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Measures of 3M™ E-A-R™ Classic™ Hearing Protection Device in Accordance with Method 1 of ASA/ANSI S3.71-2019, "Methods for Measuring the Effect of Head-worn Devices on Directional Sound Localization in the Horizontal Plane"

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This manuscript reports the effect of the 3M™ E-A-R™ Classic™ Earplug on directional sound localization in the horizontal plane when tested in accordance with Method 1 described in ASA/ANSI S3.71-2019 "Methods for Measuring the Effect of Head-worn Devices on Directional Sound Localization in the Horizontal Plane". Results indicate that, when properly fit and functional, the 3M™ E-A-R™ Classic™ will result in errors in directional sound localization in the horizontal plane 24.6% of the time (21.4% higher than baseline error-rate).

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Executive Summary

This manuscript reports the effect of the 3M™ E-A-R™ Classic™ Earplug on directional sound localization in the horizontal plane when tested in accordance with Method 1 described in Acoustical Society of America/American National Standards Institute (ASA/ANSI) S3.71-2019 "Methods for Measuring the Effect of Head-worn Devices on Directional Sound Localization in the Horizontal Plane." The overall mean (and standard deviation [SD]) percent correct for the fine resolution when using the 3M™ E-A-R™ Classic™ were found to be 75.4% (7.4%) for all stimuli (long and short), 68.5% (8.7%) for short stimuli (a single 250 ms duration noise), and 96.0% (7.9%) for long duration stimuli (a repeating 250 ms duration noises). The calculated overall mean (SD) of front-back reversals for the 3M™ E-A-R™ Classic™ was 17.1% (5.6%) for all stimuli, 21.9% (6.8%) for short stimuli, and 2.9% (5.3%) for long duration stimuli. These Method 1 results indicate that, when properly fit and functional, the 3M™ E-A-R™ Classic™ will result in errors in directional sound localization in the horizontal plane 24.6% of the time (21.4% higher than the facility's measured error-rate without hearing protection donned).

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1. Introduction

The Acoustical Society of America (ASA) and American National Standards Institute (ANSI) published a new standard in 2019 that provided scientists and researchers with a standard procedure to measure the effect hearing protection devices (HPDs) and other head-worn devices (e.g., helmets) have on the ability of humans to localize to sound originating in the horizontal plane. This standard, S3.71-2019 "Methods for Measuring the Effect of Head-worn Devices on Directional Sound Localization in the Horizontal Plane" (hereafter referred to as 'the standard') is comprised of three methods that vary in purpose and facility requirements. The first method, Method 1, is designed to be easiest to implement, requires the least amount of time for testing, and can take place either indoors or outdoors. Method 1 is the focus of the current report. It is an auditory search task, with eight loudspeakers and eight possible responses. The main metric of performance is total percent accuracy in identifying the correct loudspeaker. Method 1 is designed to quickly measure the effect of any head-worn device on directional sound localization in the horizontal plane using eight loudspeakers. Contained in this report are the methodology, test results, and conclusions for the 3M™ E-A-R™ Classic™ Earplug on its impact on the ability to localize in the horizontal plane following Method 1 of the standard.

2. Background of Methodology

For detailed descriptions of each of the requirements in the standard, the interested reader is referred to the full text in ASA/ANSI S3.71-2019. Exact sections of each requirement followed in this report are presented in Table 1.

Table 1. List of ASA/ANSI S3.71-2019 Requirements Followed

Requirements	Section
Screening physical characteristics	4.1.1
Head, pinnae, and ear canals inspection	4.1.2
Physical measures of the head	4.1.3
Gender[1]	4.1.4
Visual acuity	4.1.5
Unaided air-conduction hearing thresholds	4.1.6.1
Minimum localization performance	4.1.6.2
Test stimulus presentation	8.2
Use of chin rest and Subject head position during testing	8.3
Generation, presentation, and measurement of background noise	8.6.1
Test paradigm	8.6.2
Data analysis	8.6.3

[1] "Gender" is not recommended by the American Psychological Association as equivalent to "sex," but was the word used by ASA/ANSI, and is inferred to refer to the two most common biological sex assignments at birth, rather than any other meaning.

