Temporal weighting for interaural time differences in low-frequency pure tones

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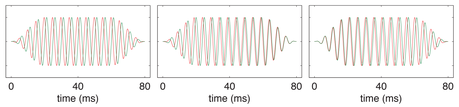
Purpose and background

In contrast to envelope-based interaural time differences (ITD) at high frequencies, where sound onsets play a dominant role [Stecker & Brown 2010], the reliability and salience fine-structure ITD at low frequency (<1500 Hz) suggests uniform sensitivity to information across periods of an ongoing stimulus waveform. Several past studies, however, have demonstrated low-frequency ITD thresholds to improve sub-optimally with increasing sound duration [e.g. Houtgast & Plomp 1968], suggesting that the initial periods of a brief tone play a greater role in ITD processing than do later periods.

Methods



"RR" Condition **"R0" Condition** **"0R" Condition**

figure 1. Stimuli (not to scale). Targets in all conditions carried right leading ITD or ILD cue, ITD shown here. "RR" condition provided a constant binaural cue throughout the duration of the pure tones, while the "0R" and "R0" conditions progressed linearly to eliminate the cue from either the beginning or the end of the tones, eliminating the offset or onset cue (respectively).

Experiment 1:

Task: 4 interval 2 alternative forced choice
Right-leading target ITD in interval 2 or 3

1
2
3
4

Stimulus conditions:
1) **RR**: fixed ITD
2) **R0**: no offset ITD
3) **0R**: no onset ITD (see **figure 1**)

Stimulus:
Frequency 500 Hz
Intensity 60 dB SPL
Duration: 40 – 640 ms
20 ms diotic ramps (to minimize envelope cues)

Experiments 2 & 3:

Task and stimulus conditions as in Experiment 1

Stimulus:
Frequencies: 250, 500, & 1000 Hz
Intensity 60 dB SPL
Frequency rove ± 10%
Intensity rove ± 5 dB
Duration: 80 ms, with 20 ms diotic ramps

Results

Experiment 1: ITD Discrimination at 500 Hz

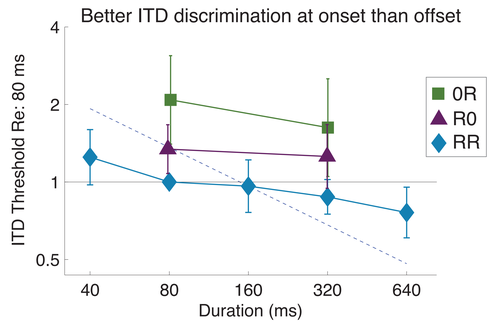


figure 2. Results from varying duration using 500 Hz pure tone stimuli in the RR, R0 and 0R conditions. Thresholds normalized to 80 ms RR condition. Dotted line represents optimal performance. RR condition was tested at all of the durations; R0 and 0R conditions tested at 80 and 320 ms.

Significant effect of condition 0R with R0 (paired t-test, $p<0.05$)
RR improves sub-optimally with duration
Mean slope = -0.181 vs. Optimal slope of -0.5 (z-test, $p<0.05$)

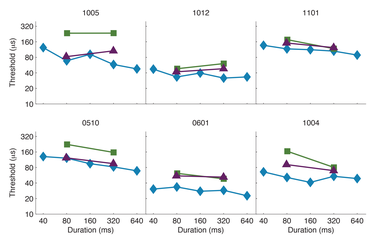


figure 3. Individual results for the 6 participants in experiment 1. Thresholds in ms plotted for performance in the RR, R0 and 0R conditions tested at 500 Hz.

