The precedence effect: Spatial versus cue specificity

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Purpose and background

This study assessed the specificity of the precedence effect for interaural time and level differences (ITD and ILD) matched in subjective lateralization

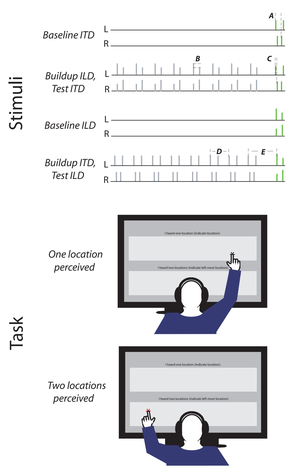
-Normal hearing listeners localize sound sources by responding to early-arriving rather than spurious late-arriving spatial cues - i.e., by localizing direct rather than reflected sound (Wallach et al., 1949)

-The temporal extent of this "precedence effect" is strongly dependent on the stimulus context: baseline echo thresholds of 5-10 ms for "lead-lag" click pairs are "built up" to 10-25 ms by stimulus repetition (e.g., Clifton & Freyman, 1989)

-The dynamic nature of the precedence effect has been attributed to listeners' establishment of a dynamic internal model of auditory space, presumed to depend on high-level (i.e., cortical) processing (e.g., Sanders et al., 2008; Keen & Freyman, 2009)

-However, echo thresholds for ITD and ILD are affected differently by stimulus context (e.g., Krumbholz & Nobbe, 2002; Brown & Stecker, 2011), suggesting that precedence is *cue*-specifc and thus perhaps controlled in part by lower-level mechanisms

Lateralization of headphone ITD and ILD



-Stimuli were 120 μs rectangular pulses presented at ~60 dB SPL over headphones in "lead-lag" pairs or trains of such pairs:

-"Lead-lag delay" (***A***) was varied adaptively to estimate 50% echo threshold

-ITD (***B***) was fixed at ±300 μs; ILD (***C***) was **subjectively matched** for equivalent lateralization (mean=±9.9 dB)

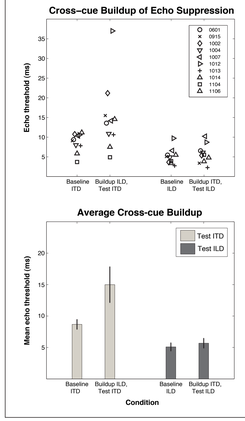
-ITD stimuli were preceded by silence or 12 lead-lag ILD conditioner pairs presented at (***D***) 250 ms ISI, followed by (***E***) a 500 ms pause; ILD stimuli by silence or 12 ITD pairs

-Task was to indicate for test pair the number of locations perceived and lateral position

-If two locations, instructed to indicate *left-most* location perceived

-10 normal-hearing subjects; all exhibited significant within-cue buildup for both ITD and ILD in a previous experiment (Brown & Stecker, 2011)

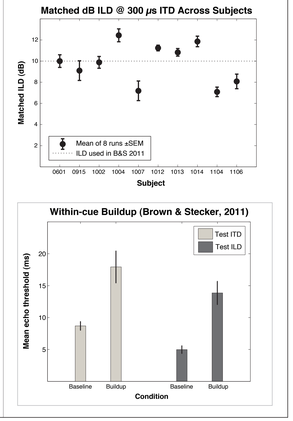
Echo thresholds



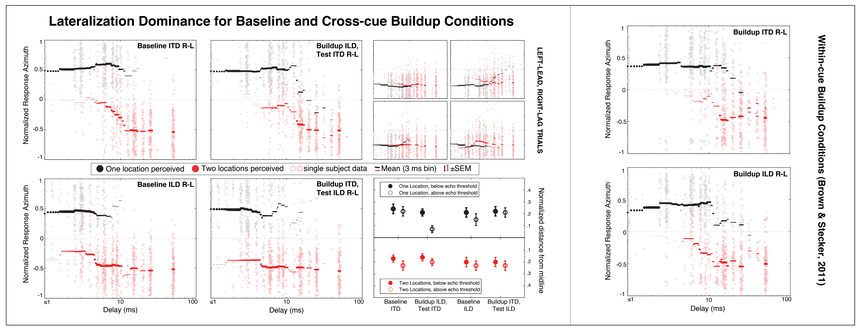
-Baseline fusion echo thresholds were higher for ITD than ILD [$t(9)=5.17$, $p<0.05$] despite equivalent lateralization of tested cue values (cf. Brown & Stecker, 2011, see panels at right)

-Buildup ILD, Test ITD echo thresholds were significantly higher than Baseline ITD echo thresholds [$t(9)=2.65$, $p<0.05$], and did not differ from "within-cue" Buildup ITD thresholds measured previously [$t(9)=1.48$, $p=0.17$]

-Buildup ITD, Test ILD echo thresholds did not differ from Baseline ILD echo thresholds [$t(9)=1.16$, $p=0.27$], and were significantly lower than "within-cue" Buildup ILD thresholds measured previously [[$t(9)=4.18$, $p<0.05$]



Lateralization responses



-"One Location" responses (**black**) were generally lateralized according to the sidedness of the lead; however, the magnitude of lateralization was reduced at "long" delays (lower center right panel, open circles), particularly in the Buildup ILD, Test ITD condition [t(9)=4.50, p<0.05]. Result is consistent with reduced lateralization dominance for fused "built-up" stimuli measured previously in within-cue buildup conditions (right panels), possibly attributable to salient "0 cue" (see Summary and discussion)

-"Two Locations" responses (**red**) at "short" delays (lower center right panel, solid red circles) fell nearer the midline than those at "long" delays (open circles) [t(39)=4.13, p<0.05], and also nearer the midline in ITD than ILD conditions [t(19)=2.34, p<0.05]

Summary and discussion

Evidence for at least partially segregated ITD and ILD precedence effects

-Baseline conditions featured higher echo thresholds and greater lateralization dominance for ITD than equivalent ILD

-"Cross-cue buildup" did not occur for ILD test stimuli preceded by equivalently lateralized ITD conditioner stimuli

-"Switching" from 0 dB ILD in the conditioner to ±~10 dB in the test stimulus produced perception of two new and well-lateralized sources, with no evidence of prior buildup

-Result suggests segregated ITD and ILD buildup effects, consistent with different degrees of echo suppression (i.e., echo thresholds) and lateralization dominance for the two cues

-Fusion data suggest that cross-cue buildup *did* occur for ITD test stimuli preceded by equivalently lateralized ILD conditioner stimuli

-However, midline lateralization for "built-up" stimuli iindicates weak lateralization dominance at built-up delays (as in the within-cue buildup conditions of Brown & Stecker, 2011)

-"0 cue" problem - subjects attending ILD image in Buildup ITD, Test ILD condition should indicate "One Location" regardless of fusion (0 dB ILD in both lead and lag)

-Alternatively, near-midline responses at long delays may indicate diffuse perception (e.g., fusion in the absence of lateralization dominance, or ITD-ILD disagreement)

Additional experiments required to further specify contributions of multiple cues to dynamic precedence effect

-Follow-up experiment will combine nonzero ITD and ILD cues and shift lead and lag in azimuth to differentiate perception of "0 cue" from perception of spatially diffuse image centered at midline

-Additional experiments may employ similar stimuli in anechoic chamber to permit explicit comparison of localization and lateralization

-Experiments in bilateral cochlear implant listeners, who lack sensitivity to ITD, may further specify independent contributions of ITD and ILD to "real-world" precedence

Acknowledgements

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