

Does multi-second monaural adaptation reduce sensitivity to interaural time differences in human listeners?



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Introduction

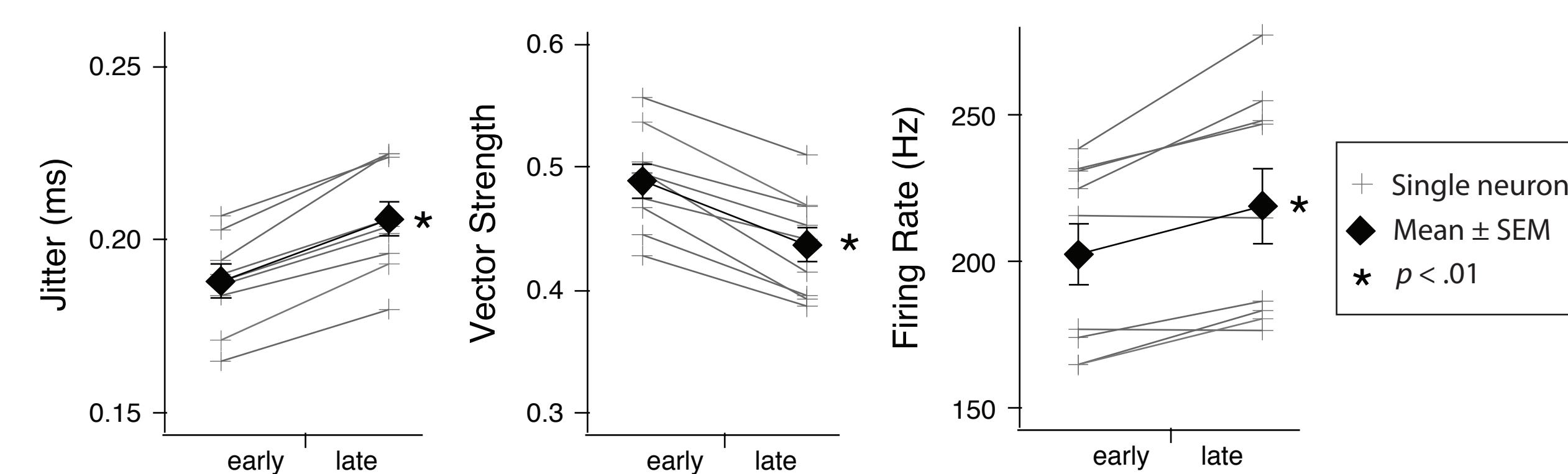
Numerous psychoacoustical investigations have characterized the effect of repeated stimulation on the discriminability of interaural time differences (ITD) and to a lesser degree interaural level differences (ILD). Such investigations have demonstrated that sensitivity to many types of binaural stimuli adapts over time, being highest at sound onset and diminishing thereafter.

Adapted sensitivity in lateralization has been observed on multiple time-scales, from a few milliseconds (Zurek, 1980, Hafter & Dye, 1983, Hafter et al., 1983, Freyman et al., 1997) to several seconds (Kashino & Nishida, 1998, Krumbholz & Nobbe, 2002, Phillips & Hall, 2005, Pecka et al., 2007). Correspondingly, neural adaptation has been observed on multiple time scales at nearly every level of the auditory system, and various mechanisms have been proposed to account for binaural psychoacoustical data (e.g. Hafter et al., 1990, Yin, 1994, Pecka et al., 2007).

Recently, Kuznetsova and colleagues (2008, 2009) (see below) showed that presentation of a multisecond simulated tonal stimulus caused adaptation of spike-timing precision in the cells of avian cochlear nucleus *in vitro*, thereby causing a frequency-specific reduction in the sensitivity of target binaural cells to simulated ITD. Here, we tested the hypothesis that similar adaptation might reduce the discriminability of ITD in human listeners.

