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The dominance of ILD cues when tracking talkers in real-room reverberation

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Introduction

- Listeners can selectively attend to ('track') a single talker in the presence of other, simultaneous talkers, even in reverberant conditions
- Diverse signal characteristics can help listeners track a speech message over time (e.g. , a filtering difference; Spieth and Webster, 1955)
- Two main sources of such 'tracking cues' in real rooms:
  1. Cues from differences in spatial position such as the interaural time and level relationships (ITD & ILD, Broadbent, 1954; Darwin and Hukln, 2000)
  2. Cues from differences in talker characteristics such as pitch and vocal-tract size (Darwin and Hukin, 2000)
- Interaural cues are corrupted by reverberation in rooms (Kidd et al., 2005), whereas talker-difference cues are very resistant to reverberation (Darwin and Hukin, 2000)
- So, in real-room talker-tracking, do listeners simply ignore the corrupted cues from spatial position and rely on cues from talker differences?

Experimental paradigm

- Listening task where cues from talker- and spatial-differences are in conflict, and where listeners' responses indicate which cue they're tracking
- Based on Darwin and Hukin's (2000) paradigm, where listeners hear two simultaneous messages played in a (simulated) room:

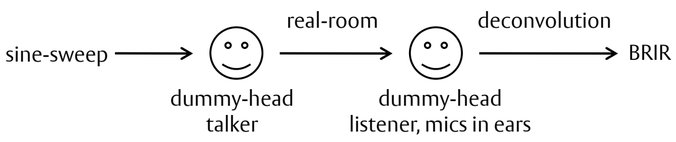
Target sentence: "**On this trial you'll get the word <> to select"**

Distractor sentence: "**You'll also hear the sound <> played here**"

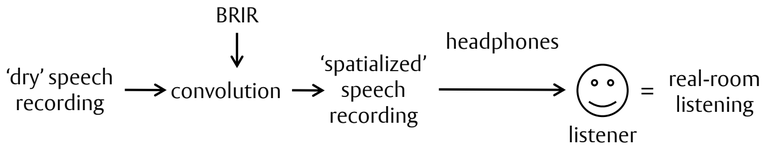
- Recorded with 1 female and 2 male talkers, along with two test words: "**bead**" and "**globe**", which were spliced into the <> position and time-aligned
- Messages and test words were individually 'spatialised ' to vary cues from spatial position-differences
- Listeners were asked to attend to the target message and report which test word they perceived as belonging in it

Real-room spatialisation

- Binaural Room Impulse Responses (BRIRs), recorded in a room using the swept-sine method (Farina, 2000):



- BRIRs were used to spatialise 'dry' speech recordings:

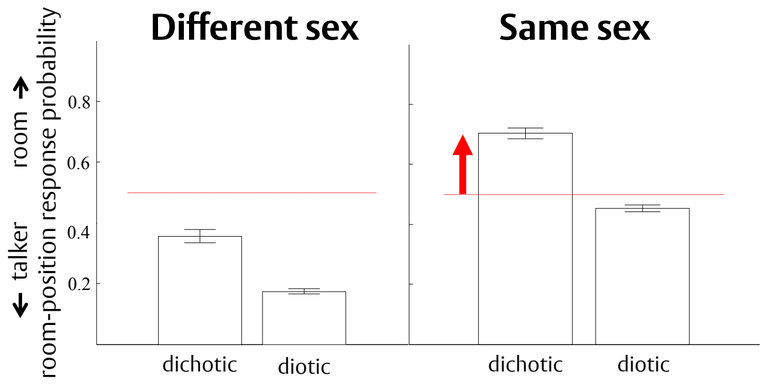


- Corrections were applied for the frequency responses of the headphones and dummy-head talker

Design

- Diverse room-position pairs were used, varying the distance between listener and talkers (0.65, 1.25, 2.5 and 5m), the bearing separation between talkers (+/- 25^0 and +/- 5^0), and both (e.g., a 0.65 m distance at $+5^0$ with a 5 m distance at -5^0)
- Listening was either dichotic, or diotic with the L or R channel presented to both ears and matched to the dichotic level
- The dependent variable was the probability of a room-position response from a listener, averaged across all room-position pairs