2.1 Facility Baseline Performance

The most recent baseline percent correct calculated means and standard deviations (SDs) for the open-ear condition (n = 20) for all stimulus durations (Overall – All Stimuli), short stimulus duration (Short Stimuli; a single 250 ms duration noise), and for long duration stimulus duration (Long Stimuli; a repeating 250 ms duration noise) in the NSMRL Method 1 test space are shown in Table 2 (Schwaller et al., 2023). As defined in the standard, 'fine correct' or 'fine resolution' means the subject identified the loudspeaker from which the target was presented. 'Coarse correct' or 'coarse resolution' means the subject identified either of the loudspeakers from the loudspeaker pair from which the target was presented (e.g., if loudspeaker 3 presented the target, the subject could respond either "3" or "4").

Table 2. Group Mean and Standard Deviation (SD for Baseline Facility Performance. This table has been adapted from the NSMRL Technical Report 2023-1415 (Schwaller et al., 2023).

Overall – All Stimuli	Mean	SD
Fine Correct	96.8%	2.3%
Fine Correct - Corrected for Guessing	96.3%	2.6%
Fine Correct - Corrected for F/B Reversals	96.8%	2.3%
Fine Correct - Corrected for Guessing and F/B Reversals	96.0%	3.0%
Proportion of F/B Reversals	0.2%	0.4%
Coarse Correct	99.6%	0.5%
Coarse Correct - Corrected for Guessing	99.4%	0.7%
Coarse Correct - Corrected for F/B Reversals	99.8%	0.5%
Coarse Correct - Corrected for Guessing and F/B Reversals	99.6%	0.8%

Short Stimuli		
Fine Correct	95.9%	3.0%
Fine Correct - Corrected for Guessing	95.3%	3.4%
Fine Correct - Corrected for F/B Reversals	96.0%	3.0%
Fine Correct - Corrected for Guessing and F/B Reversals	94.9%	3.8%
Proportion of F/B Reversals	0.3%	0.6%
Coarse Correct	99.5%	0.6%
Coarse Correct - Corrected for Guessing	99.4%	0.8%
Coarse Correct - Corrected for F/B Reversals	99.8%	0.5%
Coarse Correct - Corrected for Guessing and F/B Reversals	99.6%	0.8%

Long Stimuli		
Fine Correct	99.4%	1.4%
Fine Correct - Corrected for Guessing	99.3%	1.6%
Fine Correct - Corrected for F/B Reversals	99.4%	1.4%
Fine Correct - Corrected for Guessing and F/B Reversals	99.2%	1.8%
Proportion of F/B Reversals	0.1%	0.6%

Coarse Correct	99.7%	1.0%
Coarse Correct - Corrected for Guessing	99.6%	1.4%
Coarse Correct - Corrected for F/B Reversals	99.8%	0.9%
Coarse Correct - Corrected for Guessing and F/B Reversals	99.6%	1.7%

Note. As described in section 8.6.3 of the standard, the data presented are the front-back (F/B) reversals, fine percent correct, coarse percent correct, and the percent correct data with and without corrections for F/B reversals and guessing.

3. Methods

3.1 Institutional Review Board (IRB) Approval

All reported research was conducted under the purview of the Institutional Review Board at NSMRL (Department of Defense IRB Assurance number: DoD N-40035) under protocol number NSMRL.2021.0003.

3.2 Subjects

A total of 25 adults provided verbal consent to participate. Twenty subjects, aged 18 to 50 years (mean of 33 ± SD of 10), met inclusion criteria, completed a seven-item ANSI-designed survey, and completed data collection with the E-A-R™ Classic™. Specifically, each subject was found to have binaural hearing sensitivity equal to or better than 20 dB HL at octave band frequencies 125 to 8000 Hz (see 4.1.6.1 in the standard); ear canals clear of excessive cerumen and/or foreign debris, able to use insert earplugs (see 4.1.2 in the standard); and visual acuity better than 20/30 as measured with a Snellen test (see 4.1.5 in the standard). Of the 20 subjects who completed data collection, 55% said they were female (n = 11), 45% said they were male (n = 9), and 0% responded with something other than male or female (n = 0). This ratio was found to be within limits stipulated in the standard (see 4.1.4 in the standard). The data for these 20 subjects are included in the analysis.

Two of the 25 subjects did not meet hearing sensitivity requirements (see 4.1.6.1 in the standard). One of the 25 subjects did not meet the inclusion criteria for performance in the standard (section 4.1.6.2); that subject scored less than 90% correct during the unoccluded testing. Two of the remaining 22 subjects were excluded at the principal investigator's discretion. They were excluded from statistical analyses due to an anomaly with study test stimuli.