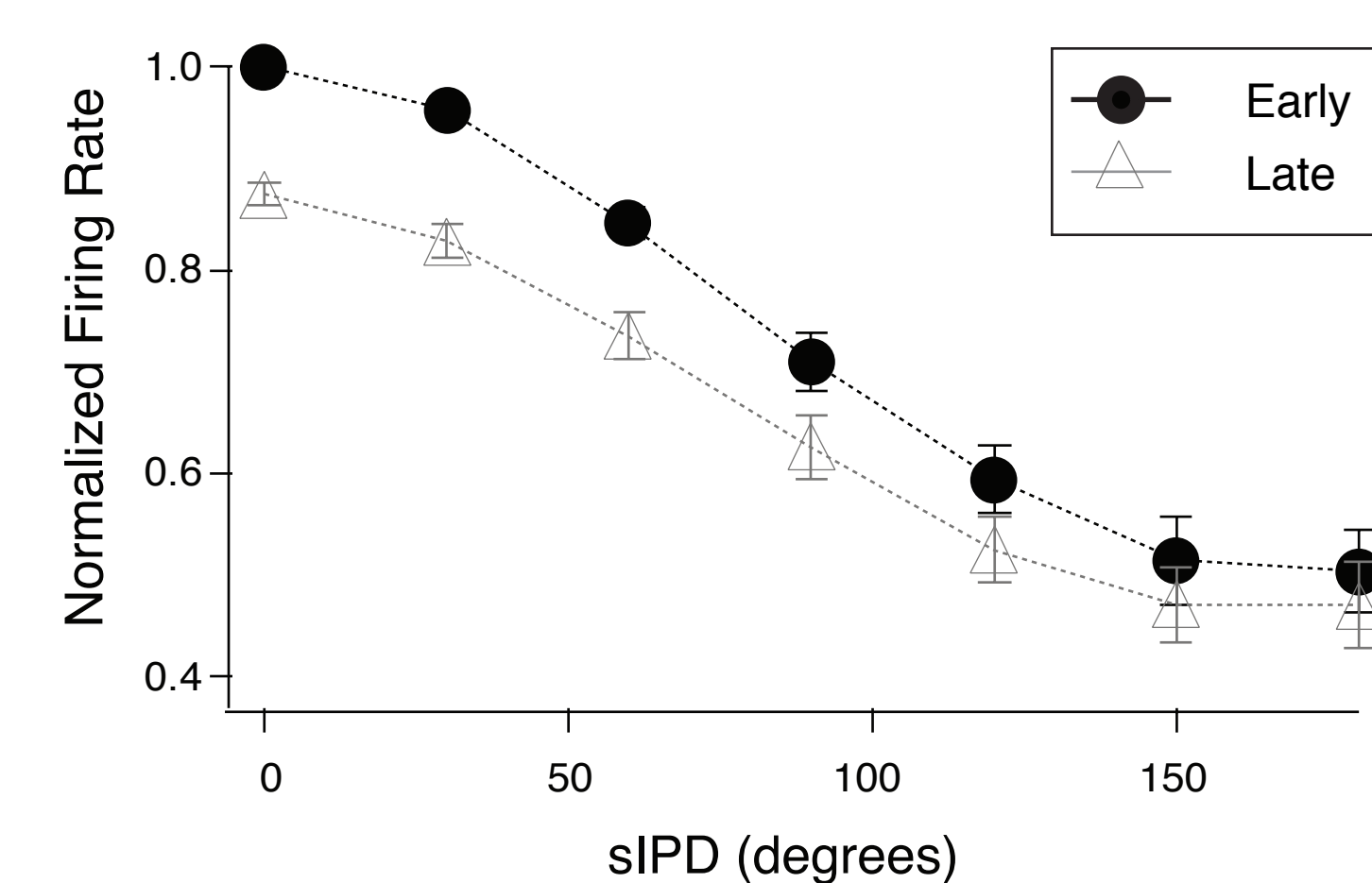
Kuznetsova et al. (2008)

Action potential responses of cells in chick nucleus magnocellularis recorded during early (200-700 ms) and late (9200-9700 ms) portions of a simulated auditory nerve input phase-locked to a 1000 Hz tone



Kuznetsova & Spain (2009)

Action potential responses of cells in chick nucleus laminaris to simulated interaural phase difference (sIPD) stimuli comprised of early and late outputs of magnocellular neurons (see above)