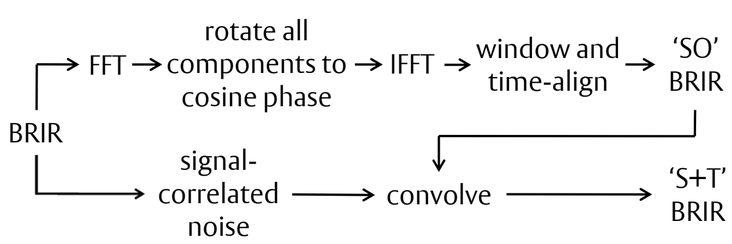
Results: Talker differences



- Talker-difference tends to dominate over room-position, particularly for the different-sex pair
- However, room position is not always ignored, and can be dominant for same-sex pairs ***in dichotic conditions***

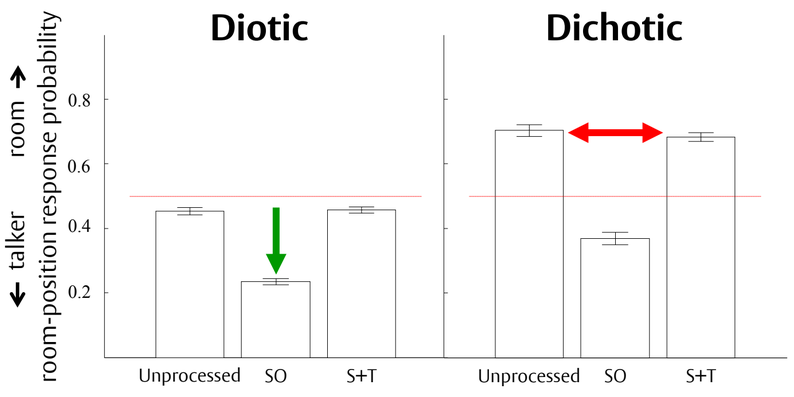
BRIR processing

- To investigate which cues from position are responsible for this dichotic effect, the BRIRs were processed to limit the cues available to listeners as follows:



- Spectral-Only ('SO') BRIRS:
  – all ITDs and temporal-envelope 'tails' are removed
  – leaves only spectral-envelope and level (e.g. ILD) info.
- Spectral-plus-Temporal-envelope ('S+T') BRIRS:
  – as 'SO' but with 'tails' restored

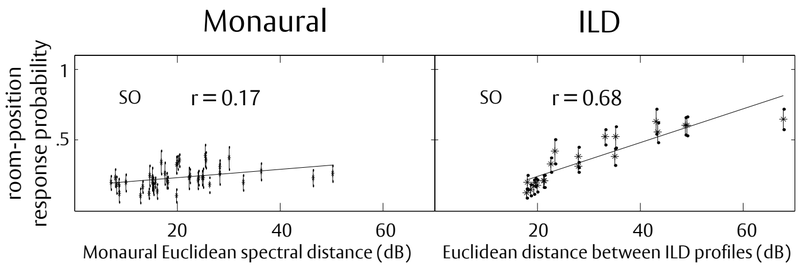
Results: Processed BRIRs



- Talker dominates in diotic conditions, particularly when there are no 'tails'
  – suggests 'tails' disrupt pitch cues (Culling et al., 1994)
- Room position dominates in dichotic conditions, **even in the absence of ITD cues**

Spectral distance between BRIRs

- In dichotic conditions, when listeners track by room-position, do they 'select' the ear with the bigger spectral-distance between the two messages?
- An 'auditory' (gammatone) filter-bank analysis allows calculation of *monaural* spectral distances (d) between the BRIRs in an ear (Euclidean distance, d = the rms of the pairwise dB differences in frequency channels)



- In SO, *diotic* conditions, there is only a weak correlation between monaural spectral distance and room-position response probability
- So ear selection on the basis of these monaural distances seems unlikely to be the origin of the dichotic effect

Spectral distance between ILD profiles

- In dichotic conditions, do room-position responses increase with the ILD difference between the two messages?
- Subtracting a BRIR's L-channel filter-bank spectrum from its R-channel spectrum gives an ILD 'profile' for that position
- The ILD-difference of the two messages is therefore the rms of the differences between their ILD profiles
- These ILD-differences are strongly correlated with the probability of a room-position response ($r^2 = 0.46$)
- So the dichotic effect seems to arise through *inter*-aural processing ***of ILD***

Conclusions

- When tracking a talker, cues from talker differences are not always dominant. Cues from position differences can sometimes be more influential - even in reverberation
- This is mostly seen when talker differences are subtle, listening is dichotic, and pitch cues are degraded
- The cues from position differences are not the messages' ITDs. They seem to be the ILDs - which still differ among positions in a typical room
- This dichotic effect doesn't seem to arise through listeners 'selecting' an ear – it seems to be due to inter-aural processing

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