Temporal weighting of interaural level differences in high-rate click trains

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Background

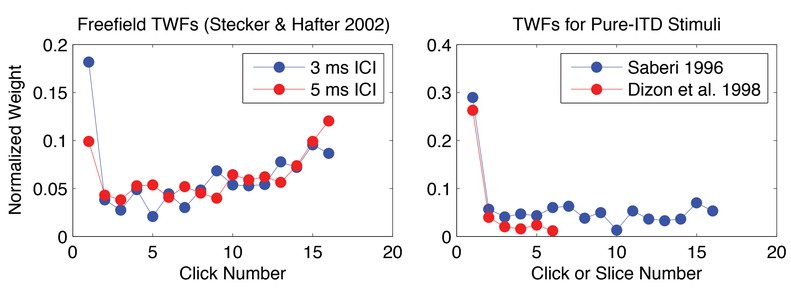
Rate-limitation of high-frequency ITD processing: Sensitivity to ongoing envelope interaural time difference (ITD) at high carrier frequency is limited to modulation rates < ~200 Hz (e.g., Bernstein & Trahiotis 2002).

Onset dominance in localization: Consequent to rate limitation is a shift to dependence on onset cues (onset dominance). Compare binaural adaptation (Hafter & Dye 1983), precedence effects (e.g, Freyman et al. 1997), temporal weighting studies (Stecker & Hafter 2002, Saberi 1996, Dizon et al. 1997).

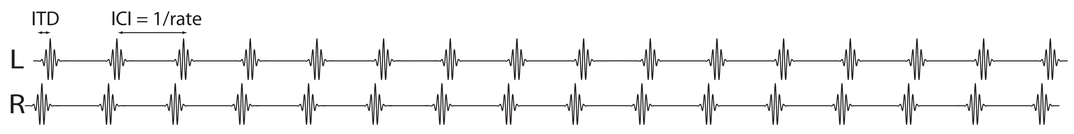
Interaural sensitivity in bilateral cochlear implant (CI) users: ITD sensitivity among CI users is limited, especially at high pulse rates (van Hoesel & Clark 1997, van Hoesel 2007); sensitivity to interaural level difference (ILD) is relatively preserved (Long, et al. 2003, Laback et al. 2004, Seeber & Fastl 2008).

Onset dominance for ILD? Similarity of binaural adaptation for ITD and ILD (Hafter et al. 1983,1990) suggests similarly onset-dominated mechanisms, but our recent work suggests that ILD discrimination does not require access to onset cues at high rates (Stecker 2007), and that ITD/ILD "trading ratio" varies with click rate (Stecker 2008) due to loss of ITD sensitivity while ILD sensitivity is maintained.

Upweighting of late-arriving sound: Temporal weighting functions (TWFs) for free-field sound localization differ from TWFs for pure-ITD discrimination (Saberi 1996) or adjustment (Dizon et al. 1997), revealing a special importance of late-arriving sound. Is this "upweighting" mediated by differences in ILD vs ITD processing? (cf. Krumbholz & Nobbe 2002)

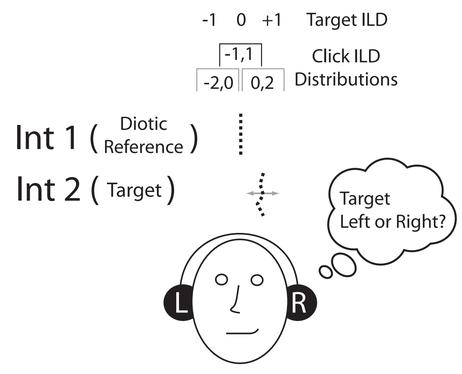


Temporal weighting for ITD, ILD discrimination

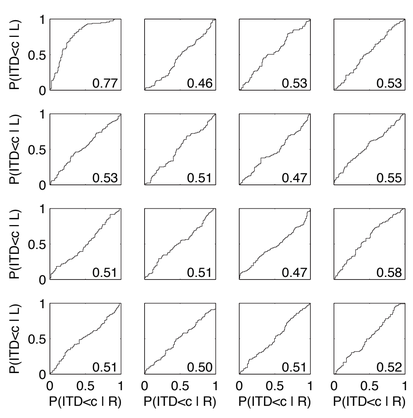


Stimuli: Trains of 16 Gabor clicks.
carrier frequency 4000 Hz
click duration ~300 μs/σ
interclick interval (ICI): 2, 5, or 10 ms
(500, 200, 100 Hz modulation)
ITD or ILD applied in separate runs

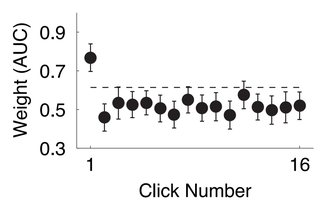
Task: 2-interval "left" / "right"
interval 1 diotic, 2 target
target ITD: -100 (25%), +100 (25%), 0 μs(50%)*
target ILD: -1 (25%), +1 (25%), 0 dB (50%)
click ITD/ILD: target +/- 100 μs or 1 dB
(jitter with uniform distribution)



