Auditory Distance Perception in Fixed and Varying Simulated Acoustic Environments

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1. Background: Distance Perception

For nearby sources in anechoic space, distance perception - is fairly accurate

- is worse for medial than lateral sources (Brungart, 1998)

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

In rooms, distance performance improves with experience (Shinn-Cunningham, 2000)

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

When room conditions change on a trial-by-trial basis, performance is degraded (Schoolmaster et al., 2003)

2. Motivation

SCHOOLMASTER et al. 2003

Subjects judged distance of virtual sources in two conditions - MIXED: simulated environment changes from trial to trial

- FIXED: simulated environment fixed within a session

Two listener groups were used, differing in condition order - FIXED-MIXED: first all FIXED runs, then MIXED

- MIXED-FIXED: first all MIXED runs, then FIXED

Three simulated environments were used,

- anechoic
- center of medium-sized classroom
- corner of medium-sized classroom

Subjects starting in

- FIXED condition did better in FIXED than in MIXED.
- MIXED condition always did worse than the other subjects (as if early, bad experience confused them)

CURRENT STUDY

- Similar, except used only 2 rooms:
- medium-size classroom (used in previous study)
- small classroom (27% of the larger room's volume)

HYPOTHESES

Expect

- bias in MIXED conditions, as if subjects use a single
- "map" to judge two different room environments
- build an appropriate distance "map" for each environment - smaller difference between FIXED and MIXED results compared to previous study (no anechoic case)
- less confusion from MIXED condition (no anechoic case)

- smaller bias in FIXED condition, which allows subjects to

3. Methods

EXPERIMENTAL PROCEDURES

Ten normal hearing subjects (5F, 5M)

Source stimuli

- Five 150-ms-long pink noise bursts (30-ms gaps)
- received level at ears 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

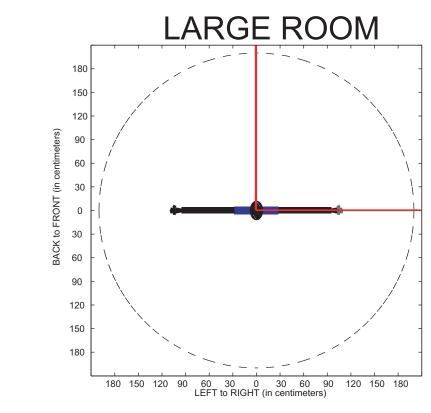
- LARGE classroom: 9x5 meters
- SMALL classroom: 3x4 meters

Each trial

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

Figure 1 Screen shot from the experiment. Subject used a mouse to click perceived location. Simulated room

indicated at top.



Each subject performed two blocks, FIXED and MIXED **FIXED**

- four sessions
- each session held room condition fixed (random order)
- session consisted of eight runs (random order)
- runs (54 trials) held direction (lateral / medial) fixed - nine distances presented randomly within run

- four sessions, each eight runs long
- runs (54 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 corner (same distance from walls) of LARGE and SMALL classroom

During experiment, listeners seated in SMALL classroom

DATA ANALYSIS

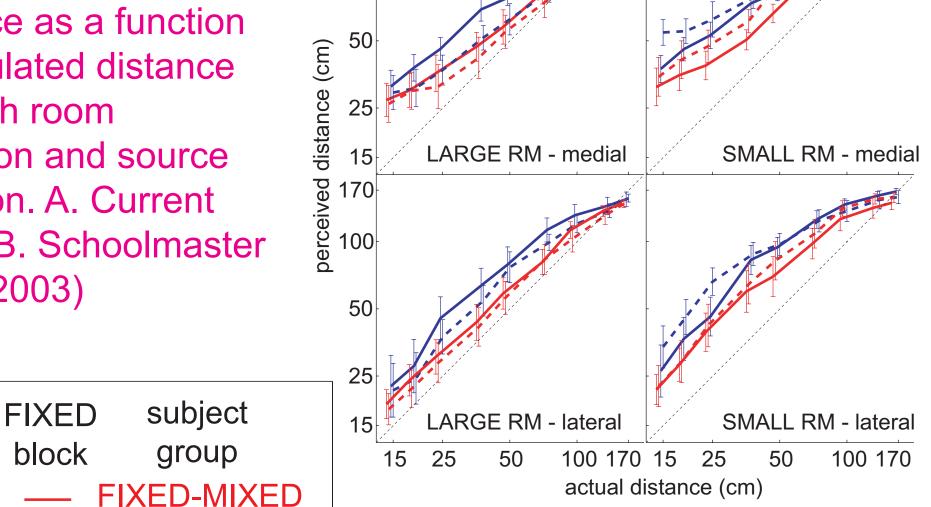
Calculated mean perceived distance, averaged across subjects, as a function of simulated distance

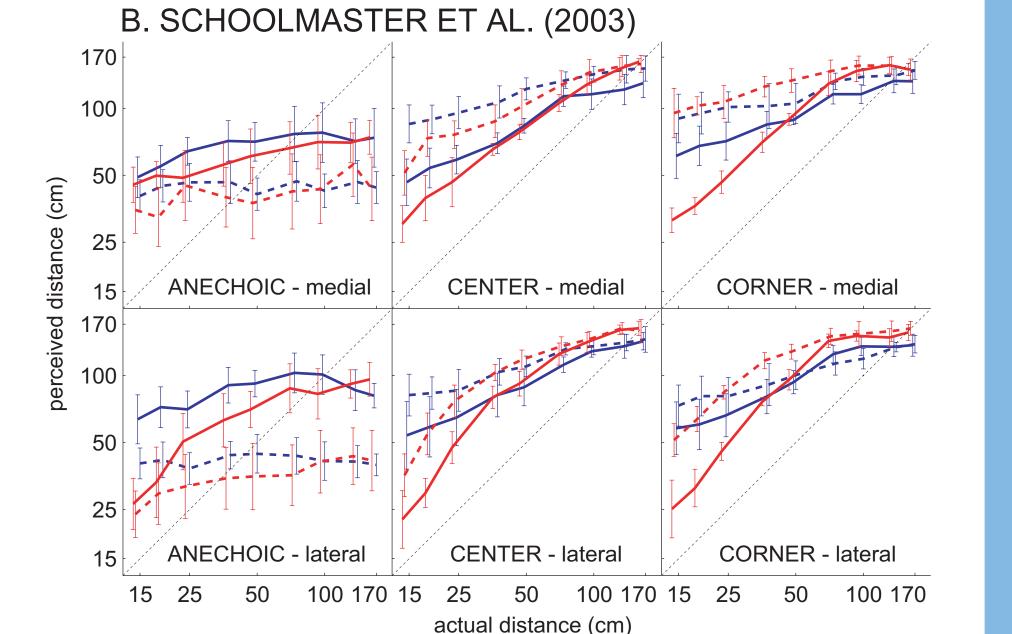
Analyzed bias, average (signed) difference between perceived and simulated distance

Analyzed variance in log(response) - log(actual distance)

. Results: Mean Perceived Distance

Figure 2 Acrosssubject mean and std. error in perceived distance as a function of simulated distance for each room condition and source direction. A. Current study. B. Schoolmaster et al. (2003)





Trial-to-trial inconsistency in simulated

less reliable

environments causes distance perception to be

The more similar the rooms, the smaller the effect.

B. SCHOOLMASTER ET AL. (2003)

medial lateral CENTER

Subjects build a single "map" to judge source

When the environment varies from trial to trial,

When the environment is fixed from trial to trial, bias

is reduced (the "map" for that session better fits the

distances of all stimuli in a session.

response bias increases.

single, fixed room).

In current study:

block

- differences across blocks and subj groups are small
- FIXED-MIXED results are similar for MIXED and FIXED - MIXED-FIXED results depend on room; distance is overestimated by more
- in MIXED than FIXED for SMALL room - in FIXED than MIXED for LARGE room

n Schoolmaster et al. (2003):

— MIXED-FIXED

- differences across blocks and subj groups are larger
- ANECHOIC results are poor in all cases (but FIXED-
- MIXED lateral FIXED results are better than chance)
- CENTER and CORNER results are similar to each other, with better performance in FIXED than MIXED
- in MIXED (vs. FIXED) sessions
- ANECHOIC results are more negatively biased

Figure 3 Difference in bias between FIXED and

- in SMALL room, MIXED bias larger than FIXED

- in LARGE room, FIXED bias larger than MIXED

- positively in CENTER and CORNER

- amount of bias grows in MIXED compared to FIXED

- there are differences between groups and directions

MIXED blocks for each room, source direction

and subject group. A. Current study. B.

Schoolmaster et al. (2003)

In current study:

- small effect of group

In Schoolmaster et al. (2003):

- negatively in ANECHOIC

- CENTER and CORNER results are more positively

5. Results: Effect of Consistency on Response Bias

FIXED-MIXED

MIXED-FIXED

individual subjects

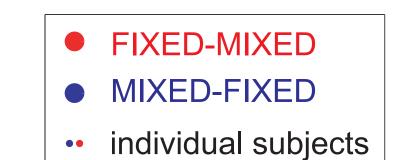
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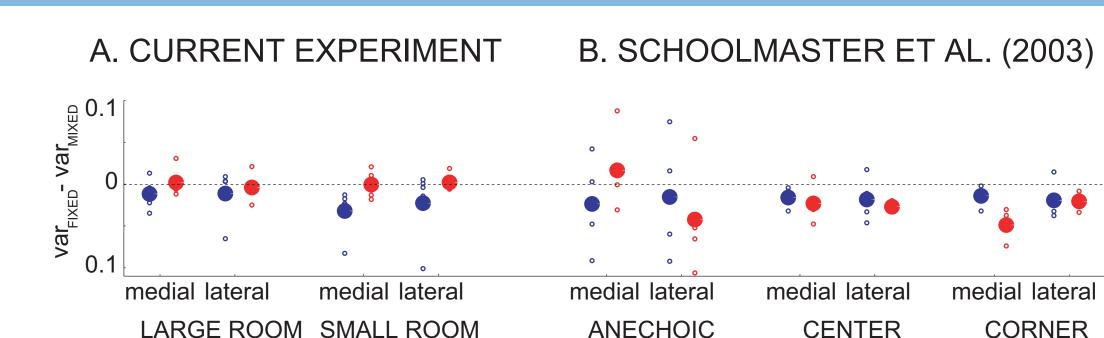
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medial lateral medial lateral LARGE ROOM SMALL ROOM

6. Results: Response Variability

Figure 4 Difference in variance between FIXED and MIXED blocks for each room and source direction. A. Current study. B. Schoolmaster et





In current study:

- FIXED-MIXED subjects did not change
- MIXED-FIXED may have smaller variability in FIXED

- CENTER, CORNER have smaller variability in FIXED

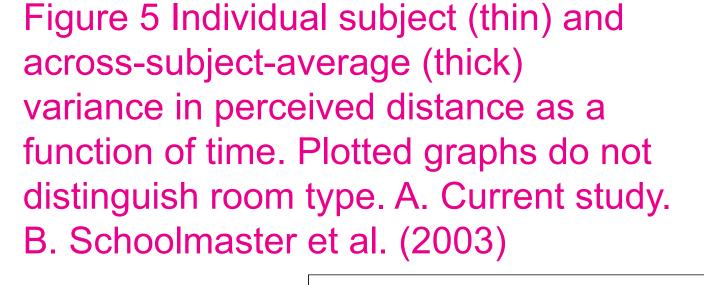
In Schoolmaster et al. (2003): - ANECHOIC responses show no systematic change

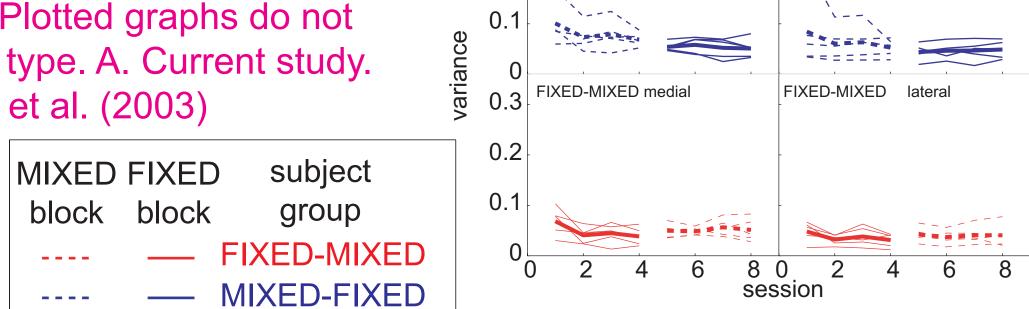
(overall, the differences above tend to be negative). The effect of trial-to-trial changes in the environment

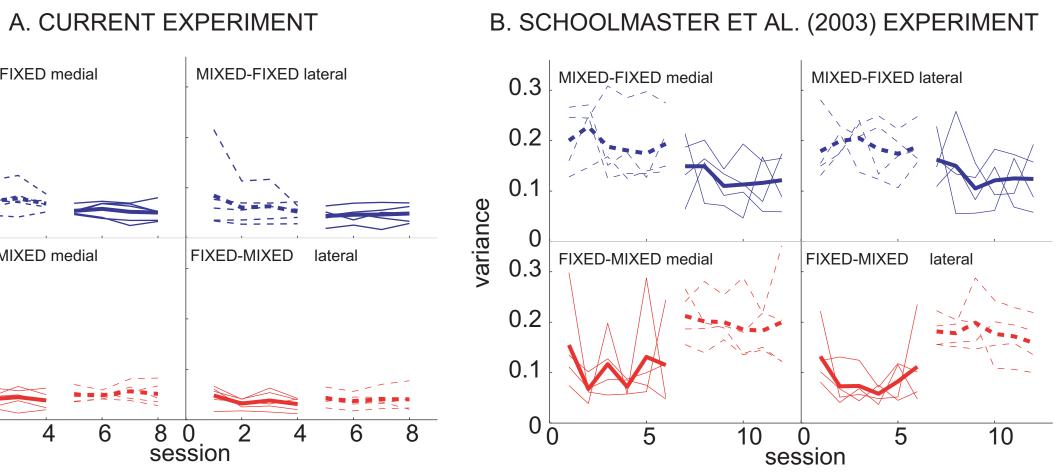
is smaller for relatively similar environments (current experiment) than when they differ dramatically (prior

Response variability tends to be larger when the room

changes from trial to trial than when it is held constant







In current study (where rooms are relatively similar), variance decreases rapidly in the initial sessions

In Schoolmaster et al. (2003; where rooms differ dramatically, from anechoic to classroom), learning is less evident, because variability is larger overall

block block

Listeners in simulated environments show learning, reducing variability in their responses through experience, even without explicit feedback (reminiscent of previous studies in real rooms; Shinn-Cunningham, 2000)

If there is large trial-to-trial variability in the environments heard within a session, responses are less accurate; i.e., responses are biased to take into account the whole range of stimuli heard in the session.

Large trial-to-trial differences in the simulated rooms increase bias and can cause greater response variability.

In all cases, response variance decreases over time, due to either procedural or perceptual learning.

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7. Conclusions

Listeners appear to construct a "map" of distance based on recent experience (i.e., over the course of a session).

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