Experiment 2: ITD discrimination across frequency

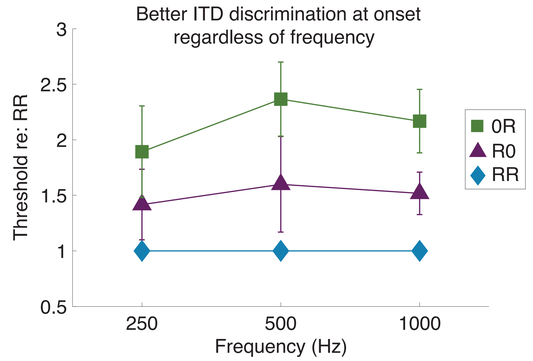


figure 4. Normalized to the RR condition for each frequency, group data shown for the R0 and 0R thresholds. Error bars represent the 95% confidence interval.

Repeated Measures ANOVA: **Condition (R0, 0R) x Frequency**
-Significant effect of condition $F(1,9)=62.21$; $p<0.001$
-No significant effect for frequency and interaction of frequency x condition, $F(2,9)=2.15$; $p=0.15$ and $F(2,9)=1.58$; $p=0.23$

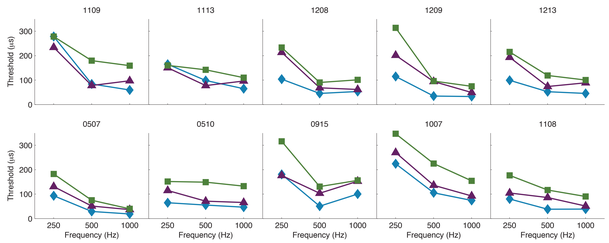


figure 5. Individual ITD thresholds for the 10 participants.

Experiment 3: ILD discrimination across frequency

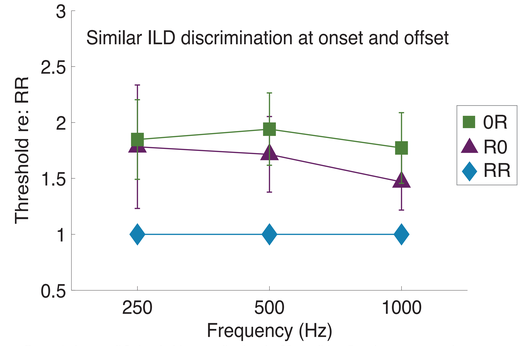


figure 6. Average ILD thresholds normalized to the RR condition. Error bars represent the 95% confidence interval.

Repeated Measures ANOVA: **Condition (R0, 0R) x Frequency**
-No significant effects of frequency, condition or interaction of frequency x condition
- Frequency $F(2, 9)=0.63$; $p=0.54$, Condition $F(1, 9)=3.72$; $p=0.09$, Frequency x Condition $F(2, 9)=0.90$, $p=0.42$

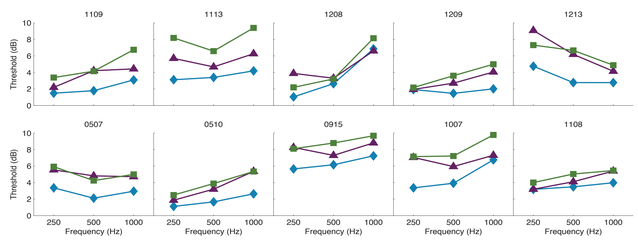


figure 7. Individual ILD thresholds for the same 10 participants as Experiment 2.

Summary and discussion

ITD detection thresholds demonstrated better sensitivity at onset than offset
(a) suboptimal improvement with duration
(b) greater sensitivity to ITD available early (R0) rather than late (0R) in the stimulus, a pattern nearly identical to that observed for high-frequency envelope ITD (Stecker & Brown, 2010)
(c) suggests sensitivity to ITD is dominated by the onset cue

ILD detection thresholds (experiment 3) demonstrated similar sensitivity at onset and offset
(a) elevated ILD thresholds in dynamic-cue conditions, consistent with smaller average cue over duration
(b) similar R0 and 0R thresholds, again showing a pattern nearly identical to that observed for high-frequency envelope ILD (Stecker & Brown, 2010)
(c) suggests sensitivity to ILD is maintained over the entire duration of the stimulus

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References

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