

IMMATURE SOUND LOCALIZATION ABILITY OF TODDLERS IN COMPLEX LISTENING CONDITION



Binaural Hearing and Speech Laboratory

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Introduction

Using the precedence effect (PE), the auditory system assigns greater perceptual weight to the leading than lagging sound in a reverberant environment [1].

When the PE is weak, spatial cues carried by the lag can reduce the accuracy with which the direct source is localized [2].

The PE does not exist at birth, but it is present at around 4-5 months of age, and matures during childhood [3, 4].

There is limited literature on children, specifically toddlers, about the PE phenomenon, however previous findings show:

- I. Left-right discrimination of the lead is worsened by the presence of the lag, more so at age 5 years than in adults, and further worse in toddlers [5].
- II. Localization of lead stimuli in the presence of a lagging sound yielded larger RMS errors in 5-year-old children than adults [2].

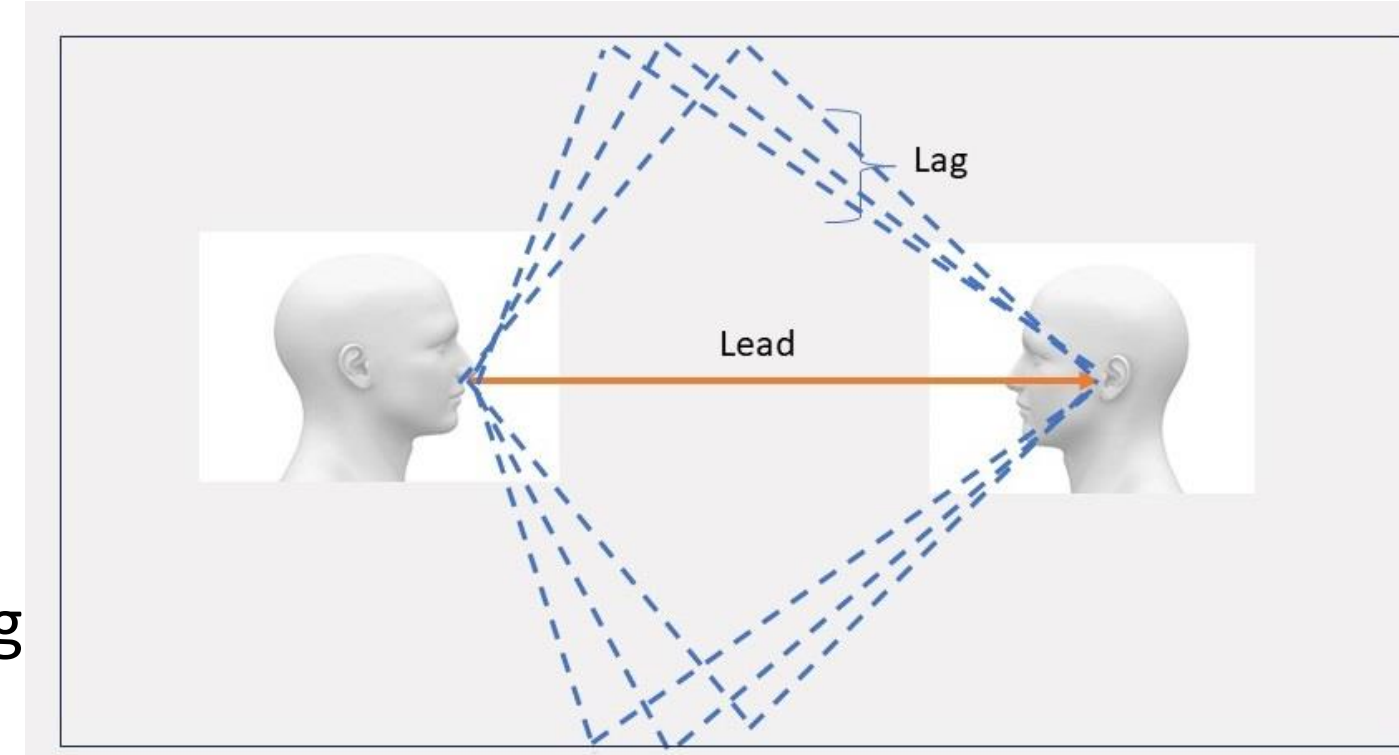


Figure 1: Lead and lag sounds in a reverberant environment
<https://img-prod.sony.com/imagelibrary/asset/images/lead-lag-sound-illustration-headset-13315976.html>

