4aPPa3

Effects of reverberation and experience on distance perception in simulated environments

Matthew Schoolmaster[1,2], Norbert Kopčo[1,2,3], and Barbara G. Shinn-Cunningham[1,2,4]

[1]Hearing Research Center, [2]Dept of Cognitive and Neural Systems, Boston University [3]Technická Univerzita, Košice, Slovakia [4]Dept of Biomedical Engineering, Boston University

1. BACKGROUND: DISTANCE PERCEPTION

For nearby sources (up to 1 m), in real anechoic space distance perception is
- fairly accurate
- worse for medial than lateral sources (Brungart, 1998)

Distance perception is better in reverberant space than anechoic, even for nearby sources (Santarelli, 2001)

In rooms, there is a learning effect: distance performance improves with experience (Shinn-Cunningham, 2000)

Learning effects generalize to different listeners locations in the same room (Kopco, 2003)

2. CURRENT STUDY

Examine learning effects on distance perception: Is consistent experience necessary for learning?

Measure distance perception in simulated environments

Two block types, differing in consistency of experience
- MIXED: environment changes from trial to trial
- FIXED: environment is fixed throughout a run of 45 trials

Two listener groups, differing in block order
- FIXED blocks, then MIXED (FIXED - MIXED)
- MIXED blocks, then FIXED (MIXED - FIXED)

Three room conditions, differing in reverberation

Two sound source directions (medial and lateral)

HYPOTHESES

FIXED results will be better than MIXED

Experience will be more helpful in FIXED than MIXED

Listeners hearing FIXED first may transfer learning to MIXED (there will be differences between listener groups)

Reverberation will improve performance

Lateral performance will be better than medial (especially without reverberation)

3. METHODS

EXPERIMENTAL PROCEDURES

Eight normal hearing subjects (3F, 5M)

Source Stimuli
- Five 150-ms-long pink noise bursts (30-ms gaps)
- roved by 15 dB from trial to trial
- headphone presentations, simulating different source locations and room conditions

Source Locations (see Figure 1)
- Nine distances (15 to 170 cm, log spaced)
- Two directions (medial and lateral)

Room conditions
- anechoic, center, and corner

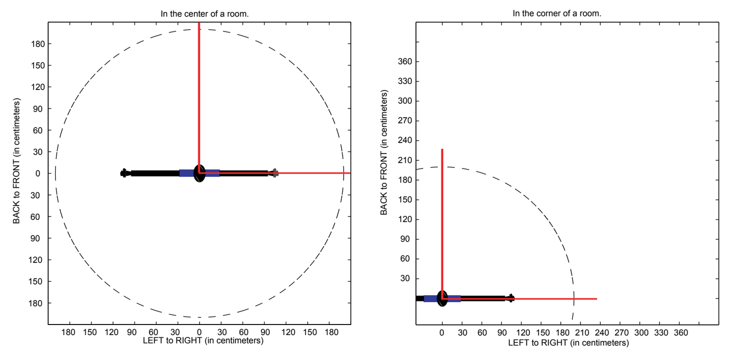


Figure 1 Screen shots from the experiment. Subject used a mouse to click perceived location.

Each trial
- subject informed about room condition
- simulated source presented
- subject indicated heard position on screen (Figure 1)

Each subject performed two blocks, FIXED and MIXED

FIXED
- six sessions
- each session held room condition fixed (random order)
- session consisted of eight runs (random order)
- runs (45 trials) held direction (lateral / medial) fixed
- nine distances presented randomly within run

MIXED
- six sessions, each eight runs long
- runs (45 trials) held direction (lateral / medial) fixed
- nine distances presented randomly within run
- room condition randomly selected from trial to trial