Methods

Subjects

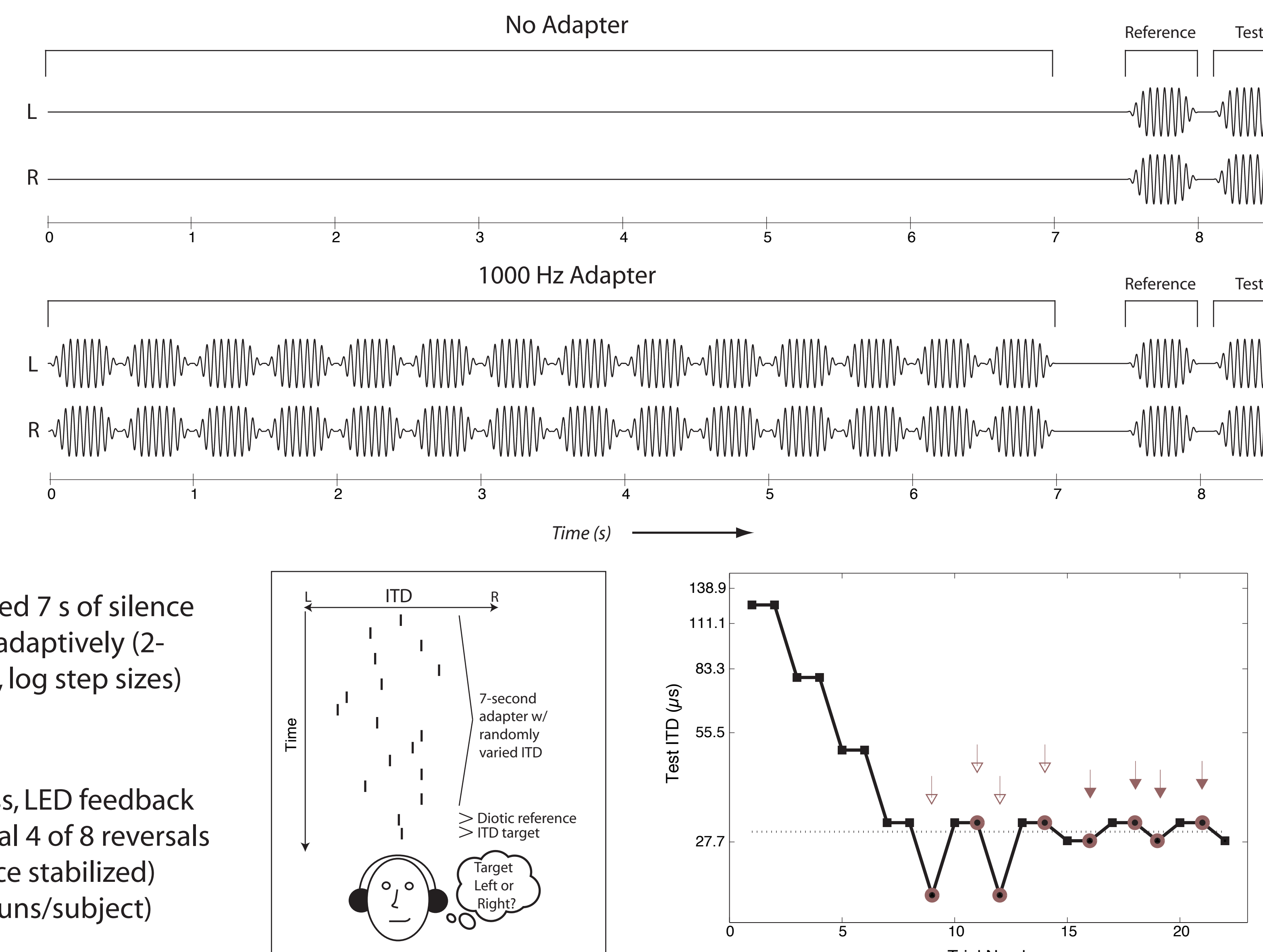
-4 normal hearing adults

Stimuli

- 500 ms tone bursts (20 ms rise/fall)
- Presented bilaterally at 74 dB SPL
- ITD imposed in ongoing waveforms
- 7 s "adapter" stimulus followed by 500 ms pause, 1000 Hz diotic reference, 100 ms pause, 1000 Hz ITD target
- Three "adapters" (200, 665, and 1000 Hz), comprised of 14 bursts carrying random ITD from uniform distribution spanning ± 25 cycles IPD
- Baseline "No Adapter" condition presented 7 s of silence
- Test ITD carried by 1000 Hz target adjusted adaptively (2-down, 1-up procedure; starting value 125 μ s, log step sizes)

