



# Assessing Changes to Interaural Cues as a Consequence of Open-fit Hearing Aids and Simulated Rooms

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## Background

Interaural time differences (ITD) and interaural level differences (ILD), the major cues for horizontal localization, are susceptible to distortion by multipath acoustics (e.g., reverberation, echoes, and standing waves). Particular styles of hearing aids could additionally interact with sound localization cues. Specifically, open-fit hearing aids mix two copies (processed and unprocessed) with a slight (~2-5 ms) delay. Here, we assessed binaural recordings of broadband noise to estimate ITD and ILD in a frequency specific manner.

## Methods

### Test Conditions



#### Room

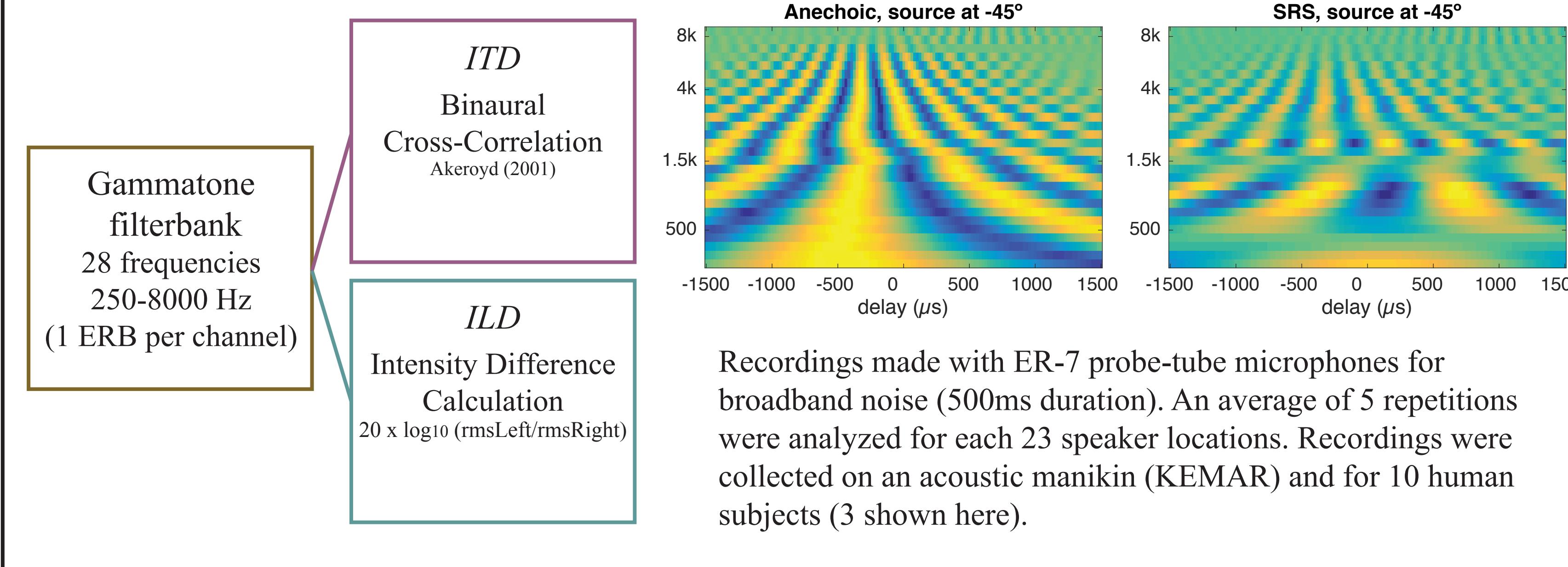
- Anechoic
- Single Reflective Surface (SRS)
  - 80% reflective ( $\alpha=0.2$ )
  - 5m to the right, parallel to listeners forward gaze
- Simulated Room
  - four virtual walls ( $\alpha=0.5$ )
  - 5m left/right, 6.67m front, 3.33m behind
  - image method (Allen & Berkley, 1979)
  - simulated 13 orders of lateral reflection

