.12	DNT	Yes
CIAW	14/16	No Sensitivity	12/10	666.14	788.7	DNT	No
CIBI	DNT	DNT	12/12	No Sensitivity	No Sensitivity	No Sensitivity	No
CIEV	14/14	No Sensitivity	12/14	No Sensitivity	No Sensitivity	No Sensitivity	No
CIDJ	12/12	No Sensitivity	12/12	No Sensitivity	No Sensitivity	No Sensitivity	No
CIAG	12/12	No Sensitivity	12/14	No Sensitivity	No Sensitivity	No Sensitivity	No
CIEU	12/12	No Sensitivity	12/12	No Sensitivity	No Sensitivity	No Sensitivity	No
CIEH	12/14	No Sensitivity	12/13	No Sensitivity	No Sensitivity	No Sensitivity	No

Table 3: Summary of electrode pairs and JNDs for subjects that completed all three experiments.

Experiment II: Relationship of rate and ITD sensitivity

Results:

• Of the four subjects who showed ITD sensitivity, three had sensitivity to both the 100 pps and the 1000 Hz stimuli with AM. Subject CIBO had sensitivity to the 100 pps but was not sensitive to the 1000 Hz stimuli with AM. CIAY was sensitive to the 1000 pps unmodulated stimuli but the other 3 subjects with ITD sensitivity were not tested on the 1000 pps unmodulated stimuli due to time constraints.
• The remaining subjects did not show ITD sensitivity for all stimulation rates.

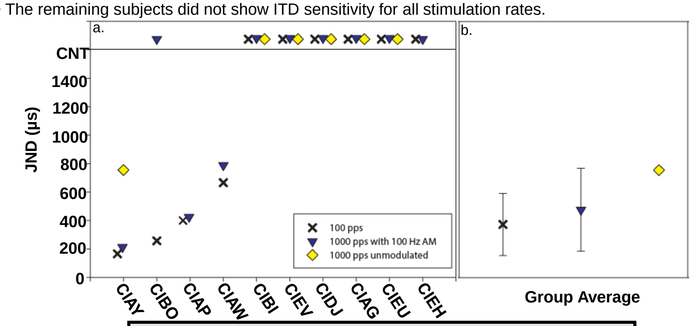

Figure 4a &b: Individual ITD JNDs for each stimulus condition (a) and average measurable JNDs for each stimulus condition (b).

Conclusions

• In Ehlers et al, (2015) 50% of subjects did not demonstrate sensitivity to ITDs, even when tested at basal, medial, and apical locations along the electrode array.
• Experiment I demonstrated that pitch matching appears to be an effective method for identifying an electrode pair that can yield ITD sensitivity for children who use bilateral cochlear implants.
• Experiment II confirmed that, for most subjects, ITD sensitivity is comparable for low-rate (100pps) stimuli and high-rate (1000 pps) stimuli amplitude modulated at a low rate of 100pps.
• Subjects who had ITD sensitivity in previous experiments (Ehlers et al, 2015) maintained ITD sensitivity in the current experiments. However, neither a change in rate of stimulation nor interaural place of stimulation provided ITD cues to subjects who did not previously demonstrate ITD sensitivity.
• The current set of experiments suggest that factors other than anatomical mismatch between the two ears, and stimulus rate may be responsible for a lack of ITD sensitivity in this population. Another possible hypothesis is that early acoustic experience and/or binaural maturation may be required for ITD sensitivity.

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