Are Envelope Fluctuations Necessary for Binaural Cue Extraction?

A. C. Diedesch and G. C. Stecker

Department of Hearing and Speech Sciences, Vanderbilt University

#439

The Questions:

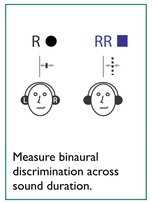
How do onsets and other envelope fluctuations shape binaural cue sensitivity?

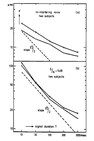
Do such effects vary across stimuli?

Do they vary across binaural cue type?

Approaches

Temporal Integration



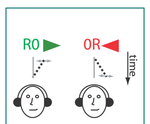


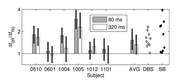
Houtgast & Plomp, 1968

- Onset dominance evidenced by shallow threshold-duration slope

Used in:
- Discrimination (Stecker & Bibee, 2014)
- Lateralization (Houtgast & Plomp, 1968)

Dynamic Cues



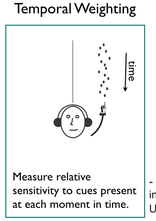


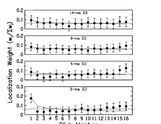
Stecker & Bibee, 2014

- Onset dominance evidenced by threshold difference 0R > R0

Used in:
- Discrimination (e.g. Stecker & Brown, 2010, Stecker & Bibee, 2014)
- Lateralization (Dietz et al., 2013)

Temporal Weighting



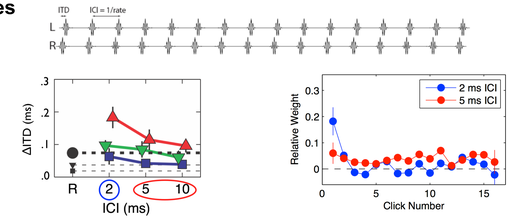


Stecker & Hafter, 2002

- Onset dominance evidenced by increased click - 1 weight

Used in:
- Discrimination (Brown & Stecker, 2010)
-Lateralization (Stecker et al., 2013)

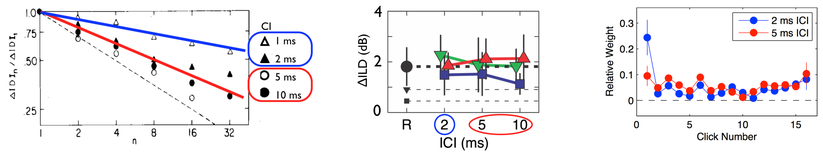
Rate-dependent onset dominance for interaural time difference (ITD) in periodically modulated high-frequency tones



Hafter & Dye, 1983, *JASA* | Stecker & Brown, 2010, *JASA* | Stecker et al., 2013, *JASA*

1. At **high modulation rates** (> 200 Hz, ICI < 5 ms), all approaches reveal onset dominance for (envelope) ITD at high frequencies. For example, the first click in a train dominates the lateral impression.
2. At **low modulation rates** (ICI ≥5 ms), ongoing information contributes more. *Each click* contributes as much binaural information as the first.

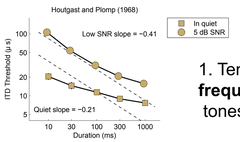
Rate-dependent onset and offset dominance for interaural level difference (ILD) in periodically modulated high-frequency tones



Hafter, Dye, & Wenzel, 1983, *JASA* | Stecker & Brown, 2010, *JASA* | Stecker et al., 2013, *JASA*

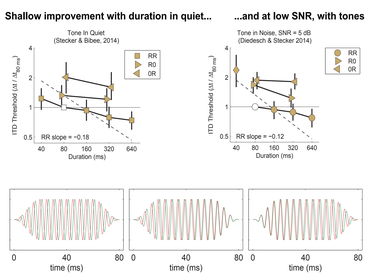
1. At **high modulation rates** (> 200 Hz, ICI < 5 ms), the ILD cue present at sound onset is more heavily weighted than that of the ongoing sound. Sound offset additionally contributes.
2. Similiar to ITD, at **low modulation rates** (ICI ≥5 ms), ongoing information contributes more. *Each click* contributes nearly equally, although late-arriving ILD may still receive increased weight.