The importance of studying the precedence effect in Toddlers:

- Toddlers engage in their social and educational life in reverberant environments like classrooms and playgrounds, where they need to accurately locate parents, teachers, or caregivers by attending to their voices in the presence of multiple lagging sounds.
- Previous studies show that the spatial hearing of children is more adversely affected than that of adults in reverberant environments suggesting less developed PE in children [2,4]. However, the extent to which PE benefits source localization in toddlers has not yet been investigated.
- Studying PE in toddlers will, in conjunction with previous findings in children and adults, enable charting out the overall developmental trajectory of the precedence effect.

Current project:

We investigated how PE operates in toddlers using a 'reaching for sound' localization task [6]. We previously showed that toddlers can localize single-source (SS) sounds with great accuracy with root-mean-square (RMS) errors near 10° [7]. Here we adapted this approach to include two PE conditions and compared the localization performance in PE conditions to that in SS condition.

Method

Stimulus:

Single Source (SS):

Three 25 ms white noise bursts, with an interstimulus interval of 250 ms, presented from 1 of 9 loudspeakers at 60dB SPL (± 4 dB) following the carrier phrase of "I'm hiding under".

Precedence Effect (PE):

Following the carrier phrase; a pair of lead-lag noise bursts occurred from two loudspeakers: the lag was at 0° and lead was at one of the other 8 loudspeakers. The delay was 5 ms, and the sound levels were as follows:

- PE60-60: both lead and lag = 60 dB SPL
- PE60-50: lead = 60 dB SPL, lag = 50 dB SPL

