# Reverberation and Sound-source Localization: A Comparison of Common Testing Environments

HARL Hearing Aid Research Lab

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## Introduction

Horizontal localization ability can be tested in environments with varying acoustic characteristics. When measured in an anechoic room, results are not impacted by reverberation. Although an anechoic space might be considered the "gold-standard" for localization testing, not everyone has access to an anechoic testing environment. Some clinicians and researchers might assess localization performance in a more reverberant environment, such as a sound-treated room. Previous research has shown that reverberant energy can degrade the accuracy of locating a sound source. Currently, it is unclear how and to what extent the reverberant energy in a sound-treated room impacts sound localization performance. Individuals who wish to carryout horizontal localization tests in a sound-treated room need to know whether the results obtained in these rooms are comparable. The present study sought to characterize localization performance in these common test environments. Specifically, the following questions were explored:

## Objectives

When comparing horizontal sound localization performance measured in an anechoic (AN) and a sound-treated room (SR):

- Is performance substantively different?
- How does the presence of background noise impact performance?
- How does stimulus frequency impact performance?

## Method

- **Participants**: 40 young adults (20 assessed in each environment) with normal hearing abilities (screened at 20 dB HL).
- **Demographics**: Sound-room: 18 Female; 18-30 years (M=24 years)
  Anechoic: 17 Female; 18-30 years (M=24 years)
- **Instrumentation & stimuli:** Localization tests were conducted in either a sound-treated room or an anechoic room. Each space was outfitted with a 360$^0$, 24-loudspeaker array. See Figure 1. Test stimuli were high-frequency & low-frequency filtered short sentences.
- **Testing:** Horizontal sound localization performance was assessed in both quiet and noisy environments.
- **Analyses:** Area of Angular Error (AAE) (Xu & Cox, 2013) was used for visual representation of localization performance in all testing conditions. Statistical analyses were based on traditional measures of total root-mean-square (RMS) errors. Statistical analyses were General Linear Model (GLM) mixed model repeated measures ANOVAs, and post hoc repeated *t*-tests with Holm-Bonferroni step-down corrections.

