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Interaural time difference sensitivity with high-rate electrical pulse trains in bilateral cochlear implant users

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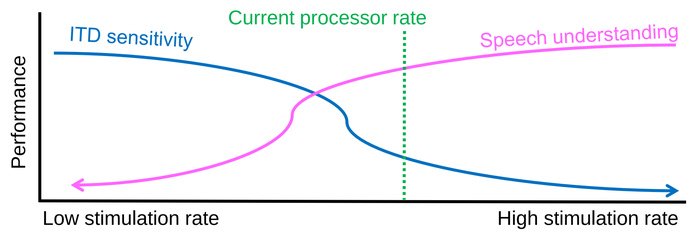
INTRODUCTION

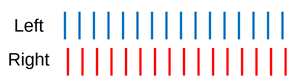
- The interaural time difference (**ITD**) is an important cue for good sound source localization and speech unmasking in noisy situations for normal hearing listeners[1,2]. However, bilateral cochlear implant (**CI**) users show little reliance on ITDs when locating sounds[3].
- Current CI processors typically operate at a fixed-interval, high-rate stimulation which supports good speech understanding but not ITD sensitivity[4,5].

Simplified model of stimulation rate vs performance



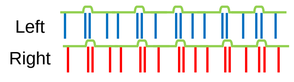
- Varying the inter-pulse interval at high stimulation rates has been shown to promote ITD sensitivity[6], but the mechanism responsible for improving ITD sensitivity remains unresolved.

***Fixed-interval* high-rate stimulation**



Poor ITD sensitivity

***Variable-interval* high-rate stimulation**



Improves ITD sensitivity but may be due to a low-frequency envelope ITD generated by the shorter inter-pulse intervals

- If the mechanism for improved ITD sensitivity with variable-interval, high-rate stimulation is due to a low-frequency envelope cue, this cue will be masked when the electrical pulses are used to encode an acoustic signal in a CI speech processing strategy.

Aim: This work examines whether an ITD cue conveyed by variable-interval, high-rate stimulation is still salient when the electrical pulses are used to encode an acoustic signal.

METHODS

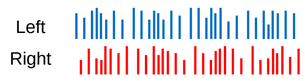
- ITD just noticeable difference (**JND**) thresholds were measured on a pitch-matched pair of electrodes. ITDs were applied as a delay of electrical stimulation in one ear.
- All stimuli were 500 ms duration, 4000 Hz electrical pulse trains delivered using a synchronized research processor (Cochlear RF Generator).
- Three conditions:

1. No Modulation (NM)

2. Frequency Modulation (FM)

- 100 Hz FM (2000 Hz bandwidth), same on both sides

3. Frequency Modulation with random amplitude (rFM)



- Amplitude randomly varied for each pulse either at 7 or 15% of dynamic range (DR), independently on both sides to simulate signal envelope encoding and to mask envelope ITD cue.

Hypothesis: If the improvement in ITD sensitivity with FM is not due to a low frequency envelope ITD cue, then ITD JNDs in the rFM and FM conditions will be similar.

- Six adult bilateral CI listeners with demonstrated ITD sensitivity in previous experiments.

ID	Age	Years with Bilateral CI	Etiology	Electrodes		rFM (%DR)
				L	R	
IAJ	70	13	Unknown; Progressive loss from birth	12	12	15%
IBF	64	8	Hereditary	12	12	7%
IBK	75	6	Hereditary or noise-induced	12	12	7%
IBO	51	5	Otosclerosis	12	12	15%
ICD	58	7	Unknown; Progressive loss from birth	12	12	15%
ICS	88	4	Gradual loss	12	12	7%

RESULTS

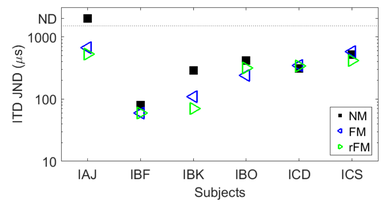


Figure 1: ITD JNDs measured for each listener in each stimulus condition. ND implies that an ITD JND could not determined.

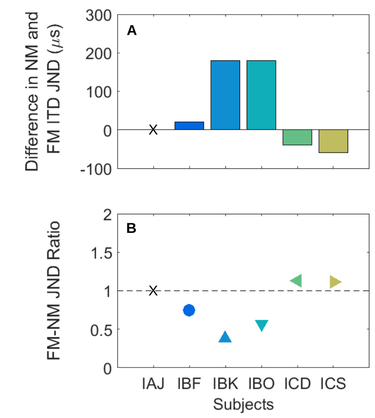


Figure 2: (A) Improvement in ITD JNDs with the introduction of FM. (B) Ratio of FM to NM ITD JNDs. A ratio of 1 implies the same ITD JND for NM and FM conditions, and a ratio smaller than 1 shows an improvement. X indicates data for IAJ could not be calculated.

- No measurable JND threshold for IAJ in NM condition. Otherwise all listeners had measurable thresholds (Fig 1).
- IBK and IBO showed a substantial improvement in ITD JND threshold with variable high-rate stimulation introduced by FM (Fig 2).
- Improvement in ITD JNDs does not appear to be substantially disrupted when the amplitude of each pulse was randomized (Fig 3).

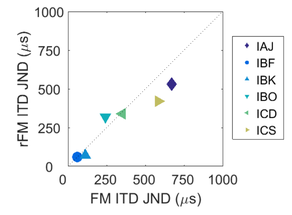


Figure 3: Comparison of ITD JNDs between FM and rFM. The diagonal line signifies JNDs between the two conditions are the same.

SUMMARY

- Some bilateral CI users show an improvement in ITD sensitivity with variable-interval high-rate stimulation.
- Improvement in ITD sensitivity does not appear to be due to low frequency envelope ITD cues.
- These results suggest that variable-interval high rate stimulation can be useful for encoding signal envelopes and providing improved ITD sensitivity in bilateral CI users.

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.
2. Ihlefeld, A., and Litovsky, R. Y. (2012). "Interaural level differences do not suffice for restoring spatial release from masking in simulated cochlear implant listening," PLoS One, 7, e45296.
3. Aronoff, J.M., Yoon, Y., Freed, D.J., Vermiglio, A.J., Pal, I., and Soli, S.D. (2010). "The use of interaural time and level difference cues by bilateral cochlear implant users," JASA-EL, 127, EL87-EL92
4. van Hoesel, R. J. M., Jones, G. L., and Litovsky, R. Y. (2009). "Interaural Time-Delay Sensitivity in Bilateral Cochlear Implant Users: Effects of Pulse Rate, Modulation Rate, and Place of Stimulation," J. Assoc. Res. Otolaryngol., 10, 557–567.
5. Churchill, T. H., Kan, A., Goupell, M. J., and Litovsky, R. Y. (2014). "Spatial hearing benefits demonstrated with presentation of acoustic temporal fine structure cues in bilateral cochlear implant listeners," J. Acoust. Soc. Am., 136, 1246.
6. Laback, B., and Majdak, P. (2008). "Binaural jitter improves interaural time-difference sensitivity of cochlear implantees at high pulse rates," Proc. Natl. Acad. Sci. U. S. A., 105, 814–7.

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