Two subject groups
- MIXED-then-FIXED
- FIXED-then-MIXED

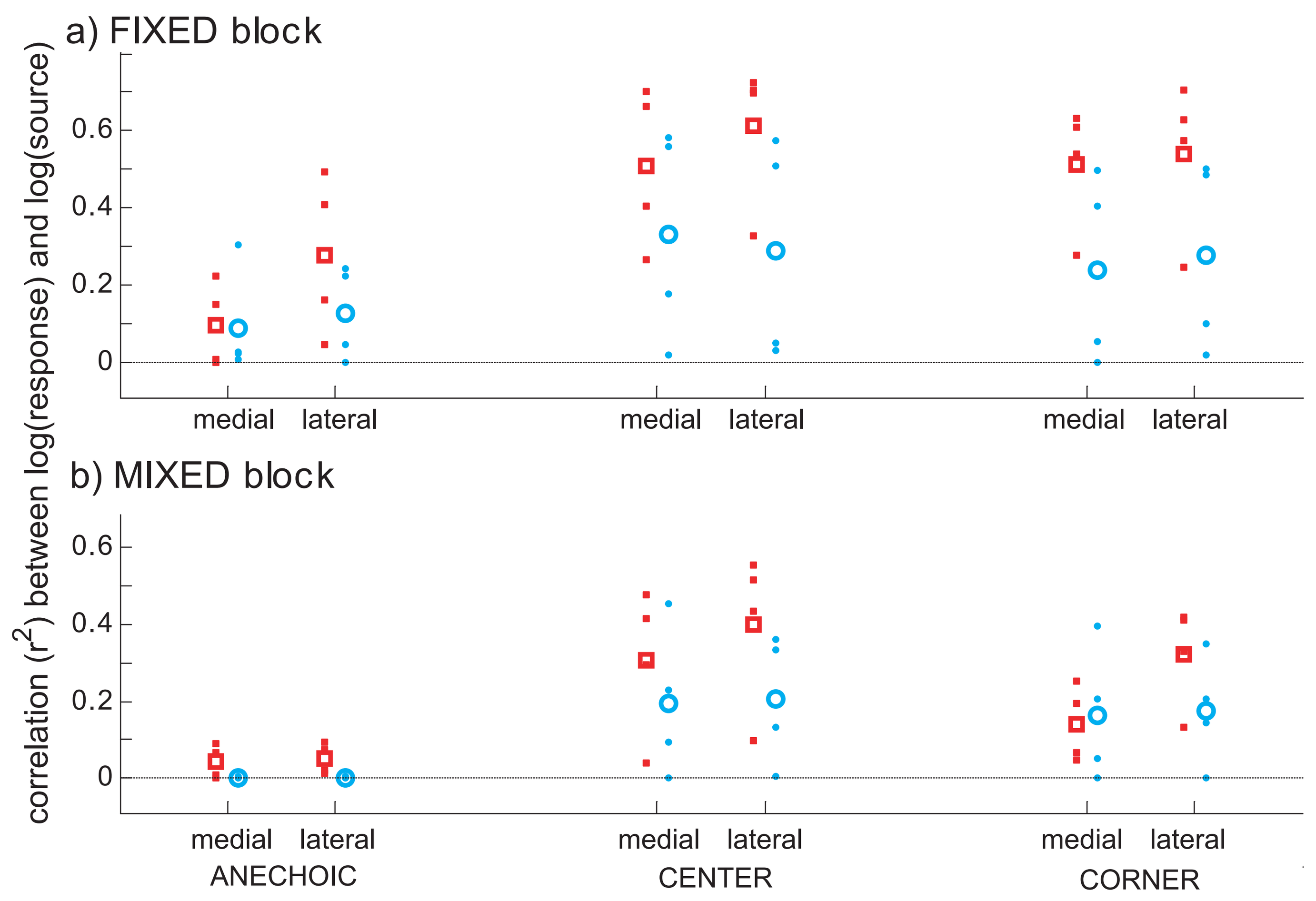
Simulation Method
- individually measured Head-Related Impulse Responses for listeners in *center* and *corner* of a classroom
- *anechoic* derived by time windowing *center* HRIRs

DATA ANALYSIS

Computed correlation coefficient r between log(response distance) & log(simulated distance)

4. RESULTS - EFFECT OF ACOUSTIC ENVIRONMENT

Figure 2. Raw results: square of correlation coefficient between log of source and log of response distance. a) FIXED block (simulated room fixed within session). b) MIXED block (simulated room randomly chosen on each trial)



DISCUSSION
- performance is better in FIXED block than MIXED block
- reverberation improves distance perception (CENTER, CORNER better than ANECHOIC)
- difference between the two echoic conditions (CENTER, CORNER) is small
- FIXED-MIXED group is better than MIXED-FIXED group
- difference between the two subject groups is larger in FIXED than in MIXED block

Figure 3. Effect of room consistency: difference in square of correlation coefficient (FIXED - MIXED)

- difference is positive (performance is better in FIXED block than MIXED block)
- difference is bigger for FIXED-MIXED than MIXED-FIXED group (order of blocks influenced results)