All subjects were compensated for their time.

3.3 Hearing Protection Device Samples

The earplug used for localization testing was the 3M™ E-A-R™ Classic™ Earplug (E-A-R™ Classic™; 3M™, St. Paul, MN). The E-A-R™ Classic™ (Manufacturer Product Number: 310-1001) is an uncorded, cylindrical earplug made from slow recovery, flame, sweat, and moisture resistant PVC foam intended for single use. The earplug comes available in two sizes (small and

regular). All subjects tested required samples that were regular size. Each sample, consisting of one set of two earplugs, was used with one subject then disposed.

Photo Credit: NSMRL

Figure 1. Tested Hearing Protection Device. One pair of E-A-R™ Classic™ Earplugs.

3.4 Experimental Staff

The testing was conducted by the NSMRL Regional Hearing Conservation team. The experimenters were Dr. Alexa Kolias, Mr. Jake See, Mr. Derek Schwaller, Dr. Meredith McGhee, Dr. Stephanie Karch, Mr. Joshua Ginsberg, and Dr. Jeremy Federman.

3.5 Dates of Data Collection

Data were collected between January and May 2022.

3.6 Sound Field Requirements

The sound field was measured to be in accordance with section 6.1 of the standard. Stimuli were generated in accordance with sections 6.1.1, 6.1.2, and 6.1.3 of the standard. The fulfillment of these requirements was verified at the beginning of each day of data collection.

3.7 Facility

All requirements of the standard were met for conducting baseline, open-ear condition testing indoors in accordance with the Method 1 procedures. Full documentation of the facility certification is documented in NSMRL Technical Report #2023-1415 (Schwaller et al., 2023). The same facility and instrumentation were used for data collection described herein.

3.8 Instrumentation

The personal attenuation rating of the hearing protection device was measured with a hearing protection device fit-testing system (Michael and Associates, Inc.®; FitCheck Solo™; S/N 0001).

3.9 Stimuli

In accordance with section 6.1.1 of the standard, randomly generated pink noise was used as the stimulus. Specifically, the noise was pink over the frequency range from 200 Hz to 14 kHz within ± 3 dB of the level at 1 kHz. In accordance with section 6.1.2 of the standard, short-duration stimuli were a total of 250 ms in duration with 10 ms linear ramps at the beginning and end of the stimulus. Conversely, long-duration stimuli were repetitions of the short-duration stimuli with a 50% duty cycle; that is, on for 250 ms then off for 250 ms, until the subject responded or for a total duration of 7 seconds, whichever was shorter. The stimuli were

randomly presented for each trial in accordance with section 8.2 of the standard. Background masking noise with an overall level of 50 dBA was presented from a loudspeaker directly above the subject in accordance with section 8.6.1 of the standard.

3.10 Procedure

The experimenter instructed each subject on how to do a hearing protection fit-test to ensure proper fitting of the HPD had been achieved. Each subject completed the unoccluded portion of the fit test. Then, the experimenter fit the hearing protection on the subject. Next, the subject completed the occluded portion of the fit test after waiting two minutes for the earplug to expand.

Although not required by the standard, the minimum acceptable personal attenuation rating (PAR) value criterion for this product was determined to be 19.7 dB. This value (four standard deviations below the manufacturer's published group mean) was selected as representative of typical user quality of fit.

The auditory localization task was conducted in accordance with section 8.6.2 of the standard. The subject responses were given verbally and manually entered into a computer by the experimenter. The experimenter instructed the subject when to change the orientation point and when the session ended. In addition to the standard's requirements, scripted instructions were used to consistently instruct every subject (see Appendix A).

3.11 Analysis Plan

In accordance with section 8.6.3 of the standard, the data were analyzed for:

1) Proportion of front-back (F/B) reversals;
2) Proportion of correct location identifications (fine resolution) both with and without correction for front-back reversals and with and without corrections for guessing; and
3) Proportion of correct location identifications (coarse resolution) both with and without correction for front-back reversals and with and without corrections for guessing.

The response data were analyzed for percent correct for both 'fine resolution' and 'coarse resolution.' In addition to the standard's requirements, each orientation was analyzed separately in order to test whether results specified in sections 7.1 and 7.2 of the standard were satisfied. Each loudspeaker location was also analyzed separately in order to examine whether there were asymmetric characteristics of the facility. The data from the questionnaires, room acoustics measures, and anthropomorphic measures were tabulated but not statistically analyzed.