Loudspeaker Array: 64 speakers cover 360° azimuth.  
23 source locations (-61° to +61°)  
Spacing 5.625°

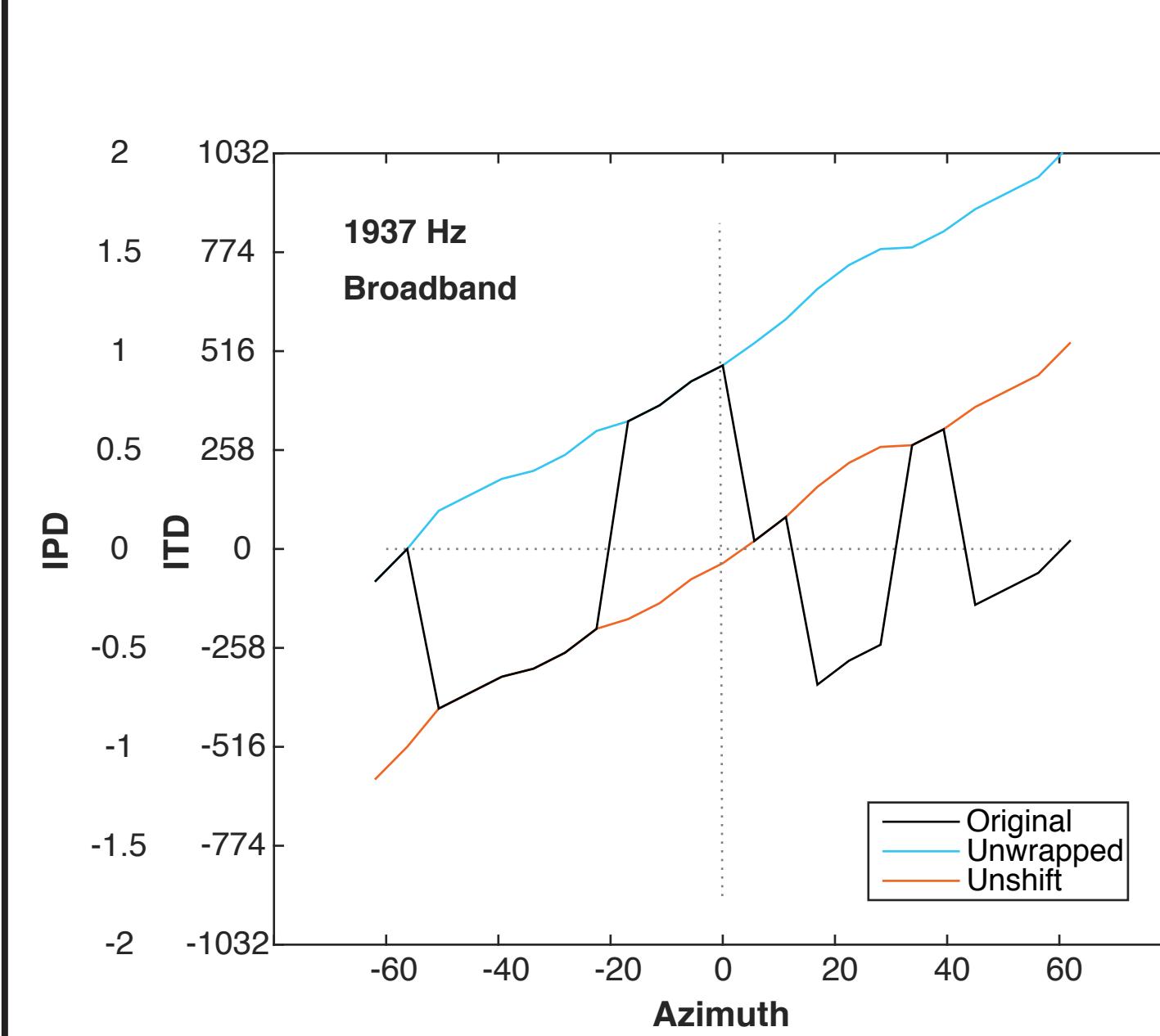