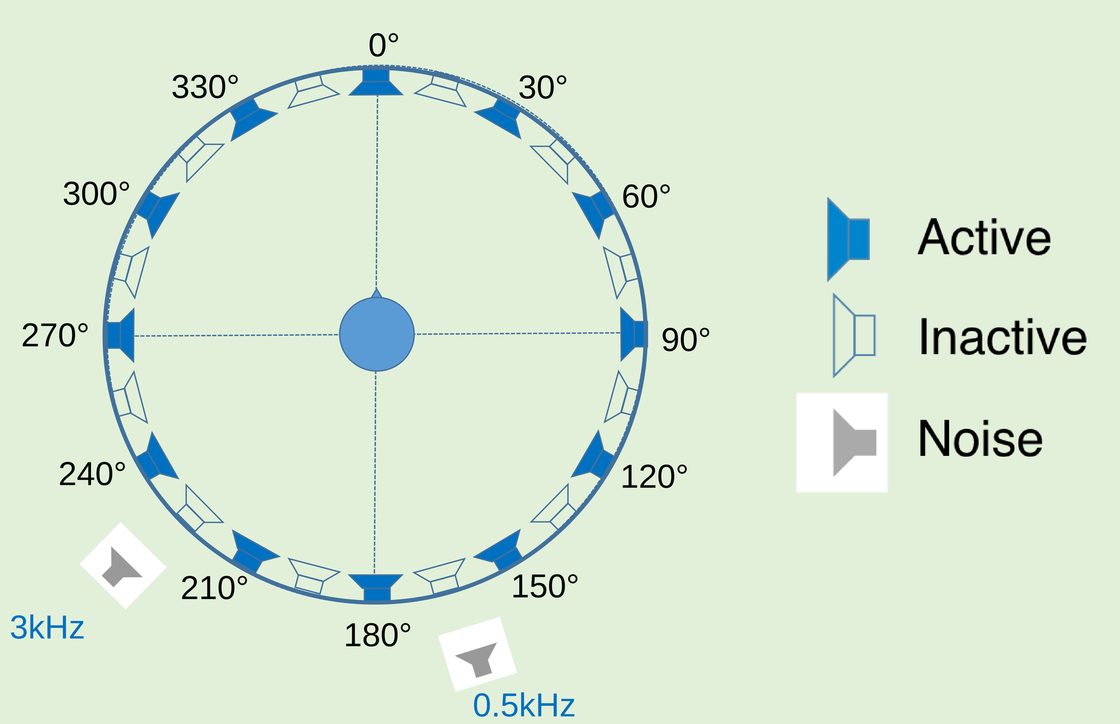
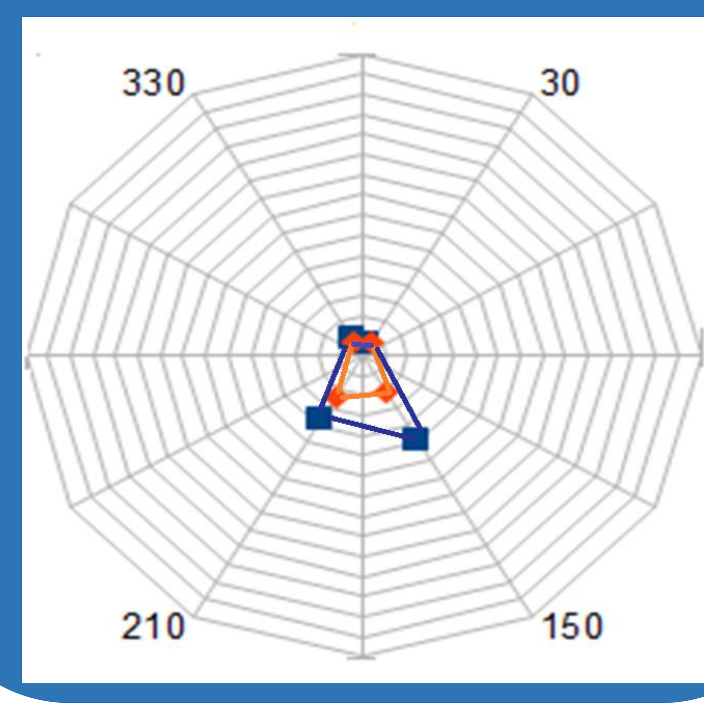



Fig 1. Experimental set-up for horizontal localization testing

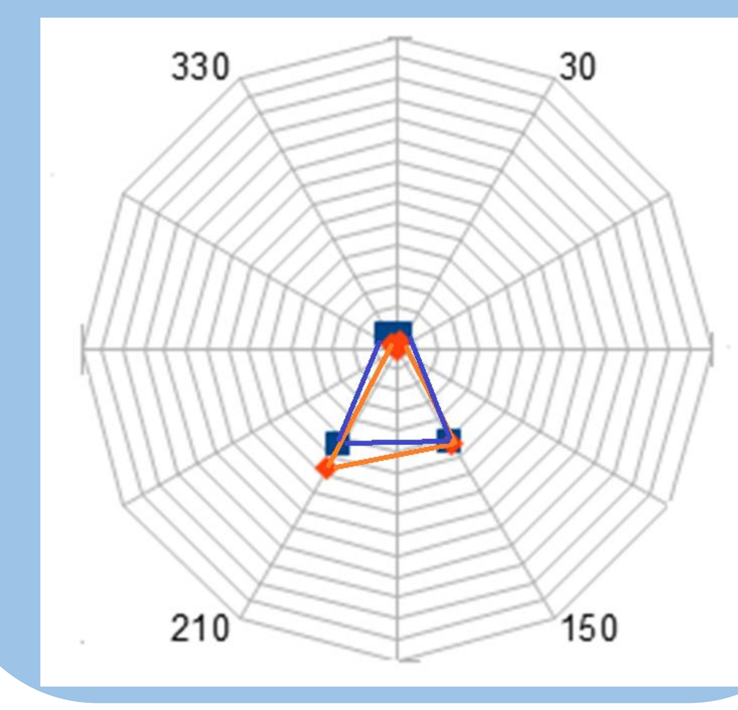
## Results

The following diagrams demonstrate comparisons of average horizontal localization performance measured in a sound-treated and an anechoic environment under four tested conditions: with Low-frequency (LF) and High-frequency (HF) test stimuli, and in Quiet and in Noise.