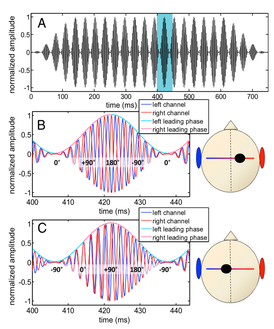
Enhanced sensitivity to low-frequency, fine-structure ITD during positive envelope fluctuations (i.e., onsets, attacks, and modulation periods)



1. Temporal-integration and dynamic-cue studies evaluating **unmodulated low-frequency tones** reveal similar results to rapidly modulated high-frequency tones. Strong onset dominance present, even with *diotic* envelopes.

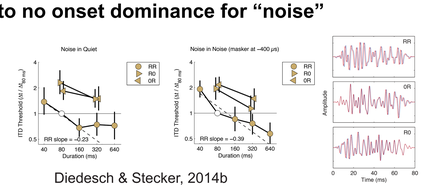
2. For **slowly modulated tones** (~30 Hz, Dietz et al., 2013), *each modulation period* contributes to the lateral impression, via fine-structure ITD present during its *rising portion*.



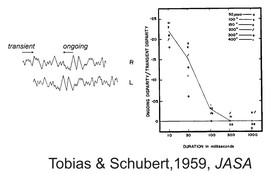


Dietz, et al., 2013, *PNAS*

Little to no onset dominance for "noise"



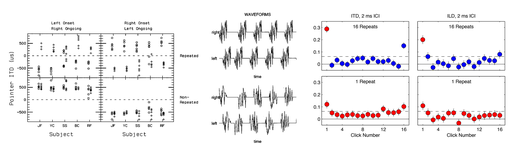
Diedesch & Stecker, 2014b



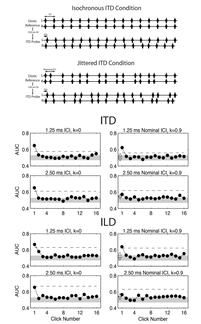
Tobias & Schubert,1959, *JASA*

1. For **stochastic signals**, numerous studies have revealed greater sensitivity to *ongoing* binaural information:

- "fresh" vs. "frozen" noise (Freyman et al., 1997, Stecker, 2013).
- temporally irregular amplitude modulation (Laback & Majdak, 2008, Goupell et al., 2009, Brown & Stecker, 2011).
- lateralization of broadband noise (Tobias & Schubert, 1959).
- ITD sensitivity in noise masking (Houtgast & Plomp, 1968, Diedesch & Stecker, 2014b).



Freyman, et al., 1997, *JASA* | Stecker, 2013, *POMA*



Brown & Stecker, 2011, *JASA*

What's going on?

Good binaural sensitivity at:
a. Sound onset
b. Each modulation event when the rate is *slow* (≥5 ms ICI)
c. When the envelope is irregular (e.g. noise)

In each case, it appears that binaural sensitivity is high when [within-band] envelope fluctuations are present.

RESTART* theory:

The representation of binaural spatial information is triggered by transient increases in the temporal envelope (Houtgast & Plomp 1968, Abel & Kunov 1983, Nelson & Takahashi 2010, Dietz et al. 2013, 2014).

Possibly due to adaptation in binaural inputs (i.e., AVCN neurons, Hafter et al. 1988) that enhance binaural processing around such events.

Or could reflect active gating of binaural information by onset detectors (e.g. Octopus cells).

All types of binaural cues are affected: envelope ITD, fine-structure ITD, ILD, etc.

