Initial findings on the influence of onset cues on auditory object formation and sound lateralization in bilateral cochlear implant listeners

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INTRODUCTION

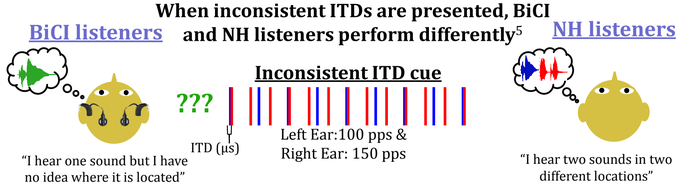
- Sensitivity to interaural time differences (ITDs) in normal hearing (NH) listeners is robust in quiet[1]. However in order to identify a target sound in noisy and/or reverberant environments, the NH binaural system relies heavily on the onset ITD to lateralize and perceive a unitary object; this is commonly known as *onset dominance*[2].
- With research devices, BiCI listeners do demonstrate ITD sensitivity[4], yet it is unclear whether they can benefit from onset dominance *while* still being able to perceive a single unitary object.

Goal: Improve the salience of the ITD in BiCI listeners by exploiting onset dominance for lateralization and object formation tasks.

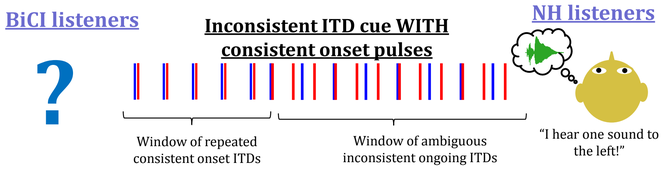
Our previous work shows that…

When consistent ITDs are presented, BiCI and NH listeners report hearing a single object and can lateralize it very well[5]

When inconsistent ITDs are presented, BiCI and NH listeners perform differently[5]



Could BiCI listeners benefit from a more consistent or "salient" onset?

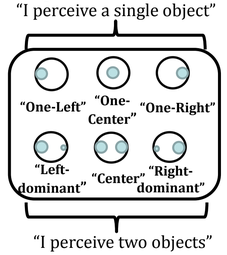


Hypothesis: If repeated consistent onset ITDs are important for lateralization and good auditory object formation in BiCI listeners, then increasing the number of onset pulses with the same ITD, would improve lateralization and reinforce perception of a single auditory object.

METHODS

- Listeners: Four post-lingually deafened adult BiCI users with demonstrated ITD sensitivity.
- Stimuli: Biphasic electrical pulse trains using synchronized research processors at a single pitch-matched pair of electrodes, presented at 100 pulses per second, 300-millisecond duration (Cochlear RF Generator). The number of pulses carrying consistent ITDs from the onset pulse was manipulated (1, 5, 10, 15, 20, 29, 25, or 30). Remaining pulses were jittered using a uniform distribution (see Table 1A &1B).
- **"Rightward-Jitter" Condition (Fig. 1A):** Consistent onset ITDs were either 0/Left/Right. Jittered ITDs were always to the right.
- **"Contralateral-Jitter" Condition (Fig. 1B):** Consistent onset ITDs were either 0/Left/Right. Jittered ITDs were always in the contralateral hemifield.
- Task (Fig. 2): single-interval task with 6 response options. Total of 20 repetitions for each onset ITD (3 ITDs) x 8 onset-pulse conditions = 480 trials total per listener. ITDs were randomized in each condition.

Figure 2: Task screen



Rightward-Jitter: simulates a secondary source to the right hemifield

Figure 1A: "Rightward-Jitter" stimuli

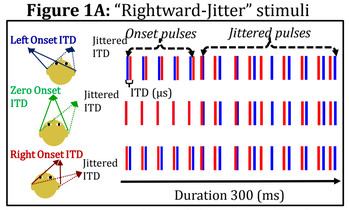


Table 1A: Parameters for each listener in "Rightward-Jitter"

ID	Onset ITD & Location of Jitter (in µs)*			Range of Jitter (µs)
ICD	-500 & +250	0 & +750	+500 &+1250	±10
IBR	-600 & +250	0 & +750	+600 &+1250	±100
IBP	-850 & +250	0 & +750	+850 &+1250	±100

Contralateral-Jitter: simulates a secondary source in the contralateral hemifield

Figure 1B: "Contralateral-jitter" stimuli

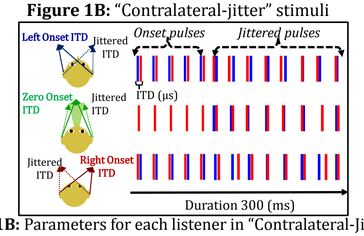


Table 1B: Parameters for each listener in "Contralateral-Jitter"

ID	Onset ITD & Location of Jitter (in µs)*			Range of Jitter (µs)
IBP	-850 & +800	0 & 0	+850 & -800	±100
ICI	-500 & +200	0 & 0	+500 & -200	±50

*negative is a leftward ITD; positive is a rightward ITD.