**A: LF/Quiet:**
**($F$=12.1, $p$=.001, $d$=1.1)**

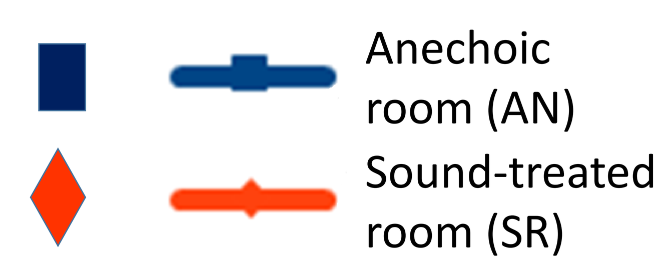



**B: HF/Quiet**
**$F$=.03, $p$>.05, $d$=-.06**



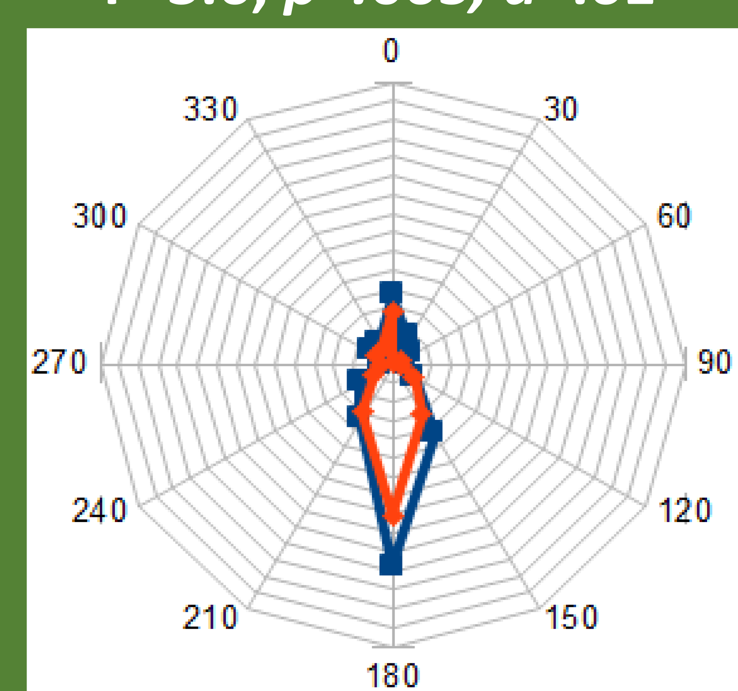

**A vs B:** With no background noise there were slightly more errors for HF stimuli ($t$=-3.211, p = .003).

**A vs C:** There were more localization errors for LF stimuli in noise compared to quiet ($t$=-6.636, p < .001).

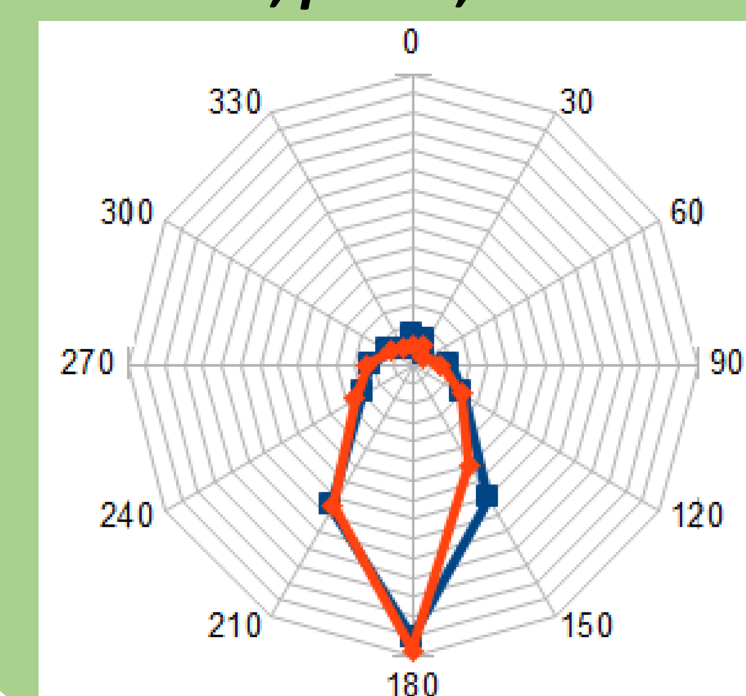



**B vs D:** For HF stimuli there were significantly more localization errors in noise compared to quiet ($t$=-3.700, p = 0.001).

**C: LF/Noise**
**$F$=3.6, $p$=.065, $d$=.61**




**D: HF/Noise**
**$F$=1.2, $p$>.05, d=0.18**




**C vs D:** With noise in the background there were substantially more errors for HF stimuli ($t$=-2.806, p = 0.008).

- Overall, it can be seen that the majority of errors occurred when the test stimuli arose from behind the listeners in all conditions. Although the main effect of testing environment did not quite reach statistical significance (F=3.96, $p$ = .054), some interesting differences were noted:
  - In both testing environments, more errors were observed for high-frequency filtered stimuli (F = 14.852, $p$<0.001), and in the presence of background noise (F = 43.617, $p$<0.001).
  - A significant interaction was observed for stimulus type (HF and LF) and the testing environment (AN vs SR; F=6.428, $p$=.015). Post hoc testing demonstrated that more errors were observed for low frequency stimuli when testing was conducted in the anechoic chamber compared to the sound-treated room. These differences were not observed for high-frequency stimuli.

*This poster presentation is available for download at www.harlmemphis.org*

## Q&A

**Q.1: Were there any substantive differences in horizontal sound localization performance when it was tested in a sound-treated and an anechoic room?**

**A:** On the whole, very little difference in performance was observed for individuals tested in the AN and SR environments. This observation was supported by the non-significant main effect of testing environment ($p$ = .054). However, differences were noted when stimuli were low-frequency, and when the environment was quiet.