(Re)triggering inhibited during refractory period of 2-10 ms ("rate limitation" Bernstein & Trahiotis 2002 / "binaural adaptation" Hafter & Dye 1983)

Sensitive to fluctuations within single auditory frequency channels; compare stochastic vs periodic noise

Changes in temporal or spectral envelope (gaps, frequency shifts) initiate new triggers ("restarting," Hafter & Buell 1990)

Events slower than 100-200 Hz (e.g. syllables) localized as independent items ("objects"? Darwin & Hukin 1999).

Successive fast events are "fused" into a common representation, which is localized on the basis of cues present at overall onset.

A sufficient temporal gap breaks a sound into two events; temporal integration across–but not within–such events can be optimal (Hafter & Buell 1990).

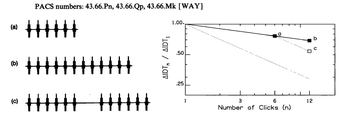
Restarting the adapted binaural system[a)]

Ervin R. Hafter and Thomas N. Buell[b)]
Department of Psychology, University of California, Berkeley, California 94720

(Received 2 May 1989; accepted for publication 9 March 1990)

Previous experiments using trains of high-frequency filtered clicks have shown that for lateralization based on interaural differences of time or level, there is a decline in the usefulness of interaural information after the signal's onset when the clicks are presented at a high rate. This process has been referred to as "binaural adaptation." Of interest here are the conditions that produce a recovery from adaptation and allow for a resampling of the interaural information. A train of clicks with short interclick intervals is used to produce adaptation. Then, during its course, a treatment such as the insertion of a temporal gap or the addition of another "triggering" sound is tested for its ability to restart the binaural process. All of the brief triggers tested are shown to be capable of promoting recovery from adaptation. This suggests that, while the binaural system deals with the demands of high-frequency stimulation with rapid adaptation, it quickly cancels the adaptation in response to stimulus change.

PACS numbers: 43.66.Pn, 43.66.Qp, 43.66.Mk [WAY]



*RESTART is an unfilled "backronym." Suggestions welcome.

Acknowledgements

This work was supported by the National Institute of Health (R01 DC011548 [G.C.S.]). Portions of this poster were presented at ASA's Fall 2014 meeting in Indianapolis, IN.

Contact Anna.C.Diedesch@Vanderbilt.edu with questions, or download a copy of this poster at: spacelab.spatialhearing.org

References

Abel & Kunov, 1983, *JASA*, 73: 955-960
Bernstein & Trahiotis, 2002, *JASA,112: 1026-1036*
Brown & Stecker, 2011, *JASA*, 129: 293-300
Darwin & Hukin, 1999, *J Exp Psych*, 25: 617-629
Diedesch & Stecker, 2014, *Poster presented at ARO*
Diedesch & Stecker, 2014b, *Poster presented at ASA*
Dietz, et al., 2013, *PNAS*, 110: 15151-15156
Dietz, et al., 2014, *J Neurophys*, 111: 1973-1985
Freyman, et al., 1997, *JASA*, 101: 1649-1659
Goupell, et al., 2009, *JASA*, 126: 2511-2521
Hafter & Buell, 1990, *JASA*, 88: 806-812
Hafter & Dye, 1983, *JASA*, 73: 644-651
Hafter, et al., 1983, *JASA*, 73: 1708-1713
Hafter, et al., 1988, Ch 22 in Edelman et al.
Houtgast & Plomp, 1968, *JASA*, 44: 807-812
Laback & Majdak, 2008, *PNAS*, 105: 814-817
Nelson & Takahashi, 2010, *Neuron*, 67: 643-655
Stecker & Bibee, 2014, *JASA*, 135: 3541-3547
Stecker & Brown, 2010, *JASA*, 127: 3092-3103
Stecker & Hafter, 2002, *JASA*, 112: 1046-1057
Stecker, 2013, *POMA*, 19: 050166
Stecker et al., 2013, *JASA*, 134: 1242-1252
Tobias & Schubert, 1959, *JASA*, 31: 1595-1605