Reweighting of binaural localization cues in virtual environment

Lucia Hucková[1] and Norbert Kopčo[1]

[1]Institute of Computer Science, P.J.Šafárik University, Šrobárová 2, 041 80 Košice, Slovakia
lucia.huckova@student.upjs.sk, norbert.kopco@upjs.sk

Abstract

The auditory system combines the binaural cues of interaural time difference (ITD) and interaural level difference (ILD) to determine the sound source location. The combining is frequency dependent. ITD dominates for low-frequency (LF) sounds and ILD for high-frequency (HF) sounds. We can experimentally measure the relative ITD/ILD weight by a localization task. A previous study (Spišák et al., 2021) showed that visually guided training on HF vs LF components in real environment induces reweighting in the binaural localization cues such that the ILD weight increases independent of the training type. We performed a follow-up experiment in real reverberant and virtual anechoic environments without training to examine the cause of the observed ILD weight increase. No reweighting was observed in this experiment, suggesting that the reweighting observed by Spišák et al. was not caused by mere exposure to different environments and that active localization is necessary to induce the binaural adaptation.

1 Introduction

Spatial auditory perception allows us to localize sounds and to separate sounds, e.g., when listening to speech in complex environments. Sound localization includes judgements about the direction (left/right and up/down) and distance of a sound source (Moore,2013)[1]. When we are presented with a sound from any position in azimuth, we can localize it due to two possible cues of the sound source an interaural time difference (ITD) and an interaural level difference (ILD). The way ITD or ILD contributes to the localization of the sound depends on the frequency content of the sound. At lower frequencies, ITDs are dominant. For higher frequencies, ILDs are dominant (Klingel et al. 2021). A previous study showed that, when listeners are trained to change the spectral weighting of components for localization in real environment, the spectral reweighting always results in an increase in the ILD weight (Spisak et al., 2021). Here, we examined whether performance of localization test in a real environment is sufficient to induce this binaural reweighting. Additionally, the study provides a control condition measurement for the Spisak et al. results.

[1] Moore (2013) stated for headphones term “lateralization“ to describe the apparent location of the sound source within the head.

2 Methods

An experiment was performed, consisting of 2 parts, pretest and posttest, performed in virtual environment (VE) and real environment (RE), using methods similar to Spisak et al. (2021).

2.1 Setup and stimuli

In real environment, 11 loudspeakers were placed in a semicircle around the subject with 11.25° spacing (range ±56.25°) in a dark reverberant room. Position of the head was recorded using a headtracker. 5 types of stimuli were created using 0.5-octave noise bands at different frequencies. Low frequency stimuli were 0.35 kHz and 0.7 kHz, mid-frequency stimuli were 2.8 kHz and high frequency stimuli were 5.6 kHz and 11.2 kHz. 2 types of stimuli that were presented are: 1, 2-channel stimulus: 1 HF and 1 LF channel from locations separated by 1 or 2 speakers; 2, 4-channel stimulus: 2 HF and 2 LF channels from locations 1-2 speakers apart. Subject’s task was to rotate their head towards the perceived sound location. Position of the head was guided with visual feedback. The experiment in virtual environment took place in a double-walled soundproof booth. We used ITD/ILD combination corresponding to one of 40 possible positions in horizontal plane in range from ±70.2° with spacing of 3.6°. The stimuli were 1-octave noises with center frequency 2.8 kHz. Subject’s task was the same as in RE.

2.2 Experimental design

14 subjects were divided in two groups, one performed experiment in real and virtual environment (7 subjects, OR group) and one performed only virtual part (7 subjects. O group). The sequence of tests for the OR group was: day 1 (VE pretraining, VE pretest, RE pretest), day 2-4 (no training), day 5 (RE posttest, VE posttest). The sequence for the O group was identical, except that no RE tests were performed. Thus, if the

RE posttest performed immediately before the VE posttest was the main cause of the increased ILD weight in Spisak et al., then it was expected that it would be observed in the OR but not in the O group.

