Effects of hearing aid venting and reverberation on narrowband localization in free field: a study of young normal hearing listeners fit with low-gain, linear amplification

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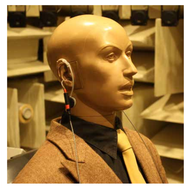
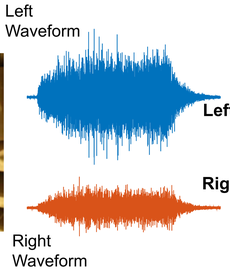
VANDERBILT

Data Collection - Acoustic Recordings





Pre-processing

Gammatone filterbank

Left Input

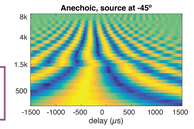
Right Input

28 frequencies 250-8000 Hz
(1 ERB per channel)

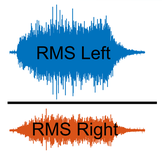
Analysis - Acoustic Recordings

Binaural
Cross-Correlation
Akeroyd (2001)

Freq. Specific ITD by cross-correlation

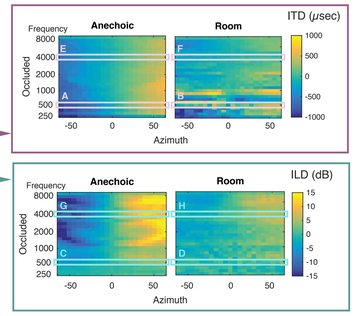


Freq. Specific ILD by RMS ratio

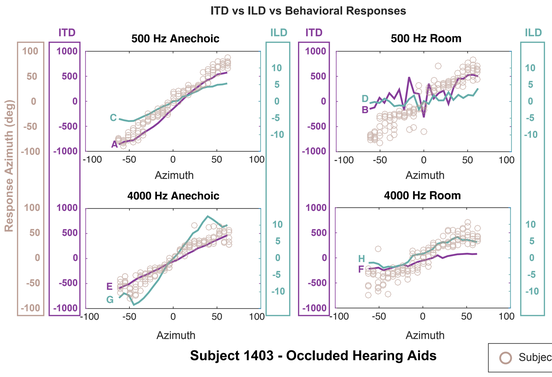


Intensity Difference Calculation
20 x log10 (rmsLeft/rmsRight)

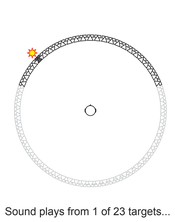
Results - Acoustic Recordings

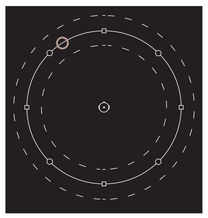


Results - Measured ITD & ILD vs Sound Localization



Sound Localization Task





INTRODUCTION

Echoes and reverberation distort interaural time (ITD) and level (ILD) difference cues needed for localization in the horizontal plane. Hearing aid venting, such as with open-fit amplification, may further contribute to distorted interaural cues due to interactions between acoustic and processed sound.

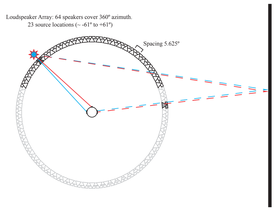
Here, we measured frequency specific interaural cues using probe-tube microphones and compared acoustic recordings to sound localization performance for narrowband noises (500 & 4000 Hz) across hearing aid and room conditions.

Ideally, as interaural cues become distorted in rooms or by open-fit hearing aids, listeners should be able to alter their interaural cue-weighting to the more stable cue. Interaural cue ratio (ICR) may be a useful measurement to track cue-weighting across test conditions and clinical populations.

METHODOLOGY

Participants

-10 young normal hearing adults
2 males, mean age 28 (7.1 SD)
-KEMAR



Test Conditions

Rooms

Anechoic
-Vanderbilt University's Anechoic chamber
-23 target locations ±61° azimuth
Simulated Room
-four virtual walls (α=0.5)
-5m left/right, 6.67m front, 3.33m behind
-image method (Allen & Berkley, 1979)
-simulated 13 orders of lateral reflection

Hearing Aids

Occluded foam tip
Open-dome
Unaided

-Siemens Motion 700 BTEs
-Linear, low-gain amplification
-Noise reduction, microphone directionality, and feedback suppression turned off

Stimuli

Broadband noise (Acoustic Recordings)

500, 4000, 500+4000 Hz Narrowband noise (Behavioral Testing)

RESULTS

Acoustic Recordings

Anechoic → Simulated room
– reduced ILD
– erratic ITD across frequency
Across hearng aids
– differences were less clear
Diedesch & Stecker (2016a, 2016b)

Sound Localization

Localization error
Occluded > Open-fit > Unaided
Room > Anechoic
500 Hz > 4000 Hz > 500+4000 Hz

Localization gain
500 Hz – expanded (slope > 1)
4000 Hz – compressed (slope < 1)
500+4000 Hz – accurate (slope = 1)

Diedesch & Stecker (2016c)

Interaural Cue Ratio

Across rooms - for some listeners:
Room > Anechoic
-As ITD became erratic, increased weight on ILD

Across Stimulus:
500 Hz > 4000 Hz

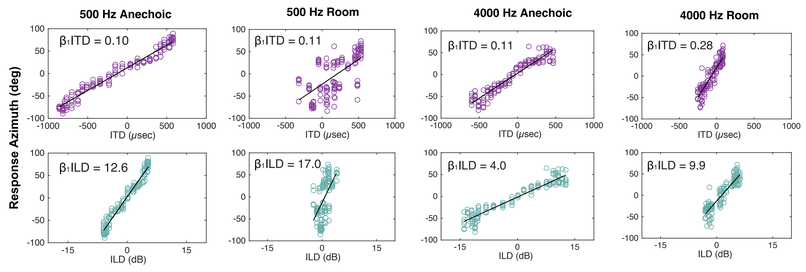
Across Hearing aids:
Differences were less clear

Multiple Linear Regression

ITD (μsec) vs Behavioral Thresholds

ILD (dB) vs Behavioral Thresholds

Interaural Cue Ratio (μsec/dB)



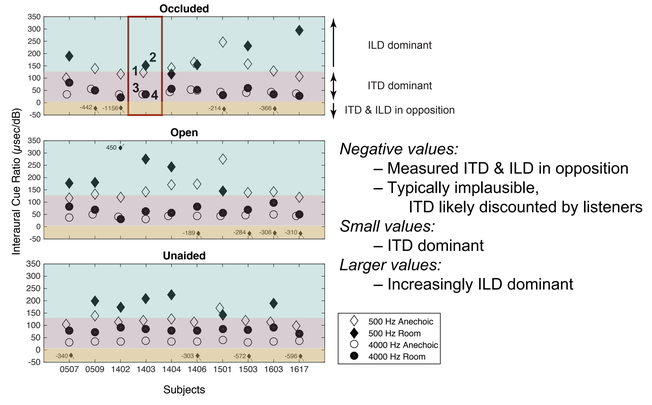
1. ICR = 124.3 μsec/dB **2**. ICR = 152.1 μsec/dB **3**. ICR = 34.8 μsec/dB **4**. ICR = 35.6 μsec/dB

Multiple linear regression was used to evaluate behavioral responses as predicted by measured ITD and ILD. Regression coefficient β_1 (slope of linear fit), represents deg/μsec ($\beta_1 ITD$) and deg/dB ($\beta_1 ILD$).

Here, data were evaluated for interaural cue ratio (ICR) to describe changes in μsec/dB across azimuth for each stimulus, room, & aided condition:

$$ICR = (\beta_1 ILD / \beta_1 ITD)$$

Interaural Cue Ratio - Results



Negative values:
– Measured ITD & ILD in opposition
– Typically implausible, ITD likely discounted by listeners
Small values:
– ITD dominant
Larger values:
– Increasingly ILD dominant

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OHSU VA RR&D NCRAR

References:
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Allen & Berkley (1979), JASA 65(4)
Diedesch & Stecker (2016a), ARO, abs 39
Diedesch & Stecker(2016c), JASA, 139(4)
Diedesch & Stecker (2016b), AAS, 41(1)

FUTURE DIRECTIONS

The interaural cue ratio (ICR) shows individual differences in binaural cue-weighting across independent variables: hearing aids, simulated reverberation and stimuli. This may be a useful tool to predict localization peformance with open-fit hearing aids in reverberant scenes.

In the future, ICR will be used to evaluate interaural cue weighting across clinical populations (i.e. aging and hearing impaired populations).