Buildup, breakdown, and re-buildup of the precedence effect: ITD versus ILD

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The precedence effect

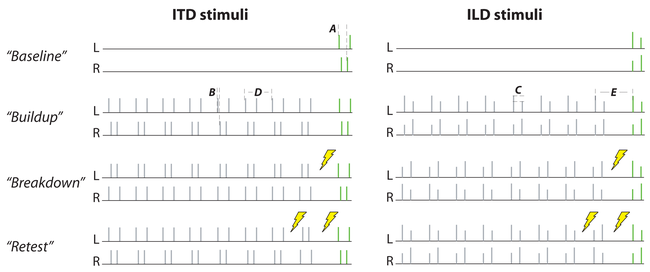
This study assessed (1) the *establishment and maintenance* of context-enhanced "echo suppression" and (2) subjective lateralization for stimuli carrying ITD or ILD under conditions of the precedence effect

-Normal hearing listeners localize sound sources by responding to early-arriving rather than spurious late-arriving directional cues (i.e., by localizing direct rather than reflected sound); this so-called "precedence effect" enables accurate localization in everyday environments (Wallach et al., 1949)

-*Echo threshold* (i.e., temporal delay producing ~50% perception of discrete lag in "lead-lag" stimulus) is modulated by the stimulus context; for impulsive signals, baseline echo thresholds of 5-10 ms are "built up" to 10-25 ms by repetition of the lead-lag stimulus (e.g., Clifton and Freyman, 1989)

-In the free field, such buildup is maintained across presentation of an intervening novel "breakdown" stimulus (e.g., Djelani and Blauert, 2001); under headphones, however, breakdown is nearly exclusive to ILD (Krumbholz and Nobbe, 2002), suggestive of a two-cue mechanism for "dynamic precedence"

Lateralization of headphone ITD and ILD



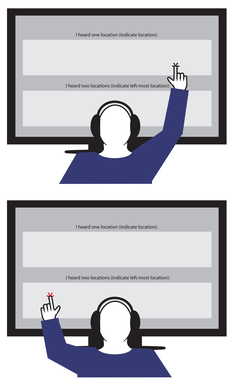
-Stimuli were 120 μs rectangular pulses presented at ~60 dB SPL over headphones in "lead-lag" pairs or trains of such pairs:

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

-ITD (***B***) was fixed at ±300 μs, ILD (***C***) at ±10 dB

-Conditioner consisted of 12 lead-lag pairs with a 250 ms inter-pair interval (***D***)

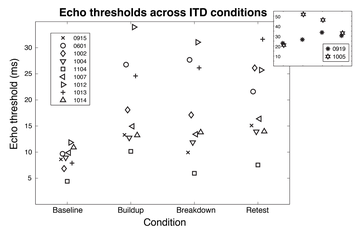
-Final conditioner pair was followed by a 500 ms pause (***E***) and final test pair



-Subject's task was to indicate for test pair the number of locations perceived and lateral position

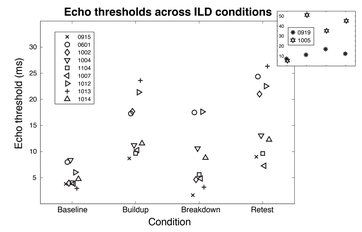
-If two locations, instructed to indicate *left-most* location perceived

Echo thresholds



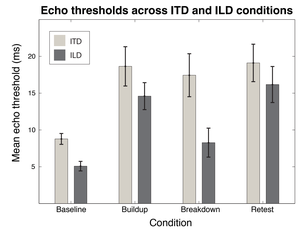
-Buildup > Baseline (t=4.13, p<.025)
-Buildup = Breakdown (t=1.81, n.s.)

-Breakdown > Baseline (t=3.32, p<.025)
-Buildup = Retest (t=0.26, n.s.)