Per-click ROC Curves



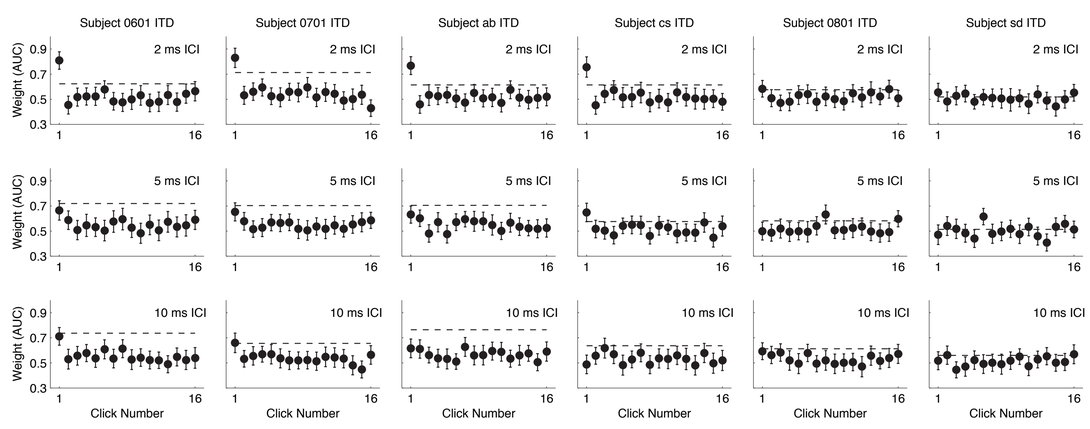
Temporal Weighting Function



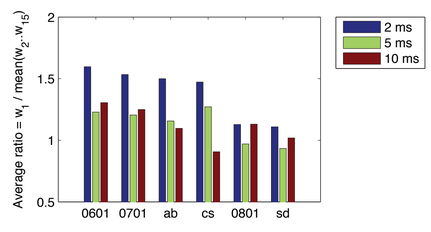
Analysis: use click ITD or ILD to classify response to "target 0" trials.
Area under ROC (AUC) describes dependence of reponses on per-click ITD or ILD.
TWF (above): plot of AUC for each of 16 clicks, and for mean of clicks (dashed line).
95% confidence intservals from 100-repeat bootstrap.

*subjects 0801, sd: -200, +200, 0 μs

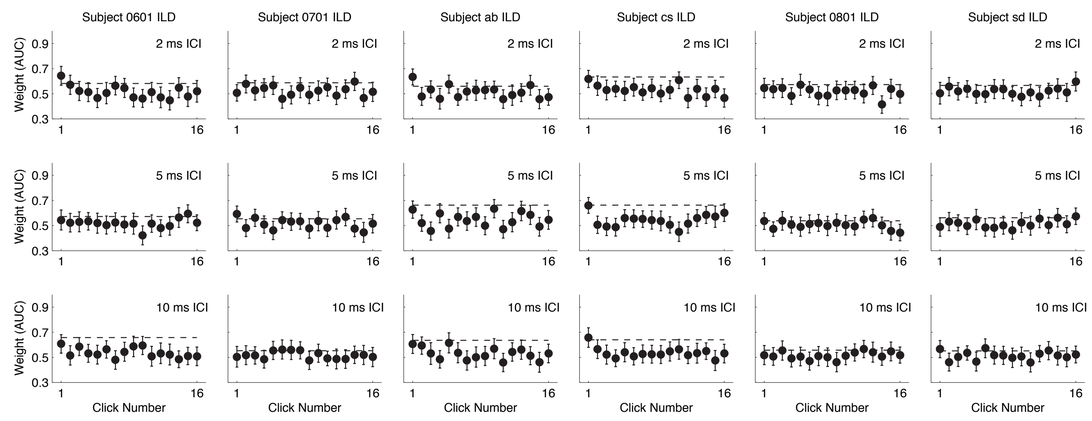
Onset dominance for ITD at high rates



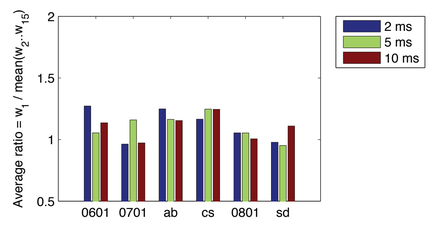
Above: TWFs for ITD among 6 subjects (columns) and 3 ICI values (rows). Onset dominance is clear at 2 ms (AUC for click 1 > AUC for mean ITD) for 4 listeners. Mild onset dominance apparent in other conditions. **Right:** average ratio (click weight 1 / mean of click weights 2-15) quantifies onset dominance at 2 ms ICI (average ratio > 1). For most listeners, average ratio ≈1 at 10 ms ICI.



Lack of onset dominance for ILD



Above: TWFs for ILD among 6 subjects (columns) and 3 ICI values (rows). Onset dominance is minimal to non-existent; in some cases similar to trends among TWFs for ITD at long ICI (but note AUC for mean ILD >= click 1 AUC). **Right:** average ratio near 1 for most listeners quantifies lack of onset dominance.



Conclusions

Onset ITD dominates ongoing envelope ITD at high rates. TWFs for ITD replicate earlier results for ITD discrimination (Saberi 1996), with strong onset dominance at short ICI. Note trend for mild onset dominance at longer ICI; in those cases, mean ITD of all clicks remains best overall predictor of subject response (dashed line).

Failure of onset dominance for ILD at high modulation rate. TWFs for ILD were flat across all tested ICI. Finding is consistent with recent work on ILD discrimination (Stecker 2007), ITD/ILD weighting (Stecker 2008), and interaural sensitivity in bilateral CI users (Seeber & Fastl 2008). Finding is inconsisent with past work on binaural adaptation using ITD and ILD (Hafter et al. 1983,1990).

Lack of clear "upweighting" of late-arriving sound. ILD TWFs did not reveal increasing weights, as hypothesized by Stecker & Hafter (2002) based on freefield TWFs. Thus, upweighting does not simply reflect the time-course of ILD (vs ITD) processing, but instead might reflect processing cues that are in natural agreement or in the context of overt localization (i.e., orientation rather than discrimination) tasks.

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