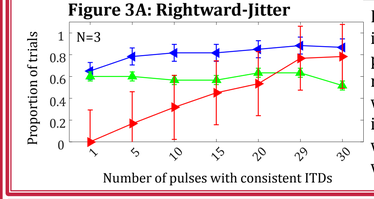
RESULTS: Group Data

Figure 3: Proportion of responses reported as a single auditory object

Responses: "One-Left" "One-Center" "One-Right"

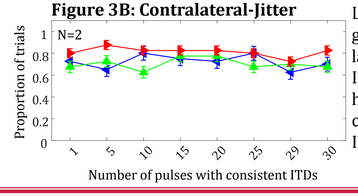
$$Proportion\ of\ trials = \frac{Number\ of\ \textit{single\ object}\ responses\ in\ the\ direction\ of\ the\ onset\ ITD}{Total\ number\ of\ trials\ in\ the\ direction\ of\ the\ onset\ ITD\ (20\ trials)}$$

Figure 3A: Rightward-Jitter



Listeners improved in lateralization performance as the number of pulses with consistent ITDs increased, but only when the onset ITD was to the right.

Figure 3B: Contralateral-Jitter

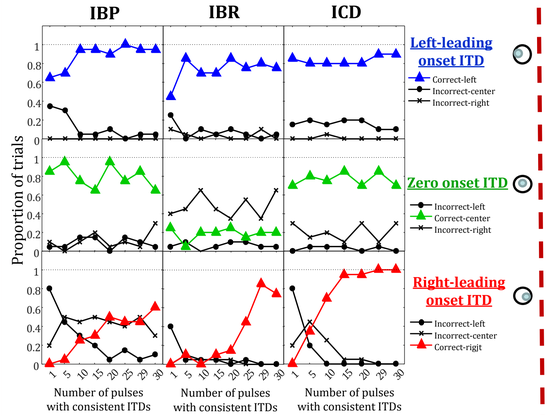


Listeners were good at lateralizing an ITD regardless of how many consistent onset ITDs there were.

RESULTS: Individual Data

Figure 4: Rightward-Jitter Responses

*colored symbols are shown as group average in Fig. 3A; black symbols show incorrect lateralizations in accordance with the onset ITD .



Condition 1: When the number of consistent onset ITDs is decreased, lateralization is poorer (red symbols in Fig. 4, bottom three panels). This was only true when there was a rightward onset ITD (i.e when the onset ITD and jitter were in the same hemifield).

- Only listener IBR perceived ITDs as a secondary sound source (Fig. 5). This this was only true when there was a rightward onset ITD.

Figure 5: Responses reported as *two* auditory objects:

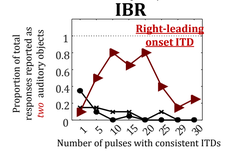
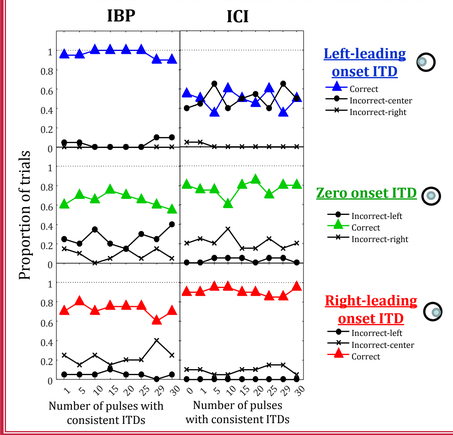


Figure 6: Contralateral-Jitter Responses

*colored symbols are shown as group average in Fig. 3B; black symbols show incorrect lateralizations in accordance with the onset ITD .



Condition 2: When the onset ITD and jittered ITD are in a different hemifields, listeners can report the correct location with just one onset pulse. Performance is independent of how many consistent onset pulses are present in the signal.

- No secondary sources were perceived for either listener.

SUMMARY

- BiCI listeners correctly report the location of the onset ITD as a function of the number of consistent pulses, this is in accordance with previous literature on onset dominance[6]. However, this is only true when the jittered source is coming from the contralateral hemifield (Fig. 3B & 6).
- BiCI listeners did not perceive any secondary objects (excluding listener IBR in Fig. 5); the jitter in the ongoing pulses does not interrupt object formation. This suggests that BiCI listeners with ITD sensitivity appear to associate the onset pulses with a single object in a single location
- Our results suggest that, regardless of the relationship between the ITD of a target source and an ambiguous late-arriving source, only a few consistent onset ITDs are needed to perform well in lateralization and object formation tasks. Larger sample sizes are needed to determine this.

REFERENCES

1. Macpherson, E. A., and Middlebrooks, J. C. (2002). "Listener weighting of cues for lateral angle: the duplex theory of sound localization revisited," J. Acoust. Soc. Am., 111, 2219–36. doi:10.1121/1.1471898
2. Stecker, G. C., and Hafter, E. R. (2002). "Temporal weighting in sound localization," J. Acoust. Soc. Am., 112, 1046–57. doi:10.1121/1.1497366
3. Brown, A. D., Jones, H. G., Kan, A., Thakkar, T., Stecker, G. C., Goupell, M. J., and Litovsky, R. Y. (2015). "Evidence for a neural source of the precedence effect in sound localization," J. Neurophysiol., 114, 2991–3001. doi:10.1152/jn.00243.2015
4. Kan, A., and Litovsky, R. Y. (2015). "Binaural hearing with electrical stimulation," Hear. Res., 322, 127–37. doi:10.1016/j.heares.2014.08.005
5. Thakkar, T., Kan, A., and Litovsky, R. Y. (2017). "The impact of asymmetric rates on interaural time difference lateralization and auditory object formation in bilateral cochlear implant and normal hearing listeners," J. Acoust. Soc. Am., 141, 3635. doi:10.1121/1.4987831
6. van Hoesel, R. J. M. (2008). "Observer weighting of level and timing cues in bilateral cochlear implant users," J. Acoust. Soc. Am., 124, 3861–72. doi:10.1121/1.2998974

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