-Buildup > Baseline (t=4.87, p<.025)
-Buildup > Breakdown (t=2.89, p<.025)

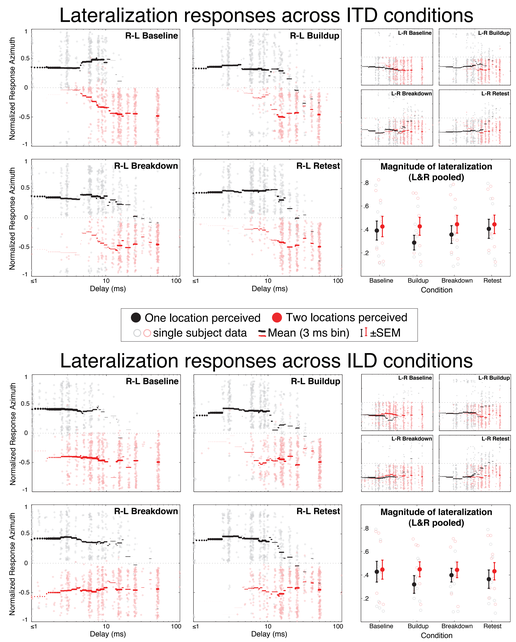
-Breakdown = Baseline (t=2.12, n.s.)
-Buildup = Retest (t=1.71, n.s.)



-Repeated-measures ANOVA:

Main effect of cue (F=23.10, p<.05)
Main effect of condition (F=15.13, p<.05)
Cue × cond interaction (F=4.48, p<.05)

Lateralization responses



-Fused ITD stimuli ("one location," **black**) were lateralized toward the side of the lead, although responses trended toward the *midline* at "long" lead-lag delays in built-up conditions

-When two locations (**red**) were perceived at "short" delays (near echo threshold), lateralization of a left lag appeared to be "pulled" toward the opposing right lead

-Across conditions, the magnitude of lateralization (i.e., the lateral deviation of responses from the midline) was greater when two locations were perceived

-As with ITD, fused ILD stimuli were lateralized toward the side of the lead, although responses trended toward (or across) the midline at longer lead-lag delays (esp. in Buildup and Retest)

-Different from ITD, when two locations were perceived, lateralization of a left lag appeared relatively unaffected by the opposing right lead (i.e., weaker "lateralization dominance")

-As with ITD, the magnitude of lateralization was greater when two vs. one locations were perceived (RM ANOVA pooling ITD and ILD, F=6.39, p<.05)

Summary and discussion

-The precedence effect is more robust for ITD than ILD

-Echo thresholds were greater for ITD than ILD for nearly all subjects across conditions (some individual differences)

-Breakdown of echo suppression *did not occur* for ITD, consistent with Krumbholz and Nobbe (2002)

-Lateralization dominance was stronger for ITD (spatial translocation toward lead of near-threshold lag did not occur for ILD)

-However, "re-buildup" did occur for ILD

-Suggests establishment *and maintenance* of built-up echo suppression can occur for ILD alone

-...although, lateralization responses at long delays in "Buildup" and "Retest" conditions trended toward midline - buildup of "0" cue?

-Two-cue mechanism for dynamic precedence?

-Breakdown not induced by ITD "switch"; suggests free field breakdown is mediated by ILD - downweighting of post-onset ITD due to "implausibility" (cf. Rakerd and Hartmann, 1985)?

-"Cross-cue" interactions in precedence effect? (follow-up study underway)

-Consequences of impovershed binaural sensitivity?

-Insensitivity to ITD (e.g., among bilateral CI users) would be predicted to severely diminish the precedence effect, impairing localization even among listeners with excellent ILD sensitivity

-Future investigation could assess buildup/breakdown in bilateral CI users

Acknowledgements

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References

Clifton, R.K., and Freyman, R.L. (1989). "Effect of click rate and delay on breakdown of the precedence effect," Percept Psychophys 46(2): 139-145.

Djelani, T. and Blauert, J (2001). "Investigations into the build-up and breakdown of the precedence effect," Acta Acustica, 87, 253-261.

Krumbholz, K. and Nobbe, A. (2002). "Buildup and breakdown on echo suppression for stimuli presented over headphones—the effects of interaural time and level differences," J Acoust Soc Am 112(2): 654-663.

Rakerd, B. and Hartmann, W.M. (1985). "Localization of sound in rooms, II: The effects of a single reflecting surface," J Acoust Soc Am 78(2): 524-533.

Wallach, H., Newman, E.B., and Rosenzweig, R. (1949). "The precedence effect in sound localization," Am J Psych, 62(3): 315-336.

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