**Q.2: Was there any impact of background noise on sound localization between the two rooms?**

**A:** Generally performance in noise was poorer for both environments. However, the interaction between noise and test environment was not statistically significant (F=0.195, $p$ = 0.662).

**Q.3: Was there any impact of stimulus frequency on sound localization between the two rooms?**

**A:** Yes. A significant interaction between stimuli and environment was observed with more errors observed for the anechoic environment compared to the sound-treated room when stimuli were low-frequency filtered. Differences were particularly apparent in the quiet environment which demonstrated a large effect ($d$=1.1).

## Discussion

These findings are interesting because they are different from what we expected. Previous research suggested that reverberation characteristics might result in poorer localization in the sound room compared to the anechoic space, but we did not find that to be the case for LF stimuli.

It is possible that early reflections resulting from reverberation in the sound room might have provided additional localization cues and improved localization accuracy in that environment. This is consistent with findings by Reed & Maher (2009).

## Conclusions & Future Directions

Clinicians and researchers who wish to measure localization in a sound-treated space should feel confident in their results; however, when using LF stimuli, especially in a quiet room, care should be taken when comparing results to those obtained in an anechoic space to account for possible effects of reverberation.

Due to our small sample size, some of the interactions approached but could not achieve statistical significance. Future research will employ a repeated measures design with a larger sample size.

## References

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Reed, D. K., & Maher, R. C. (2009). An investigation of early reflection's effect on front-back localization in spatial audio. Presented at the 127th convention of Audio Engineering Society, New York, NY.

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