#### Hearing Aids

- Occluded foam tip
- Open-dome
- Unaided

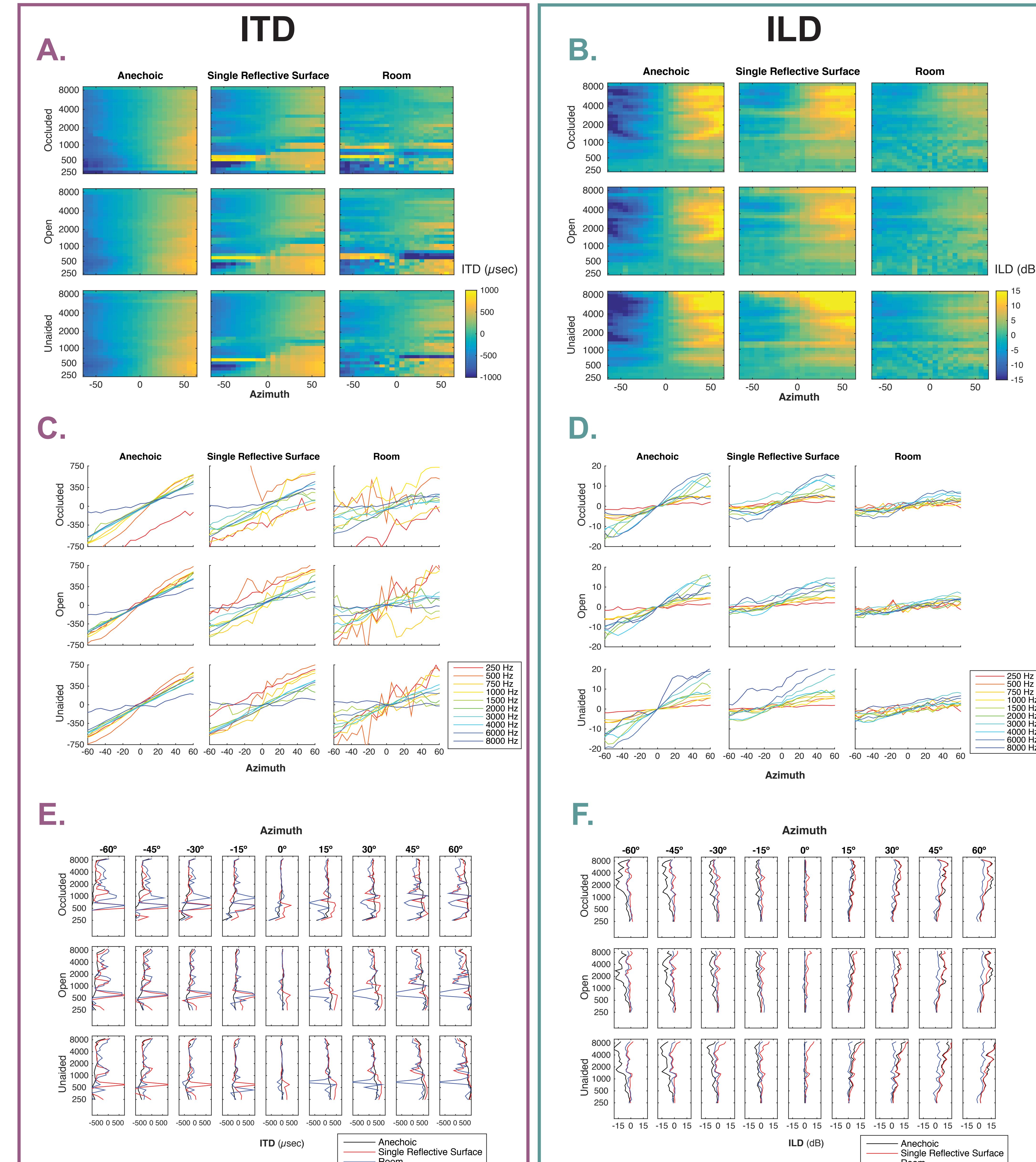
### Binaural Cue Estimation from Recordings