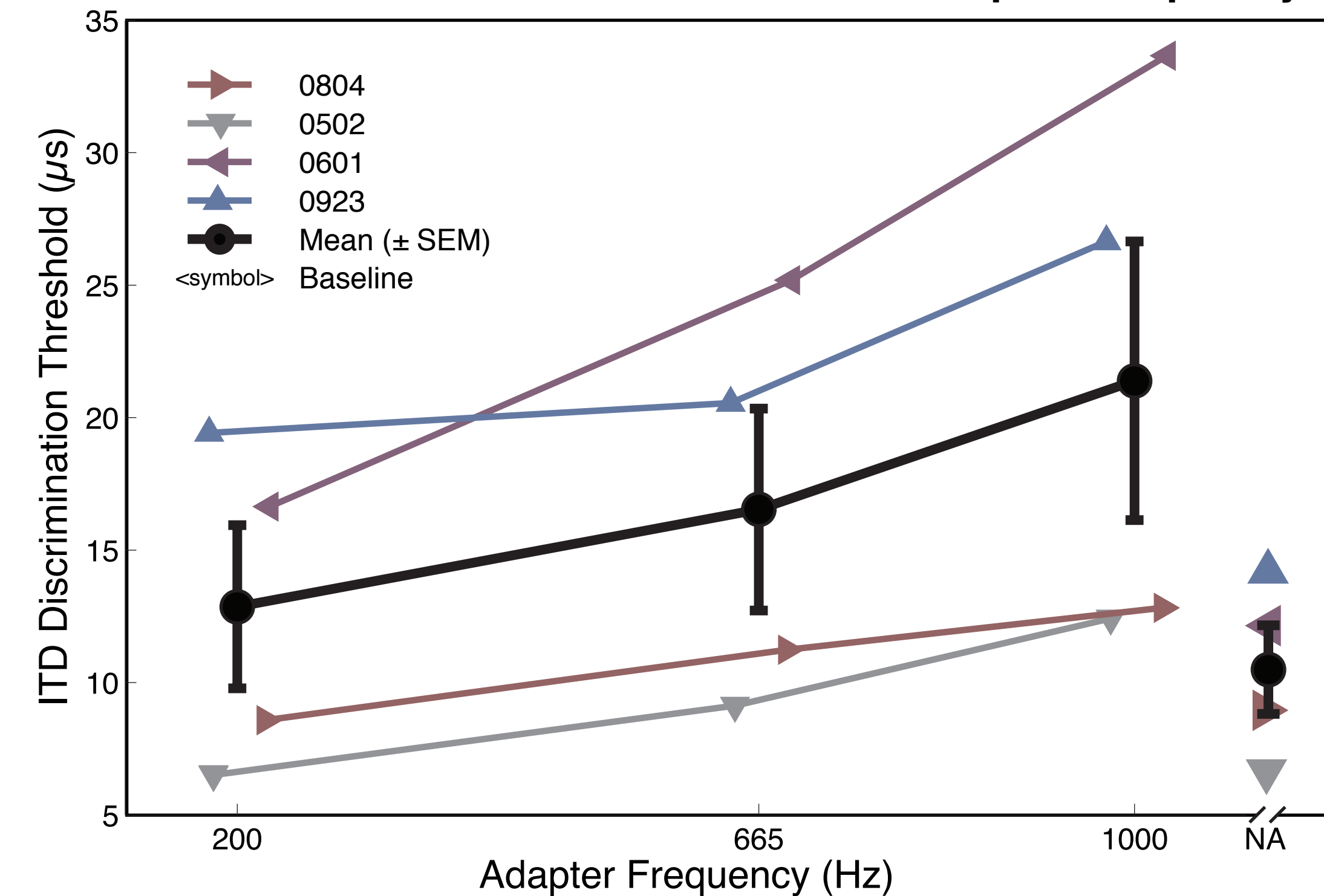
Task

- "Left"/"Right" discrimination via button press, LED feedback
- Threshold estimated by averaging ITD at final 4 of 8 reversals
- Minimum 3 hours training (until performance stabilized)
- 10 threshold estimates/condition (thus, 40 runs/subject)