3 Results

Linear regression was used to estimate w_{HL} (the spectral weight of HF vs. LF components) and binaural weight w_{LT} (weight of ILD vs ITD cues). Weight of 1 means that subject oriented only according to HF/ILD component and 0 that subject oriented only according to LF/ITD component. Weights were averaged across azimuth as training effects were similar across azimuth. Fig. 1 show weights in RE for our data with no training (NoT group) and Spišák's data (LF and HF group, trained for given component). From pretest to posttest NoT weights showed no significant increase. This was expected because we omitted training. On the other hand, LF and HF group changed its spectral weighting in desired direction (results confirmed by ANOVA).

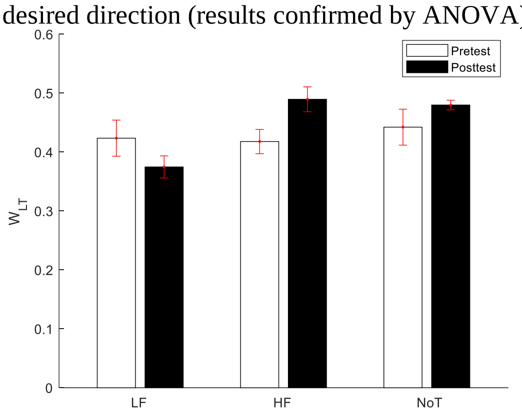

Fig. 1: Mean (±SEM) weights w_{HL} for different groups in pretest and posttest, averaged across locations.

On Figs. 2 and 3 we see results from VE. Fig. 2 is showing no significant change in weights of OR and O group, meaning that RE posttest done before VE posttest has no effect. Fig. 3 is a comparison of trained vs. not trained groups. Spišák observed the increase of ILD weight independent of the training group, the change was significant in the same direction for all groups. For our no training group, change in pretest to posttest was not significant and change in reweighting was not dependent on a group.

4 Summary and discussion

Results from RE show that change in spectral weighting does not occur, as we expected because no training of HF and LF components was present. Based on previous results we hypothesized that performing a posttest in real room immediately before the VE posttest may have caused the increased ILD weight. However, the results from virtual environment do not show the expected effect as no significant re-weighting occurred from pretest to posttest. Thus, a change in weighting cannot occur by changing from an anechoic environment to an echoic one, nor does it occur by getting used to an echoic room, but only by visual training in real environment. However, what aspect of the training is important is still unknown.

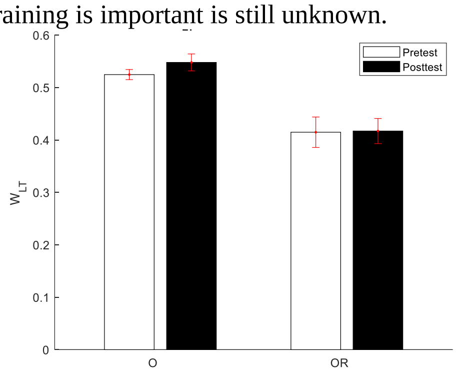

Fig. 2: Mean (±SEM) weights w_{LT} for O and OR group in pretest and posttest, averaged across locations.

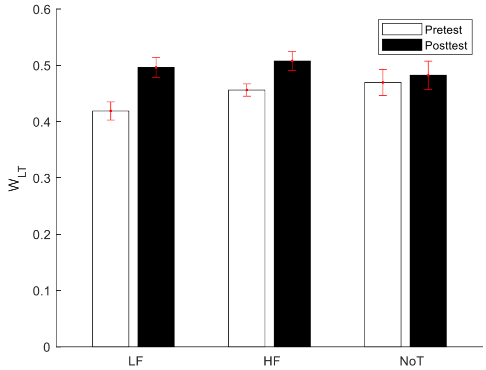

Fig. 3: Mean (±SEM) weights w_{LT} for different groups in pretest and posttest, averaged across locations.

Acknowledgment

This work was supported by VEGA 1/0350/22.

Literature

Spisak, O., Klingel, M., Lokša, P., Šebeňa, R., Laback, B., & Kopčo, N. (2021). "Reweighting the contributions of spectral regions to sound localization and its impact on binaural-cue reweighting", Proceedings of DAGA 2021, Vienna.

Klingel, M.,Kopco, N., Laback, B. (2021). Reweighting of Binaural Localization Cues Induced by Lateralization Training. Journal of the Association for Research in Otolaryngology. 22.

Moore BCJ.(2013). An Introduction to the Psychology of Hearing, Sixth Edition. Leiden, Boston, p. 245-281