### Normalization



## Acoustic Recordings



Normalized ITD (left panel) and ILD (right panel) data for representative subject 1403. (A,B,C,D) Panels represent aided (rows) and room (columns) conditions. (A,B) plots ITD or ILD for each 28 frequency bands (y-axis) and 23 speakers (x-axis). (C,D) plots ITD or ILD (y-axis) for 10 of the 28 frequency bands. Frequencies are represented by colored lines (red/oranges = low frequencies, yellows/greens = mid frequencies, and blue/purple = high frequencies) across 23 speaker locations (x-axis). Individual panels represent each room and hearing aid combination. (E,F) Panels represent aided conditions (rows) across 9 speaker locations (columns). Lines plots ITD or ILD for each room condition (Anechoic = Black, SRS = Red, Room = Blue).

### Acknowledgements:

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### References:

Akeroyd (2001), Binaural CC Toolbox for Matlab  
Allen & Berkley (1979), JASA 65(4)  
Mills (1960), JASA 32(1)  
Kuhn (1977), JASA 62(1)

## Summary & Discussion

### Effect of Room

- With increasing reflections (Anechoic → SRS → Room):
- Diminished ILD cues
  - Erratic ITD cues

ITD in low-frequency bands show strong opposing cues. These large ITD distortions are inconsistent with ILD cues within those frequencies.