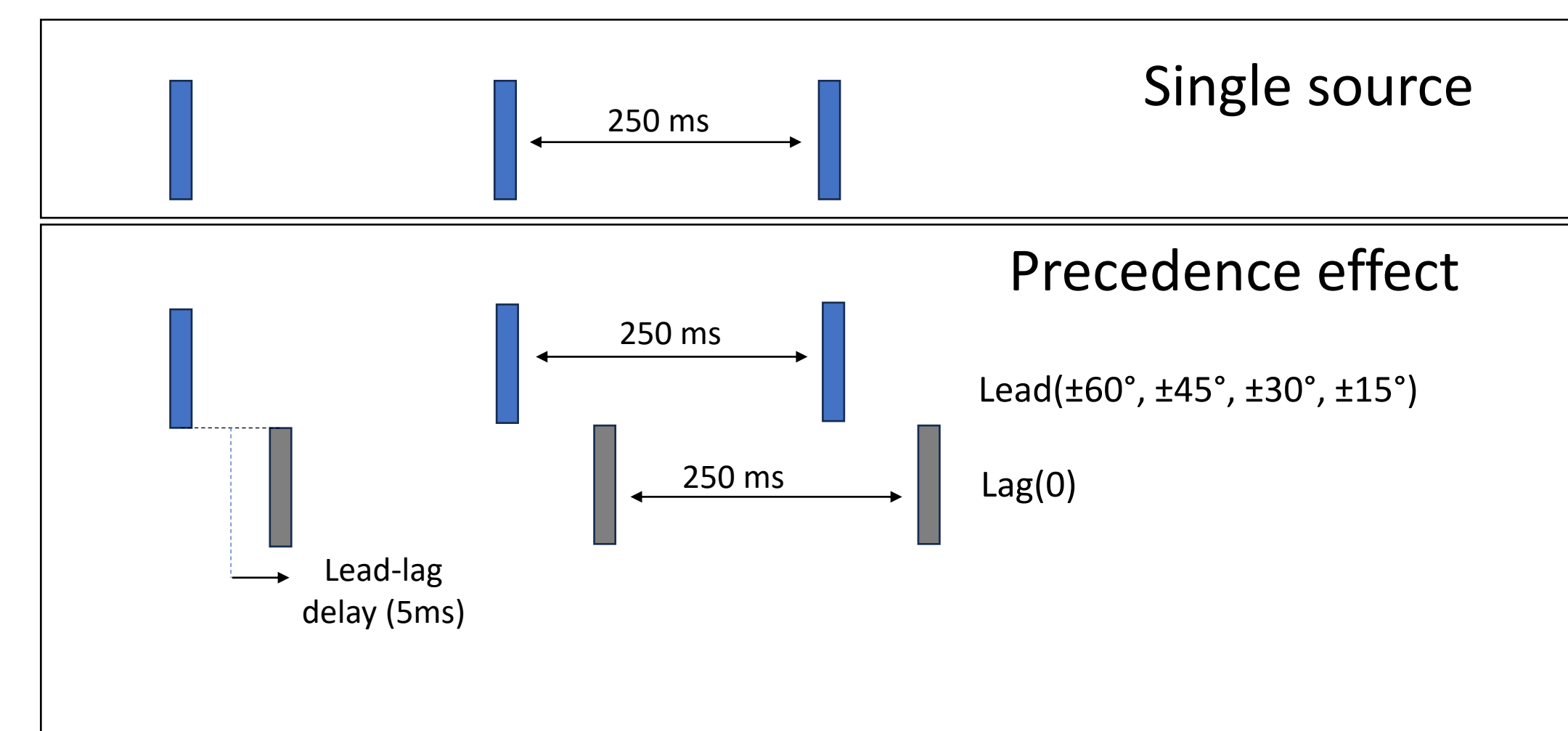


Figure 3: Stimuli configuration

Task:

On each trial, a toy was placed above 0° location. After presentation of a carrier phrase of "I am hiding under" from 0°, the toy was withdrawn. Then stimulus was presented from one of the loudspeakers behind the holes. The participants should reach the hole they perceive sounds from.



Figure 4: child reaching the hole following hearing the stimulus sound

Protocol:

Visit 1	SS Condition	9 stimulus location	Repeated X2
Visit 2	PE condition	8 lead stimulus location	Repeated X2

Results-II

A one-way repeated measures ANOVA showed no statistically significant differences ($p > 0.05$) between the 3 conditions, likely due to large variability in participants' errors.