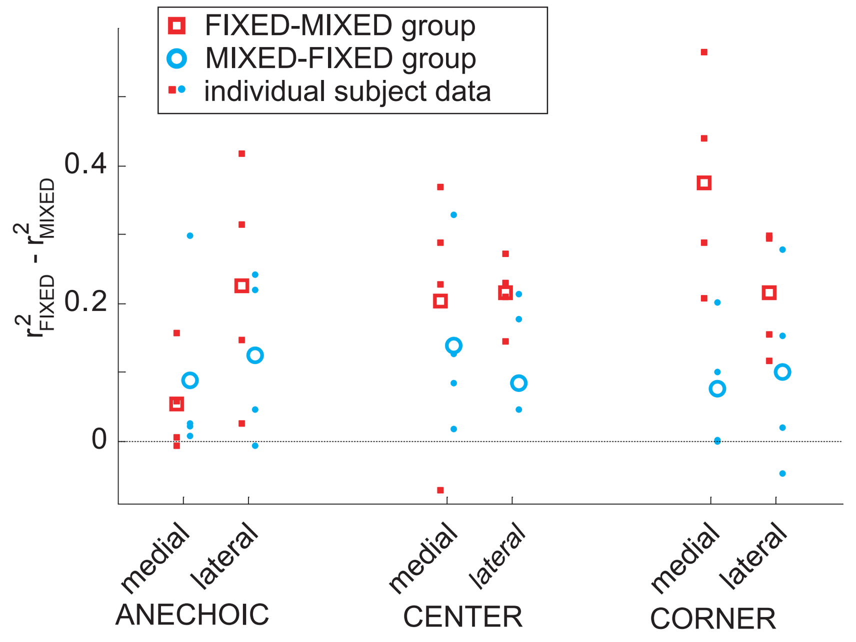
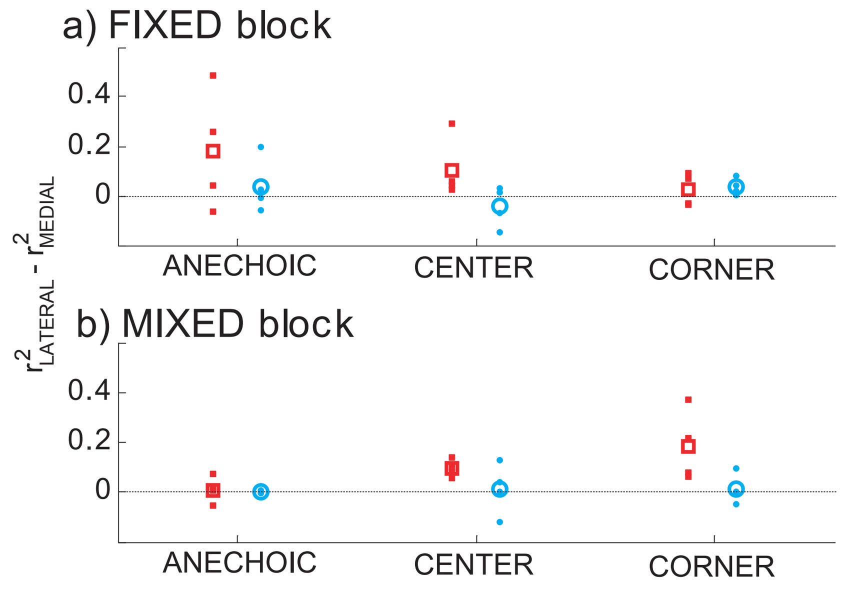


Figure 4. Effect of source direction: difference in square of correlation coefficient (lateral - medial)

- difference is zero for MIXED-FIXED group
- for FIXED-MIXED group, difference is sometimes positive (better performance for lateral than medial)



5. RESULTS - EFFECT OF EXPERIENCE

LEARNING BETWEEN BLOCKS (REFER TO FIGURE 2)

- FIXED-MIXED group performs better than MIXED-FIXED group in the MIXED condition (Fig. 2b)

=> learning in the FIXED block transfers to the MIXED block

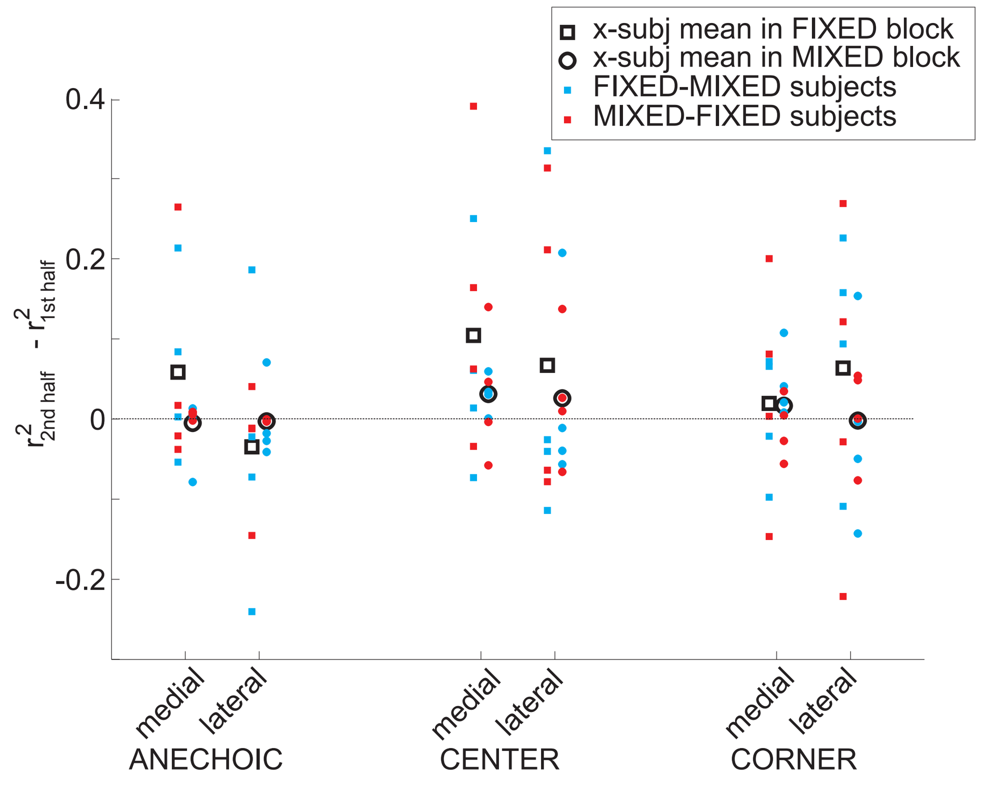
- in the FIXED condition (Fig. 2a) the FIXED-MIXED group performs better than the MIXED-FIXED group

=> prior bad, inconsistent experience degrades performance even when experience is consistent

WITHIN-BLOCK LEARNING

- no measurable learning within MIXED block (circles in Fig 5)
- small improvement (0.05 to 0.1) measured in some FIXED block conditions (squares in Fig 5)

Figure 5. Effect of experience within a block: difference in square of correlation coefficient (first - second half of block)



6. CONCLUSIONS

Consistent experience in a particular virtual environment allows listeners to
- judge distance accurately in each environment
- improve performance slightly over time
- transfer their experience (what cues are reliable?) even when simulated environments are intermingled

Inconsistent experience (simulated environment changing randomly from trial to trial) causes
- poor performance in all environments
- no improvements in performance with time
- listeners to "give up" and do poorly even when experience is consistent later on

Reverberation improves distance judgements by an amount that
- is independent of listener position in room
- depends on previous experience

Performance is sometimes better for lateral than medial sources
- but not for listeners who started in mixed block

7. REFERENCES

Brungardt, DS (1998) "Near-Field Auditory Localization". Unpublished Ph.D. Thesis, MIT

Kopco, N. (2003) "Spatial hearing, auditory sensitivity and pattern recognition in noisy environments," Unpublished Ph.D. Thesis, Boston University

Santarelli, S. (2001) "Auditory Localization of Nearby Sources in Anechoic and Reverberant Environments" Unpublished Ph.D. Thesis, Boston University

Shinn-Cunningham, BG (2000). "Learning reverberation: Considerations for spatial auditory displays," in Proceedings of the International Conference on Auditory Display, Atlanta, GA, 2-5 April 2000, 126-134.

Shinn-Cunningham, B.G., Santarelli, S., and Kopco, N. (2000). "Distance perception of nearby sources in reverberant and anechoic listening conditions: Binaural versus monaural cues." Presented at the MidWinter meeting of the Association for Research in Otolaryngology, St. Petersburg, Florida