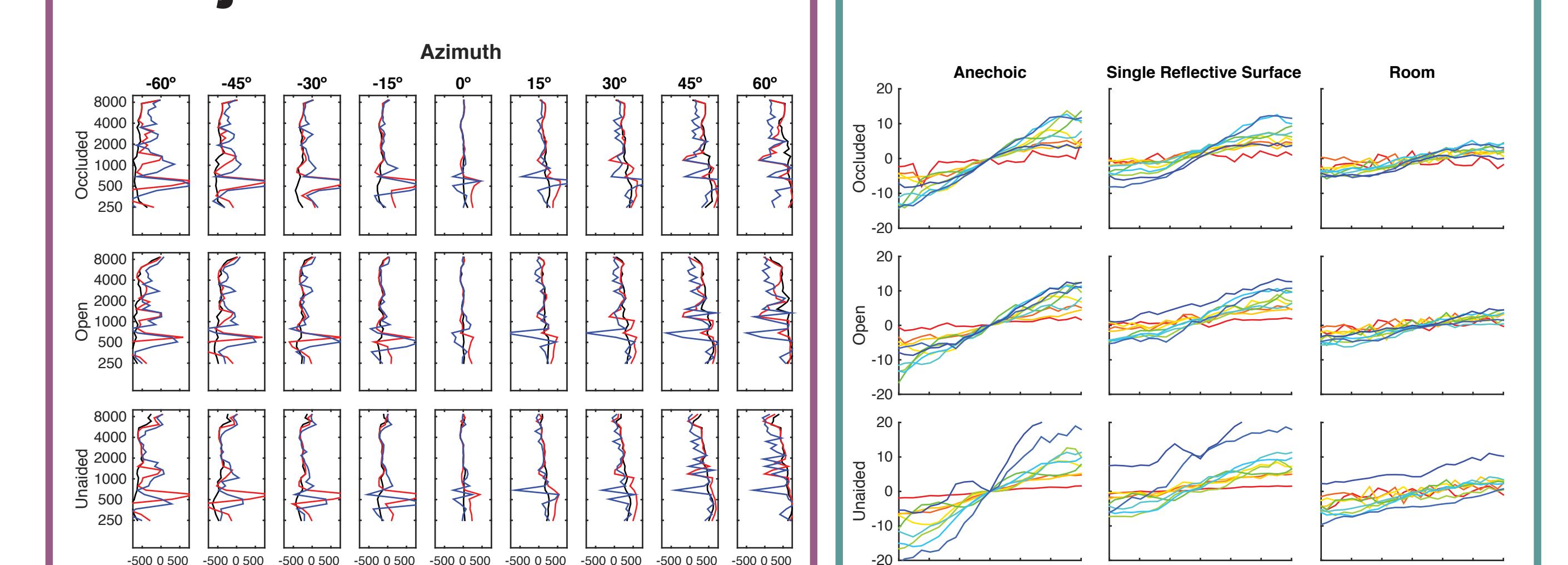
### Effect of Hearing Aids

- Results across hearing aid conditions are less clear

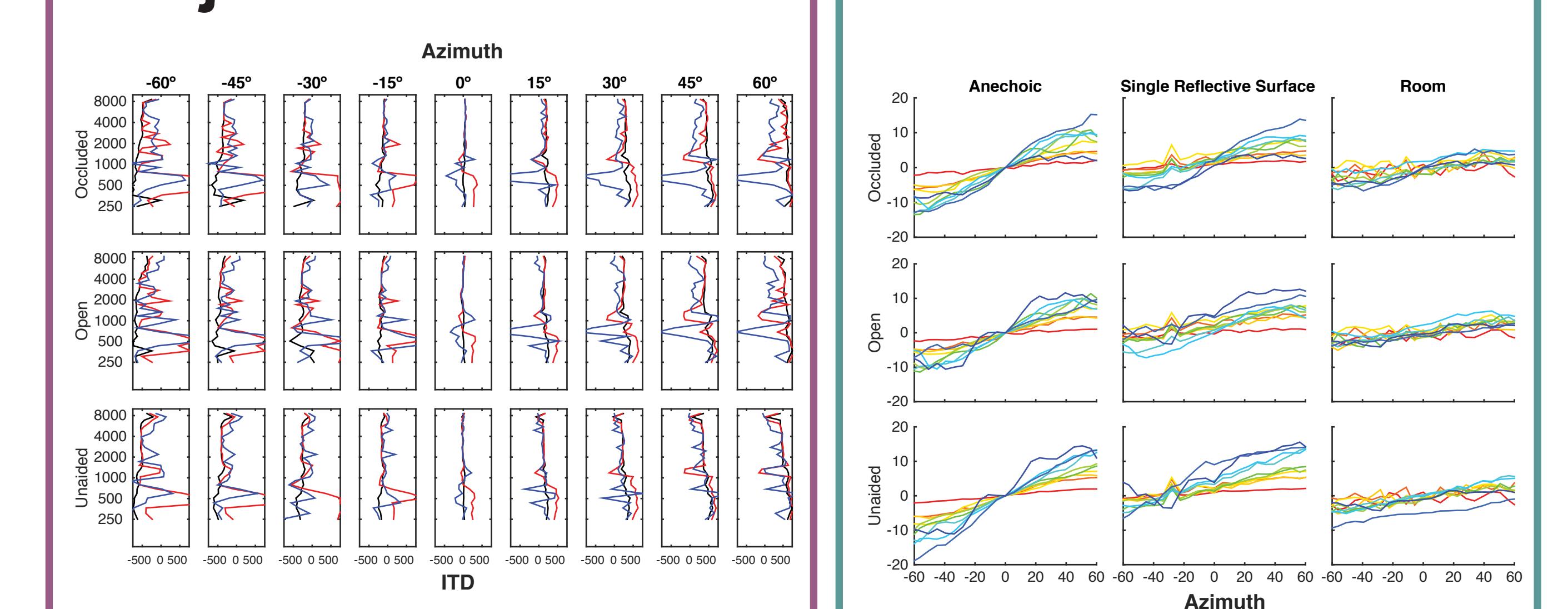
This suggests that in most cases spatial deficits of hearing aid listening are mainly caused by signal processing (e.g., wide dynamic range compression, directional microphones, microphone location, etc.) rather than acoustical effects from venting.

While hearing aid venting does not appear to have much of an effect on interaural cues, large ITD distortions in low-frequency bands may be particularly relevant to hearing aid users with normal low-frequency thresholds wearing open-fit devices. Future work investigates behavioral responses to listeners wearing hearing aids with occluded and open-fit coupling.

### Subject 1402:



### Subject 1603:



### KEMAR:

