#29

LEARNING OF INTENSITY AND REVERBERATION CUES FOR AUDITORY DISTANCE PERCEPTION IN ROOMS

Lubos Hladek[1], Aaron R Seitz[2], Norbert Kopco[1]

[1]Institute of Computer Science, P. J. Safarik University in Kosice, Slovakia [2]Department of Psychology, University of California Riverside, CA, USA.

Agentúra Ministerstva školstva, vedy, výskumu a športu SR pre štrukturálne fondy EÚ

Operačný program VÝSKUM a VÝVOJ

Európska únia

Introduction

Sound intensity and reverberation are two primary cues for auditory distance perception. (Zahorik et al., 2005)

A learning effect was observed after five days of training on distance localization task in a reverberant room with intensity of presentation varying from trial to trial. (Shinn-Cunningham, 2000)

The learning was observed between days, possibly due to memory consolidation. (Stickgold, 2005)

Auditory distance learning can be disrupted on the short time scales. (Schoolmaster et al., 2004)

The auditory system must adapt to reverberation in each room but the effect of the long term exposure on auditory distance perception is unknown.

Current study

Examines the process of spontaneous learning (without feedback) that results in improved distance judgments over time in reverberant rooms.

Presents results of a multi-day experiment in which distance perception with and without the intensity cue was measured.

Hypotheses

H1: Reverberation provides intensity-independent distance information,

but reverberation processing needs to be calibrated in each room.

Therefore, training distance perception without intensity cues will lead to better distance judgments based on reverberant cues. This improvement might generalize to the condition with intensity cue available.

H2: Learning will occur between days rather within days due to consolidation.

H3: Learning carry over effect and short-term interactions might occur as well.

Methods

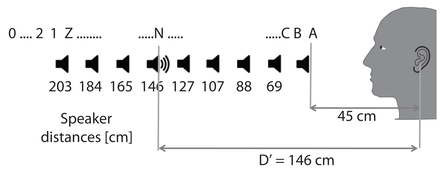


Figure 1 Experimental setup. Actual speaker locations and the letters/numbers (A-Z,1-0) used by listeners to indicate perceived distance. The nearest speaker was not used to present stimuli.

Stimuli and environment:

300 ms broadband noise

F runs: intensity was **fixed** and varies freely 49-54 dB SPL

R runs: intensity **roved** +/-12dB by equalized for distance

Small semi reverberant room (T60 300ms, 32dB SPL background noise)

Procedure and task (Fig. 1):

Localize the sound and press corresponding letter/number. Sound originated from 1 of 8 speakers at 69 cm - 203 cm.

Subject informed about condition (R or F)

One run:

80 localization trials, each speaker presented 10 times pseudo randomly

Session:

Each session contained 12 runs.

Testing: R runs and F runs **interleaved**

Training: R runs or F runs **fixed** throughout session

Experiment (Fig. 2)

7 sessions:

1t,4t,7t - testing

1,2,3;4,5,6 training

Subject groups

Finit - testing started with F run,

Rinit - testing started with R run

RF - sessions 1-3 R training, 4-6 F training

FR session 1-3 F training, 4-6 R training

32 subjects divided into 4 groups (Rinit, Finit x RF,FR)

Data analysis: Spearman correlation coefficients computed from perceived and presented distances. All data were Z transformed.

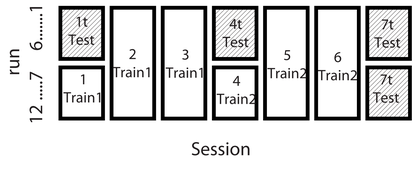


Figure 2 Ordering of test runs and training runs across sessions. Subject groups differed by order of test runs (Test = repeated pairs of Rinit or Finit, fixed throughout experiment) and by order of training sessions (Train1=F training, Train2=R training) or (Train1=R training, Train2=F training).

Results: Test Sessions

Is there more R learning compared to F learning in R testing?
Does it generalize to F testing?

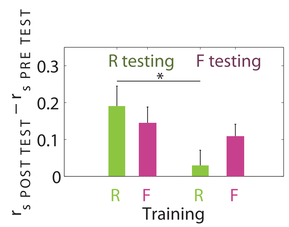


Figure 3 Amount of learning due to R training vs. F training for the R test and F test runs (* p<0.05). The pre-test and post-test data correspond to respective test sessions 1t, 4t, or 7t in Fig. 4.

Learning due to R training vs. F training (Figure 3):
R training resulted in more learning in R testing than in F testing.
F training
- produced similar amounts of learning in R testing and F testing,
- was slightly worse than R training in R testing, but slightly better in F testing.

Removing the intensity cue during training (R training) affects the amount of learning (re. standard F-training), with a positive trend in R-testing but negative trend in F testing.

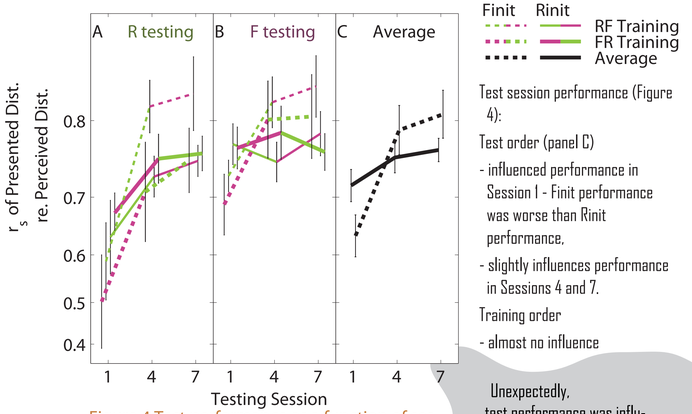


Figure 4 Test performance as a function of session separately for R testing (panel A), F testing (panel B), and averaged across training order and testing (panel C).