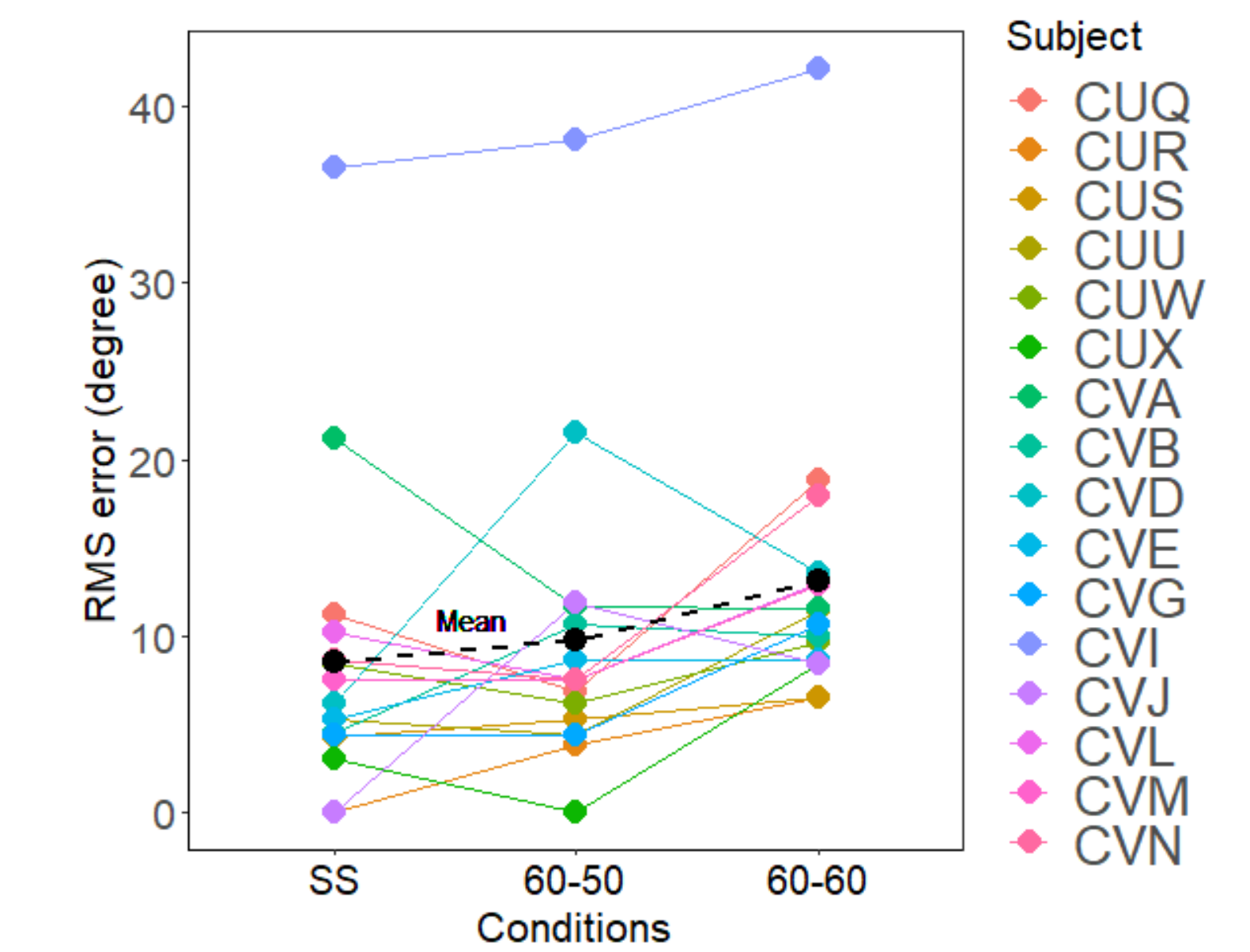


Figure 6: The colored lines represent the RMS errors for each subject across three conditions. The black dashed line indicates the mean RMS errors.

Condition	SS	PE 60-50	PE 60-60
RMS error mean (\pm SD)	8.53° (\pm 8.99°)	9.72° (\pm 8.94°)	13.13° (\pm 8.52°)
RMS error range	0°– 36.55°	0°– 38.11°	6.94°– 42.20°

Summary

- Compared to SS condition, localization errors in PE condition vary across participants, such that some show minimal increased errors while others show large increased errors in the presence of the lag. This is particularly true for the most challenging condition with the lagging stimulus presented at the same level as the lead.
- RMS errors were higher than errors shown previously in 4-5-year-old children when tested using a 5ms lead-lag delay[2].
- There is probably a developmental difference in locating sound between single source and PE conditions indicating a possible delay in the maturation of the precedence effect. In other words, the precedence effect as a measure of binaural processing has not been fully developed by the age of 2-3 years old.

Study Aims

- To investigate PE in toddlers by assessing how the presence of a lagging sound affects the ability of toddlers to localize the leading sound.
- To investigate the impact of increasing task difficulty on the PE benefit in toddlers.

Hypothesis

We hypothesized that PE would be immature in toddlers. Therefore, we expected toddlers to show higher RMS errors in reverberant conditions relative to SS condition. Further, we expected RMS errors to increase with task difficulty.

Method

Participants:

16 typically-hearing toddlers, mean age 34.8 months (range 25-44 months).