Results

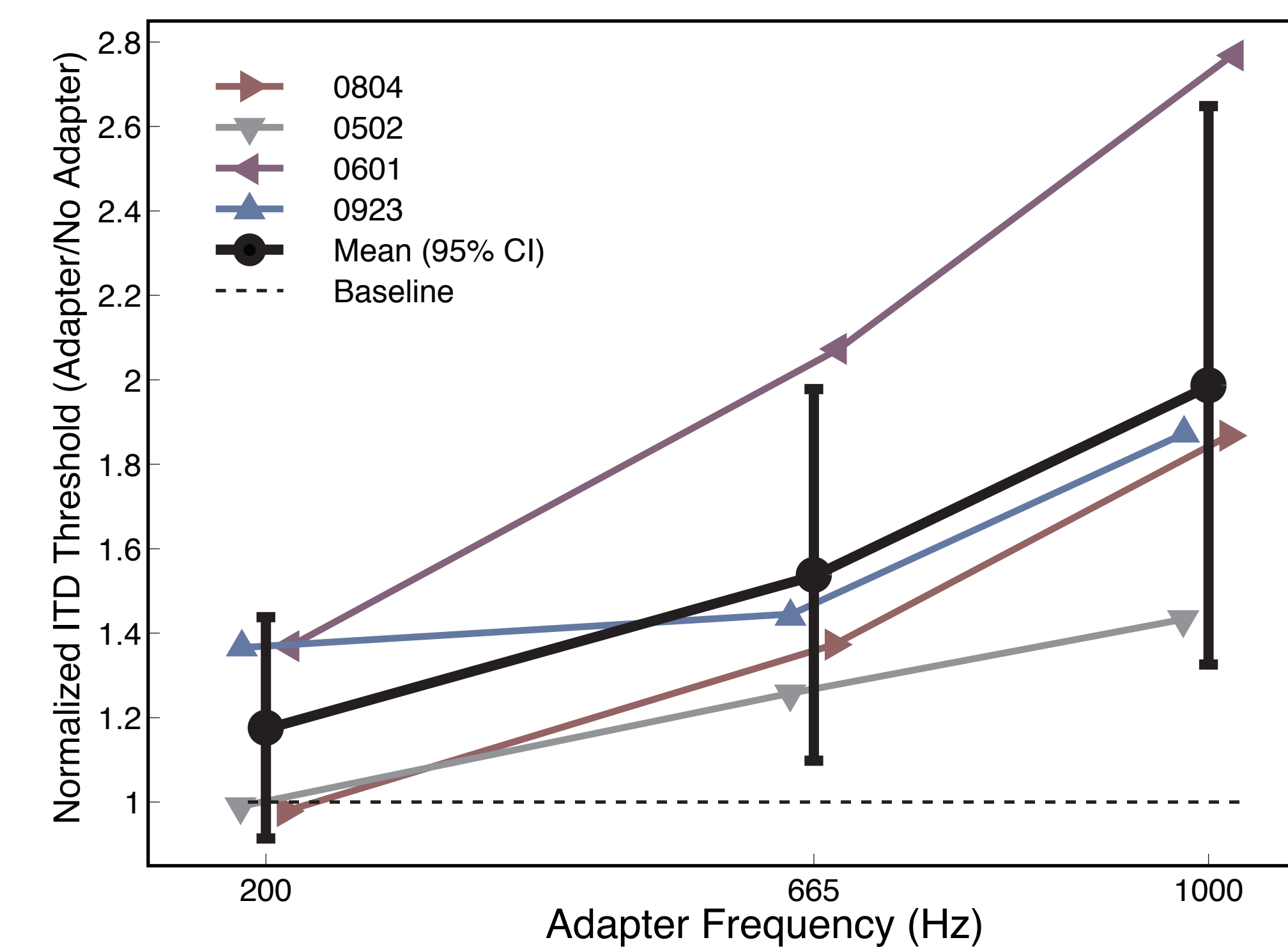
ITD Discrimination as a Function of Adapter Frequency



-Individual thresholds (colored symbols, far right) for the "No Adapter" condition (NA) varied from ~7 - 20 μ s (mean ~11 μ s, filled circles \pm SEM)

-Thresholds were minimally elevated or equal to baseline in the 200 Hz adapter condition, somewhat elevated in the 665 Hz condition, and maximally elevated in the 1000 Hz condition

Normalized ITD Discrimination Threshold



-Normalizing individual "Adapter" thresholds to "No Adapter" thresholds gives average twofold threshold increase in 1000 Hz adapter condition

-One-way repeated-measures ANOVA indicates significant main effect of condition ($F(3,3)=7.34, p<.01, \eta^2=.70$)

Discussion

-Presentation of a 7-second train of moderate-intensity tone bursts carrying random ITD degraded discrimination of an ITD target in a frequency-specific manner

-Broadly consistent with previous accounts of reduced sensitivity to binaural cues following repeated stimulation; novel sounds are more salient

-Consistent with physiological effects of monaural adaptation reported by Kuznetsova and colleagues (2008, 2009) using comparable stimuli

-Randomization of ITD in adapter bursts should have precluded adaptation to a specific ITD described previously (Kashino & Nishida, 1998, Phillips & Hall, 2005), suggesting the observed effect involved a different mechanism

-Mechanisms of ITD sensitivity differ for mammals and birds (e.g., Grothe, 2003) - however, multisecond monaural adaptation should degrade neural ITD sensitivity in any model requiring precise spike-timing (McAlpine et al., 2001, Grothe, 2003)

-Reduced discriminability of ITD resulting from pre-binaural processes has been suggested previously, but mainly for high-rate amplitude-modulated stimuli

-"Binaural adaptation" for ITD (and ILD) has been attributed to monaural effects: adaptation at a pre-binaural site (Hafter et al., 1990) or peripheral mechanisms (Tollin & Henning, 1999, Hartung & Trahiotis, 2001, Stecker & Brown, 2009)

-Next step: Degraded spike-timing precision (in Kuznetsova et al., 2008) was accompanied by increased firing rate - effect of adaptation on ILD sensitivity?

Acknowledgements

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