Test session performance (Figure 4):

Test order (panel C)

- influenced performance in Session 1 - Finit performance was worse than Rinit performance,
- slightly influences performance in Sessions 4 and 7.

Training order

- almost no influence

Unexpectedly, test performance was influenced by the order of test runs in the 1st session. Rinit (RFRFRF) performance was slightly better than Finit (FRFRFR) performance.

Results: Temporal Profile of Training and Raw Data

Does the learning occur within the training sessions, or during the consolidation between the sessions?
Is it affected by the test sessions? How alternation of runs during testing affected performance?

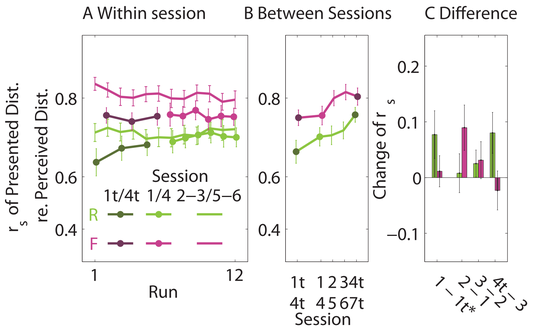
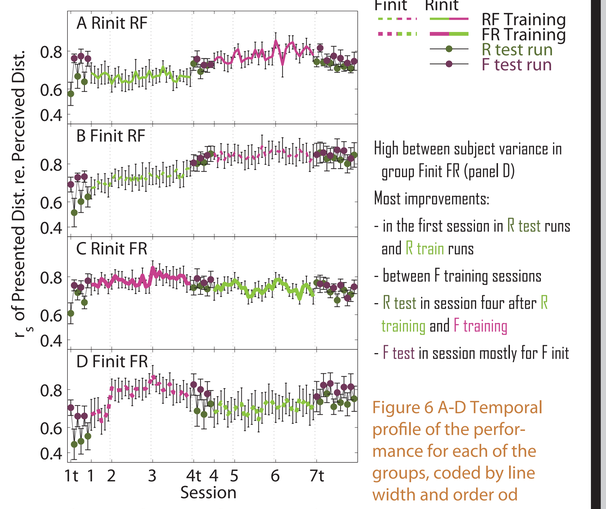


Figure 5 A Across-session average performance in training sessions as a function of run (training in sessions 1 and 4 had only 6 runs). B Average performance within consecutive training sessions and the adjacent test sessions (except 1t and 4t). C Change in performance from session to session for training sessions and the adjacent test sessions, based on panel B). (* within session comparison)

1. No within-session learning Fig. 5A. (no symbol) in training session
2. Some within session learning in R runs in the first training session from testing to training Fig. 5A (dark green circles to light green circles)
3. F performance improved the most between sessions 1 and 2 (Fig 5C and 5B).
4. R performance improved the most between sessions 3 and 4t (Fig 5C and 5B).

F learning likely due to consolidation after training sessions.
R learning seems to require presence of F runs (in test sessions).
No performance change within training sessions.



High between subject variance in group Finit FR (panel D)

Most improvements:

- in the first session in R test runs and R train runs
- between F training sessions
- R test in session four after R training and F training
- F test in session mostly for F init

Figure 6 A-D Temporal profile of the performance for each of the groups, coded by line width and order od colors, as a function of session. Each point represents one run. Labeling on x-axis corresponds to labeling in Fig.2. Performance in testing phase in session 1t,4t,7t is shown separately for each run with circles. Color codes type of the run (R or F) that was presented.

Discussion

Distance perception improves over course of days in a reverberant room.

This learning is influenced by whether the level cue is available:

- with level available during training (F training), the same amount of learning was observed when testing with or without the level cue,
- without the level cue during testing (R testing), learning was large when testing without the level cue (R testing), but smaller with it (F testing).

So, removing the level cue can be disruptive rather than enhancing for the process of learning room reverberation.

However, this result might be due in part to the experimental design used here in which the roved-level (R) and fixed-level (F) runs were interleaved.

Consolidation is important for F training (no within-training-session improvement).

R performance mostly improved during sessions in which F was also present (test sessions),

F performance did not improve or tended to get even worse during test sessions in which R runs were interleaved (Fig.5C).

It is likely that switching between interleaved R and F runs during testing affected both test performance and learning in this study, since the order of interleaved trials had a large impact.

References and Acknowledgement

Shinn-Cunningham, B. G. (2000). "Learning reverberation: Implications for spatial auditory displays," Proc. ICAD, Atlanta, GA, 126–134. doi:10.1.1.22.5056

Schoolmaster, M., Kopčo, N., Shinn-Cunningham, B. G. B. G., Kopco, N., and Shinn-Cunningham, B. G. B. G. (2004). "Auditory Distance Perception in Fixed and Varying Simulated Acoustic Environments." J Acoust Soc Am, New York, 2459–2459. doi:10.1121/1.4782332

Stickgold, R. (2005). "Sleep-dependent memory consolidation," Nature, 437, 1272–8. doi:10.1038/nature04286

Zahorik, P., Brungart, D. S., and Bronkhorst, A. W. (2005). "Auditory distance perception in humans: A summary of past and present research," ACTA Acust. UNITED WITH Acust., 91, 409–420.

This poster is the result of the project implementation: University Science Park TECHNICOM for Innovation Applications Supported by Knowledge Technology, ITMS: 26220220182, supported by the Research & Development Operational Programme funded by the ERDF .

We support research activities in Slovakia/This project is being co-financed by the European Union

Supported by APVV-0452-12 Spatial Attention and Listening in Complex Environments.