Testing apparatus:

A semi-circular arc covered by a curtain. Nine holes in the curtain, spaced 15° apart spanning -60° to +60° azimuth, each had a loudspeaker behind.



Figure 2: Testing apparatus was an arc spanning -60° to +60° azimuth. There was a loudspeaker behind each hole.

Results-I

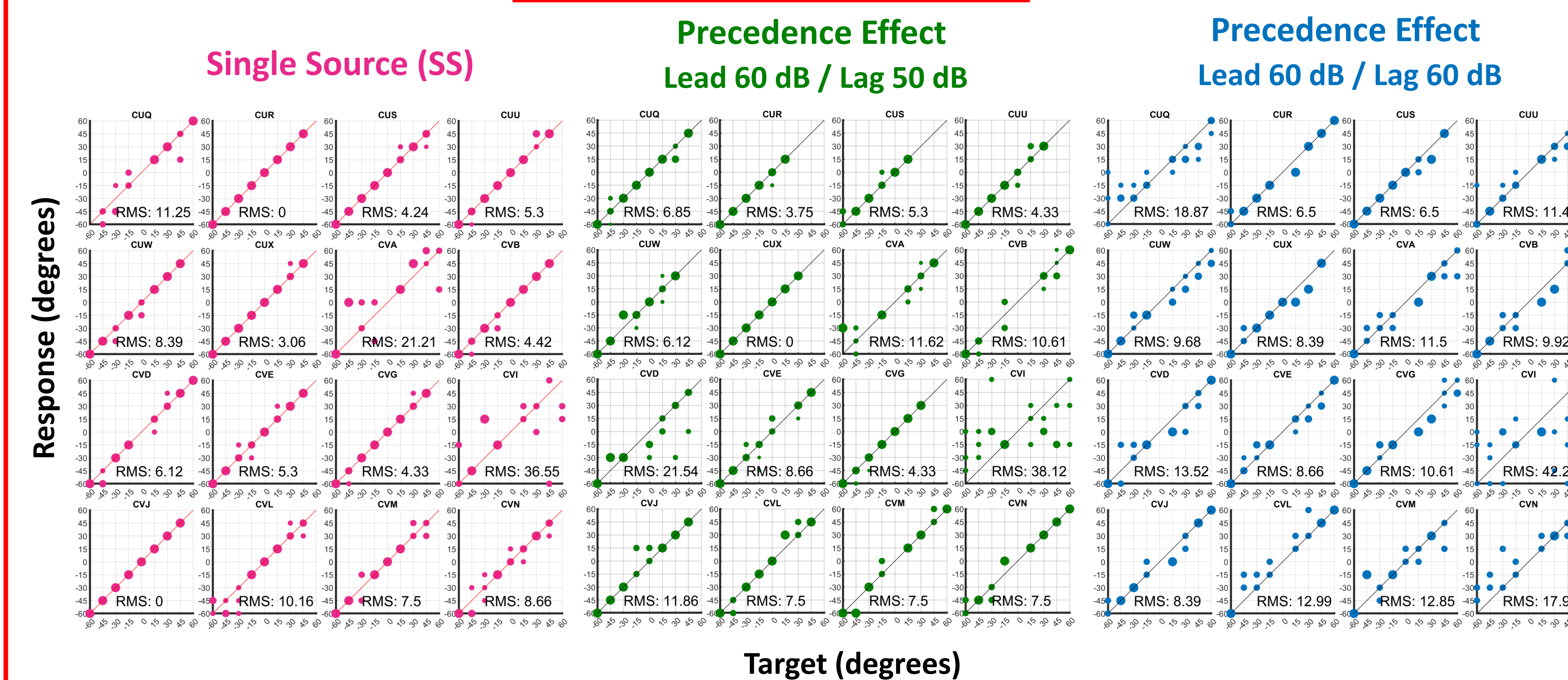


Figure 5: Individual performance on the sound localization in the 3 conditions. The size of the dots represents the number of responses for a given target location (i.e., the larger dots reflect a greater number of responses).

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