4. Results

4.1 Subject Information

Appendix B presents the tabulated results from each subject's anthropomorphic measures, hearing screening results, and questionnaire responses.

4.2 Hearing Protection Device Performance

The measured group PAR values of the 3M™ E-A-R™ Classic™ Earplug ranged from 21.0 dB to 42.9 dB, with a mean of 33.1 dB and SD of 5.6 dB. All PAR values were obtained without the need to refit the HPD to the subject.

The group means and SDs for percent correct are shown in Table 3 for occluded-ear (n = 20) for all stimulus durations (Overall – All Stimuli), short stimulus duration (Short Stimuli), and long duration stimulus duration (Long Stimuli).

Table 3. Group Mean and SD for HPD Performance.

Overall – All Stimuli	Mean	SD
Fine Correct	75.4%	7.2%
Fine Correct - Corrected for Guessing	71.8%	8.2%
Fine Correct - Corrected for F/B Reversals	82.0%	5.9%
Fine Correct - Corrected for Guessing and F/B Reversals	77.0%	7.6%
Proportion of F/B Reversals	17.1%	5.6%
Coarse Correct	85.7%	4.7%
Coarse Correct - Corrected for Guessing	80.9%	6.2%
Coarse Correct - Corrected for F/B Reversals	99.0%	1.0%
Coarse Correct - Corrected for Guessing and F/B Reversals	98.3%	1.8%
Short Stimuli		
Fine Correct	68.5%	8.7%
Fine Correct - Corrected for Guessing	64.0%	10.0%
Fine Correct - Corrected for F/B Reversals	76.8%	7.2%
Fine Correct - Corrected for Guessing and F/B Reversals	70.3%	9.3%
Proportion of F/B Reversals	21.9%	6.8%
Coarse Correct	81.6%	5.9%
Coarse Correct - Corrected for Guessing	75.5%	7.8%
Coarse Correct - Corrected for F/B Reversals	98.7%	1.3%
Coarse Correct - Corrected for Guessing and F/B Reversals	97.7%	2.4%
Long Stimuli		
Fine Correct	96.0%	7.9%
Fine Correct - Corrected for Guessing	95.5%	9.1%
Fine Correct - Corrected for F/B Reversals	97.8%	5.6%
Fine Correct - Corrected for Guessing and F/B Reversals	97.2%	7.1%
Proportion of F/B Reversals	2.9%	5.3%
Coarse Correct	97.7%	4.2%
Coarse Correct - Corrected for Guessing	96.9%	5.5%
Coarse Correct - Corrected for F/B Reversals	100.0%	0.0%

Coarse Correct - Corrected for Guessing and F/B Reversals	100.0%	0.0%

Note. As described in section 8.6.3 of the standard, the data presented are the front-back (F/B) reversals, fine percent correct, coarse percent correct, and the percent correct data with and without corrections for F/B reversals and guessing.

Performance analyzed for each orientation is reported in Appendix C.

Performance analyzed for each loudspeaker location is reported in Appendix D.

4.3 Uncertainty Analysis

The standard and expanded uncertainty for the total measurement including all the individual contributing parameters and their measured or estimated uncertainty values are reported in Table 4.

Table 4. Uncertainty Metrics.

Quantity	Estimate %	Standard uncertainty U_i %	Probability distribution	Sensitivity coefficient C_i	Uncertainty contribution $C_i U_i$ %
PFB_e	$\overline{PFBe}$	3	Normal	1	3
PC_{FR}	$\overline{PC}_{FR}$	5	Normal	1	5
PC_{CR}	$\overline{PC}_{CR}$	1	Normal	1	1
δ_{AM}	0	0.5	Normal	1	0.5
δ_{HT}	0	2	Normal	1	2
$\delta_{RESPONSE}$	0	0.2	Normal	1	0.2
$\delta_{SUBJECT}$	0	1	Normal	1	1
$\delta_{SOUND\ FIELD}$	0	0.5	Normal	1	0.5
$\delta_{DEVICE\ FIT}$	0	1	Normal	1	1

Metric	Standard (%)	Expanded (%)
PFB_e	3.9	7.9
PC_{FR}	5.6	11.2
PC_{CR}	2.7	5.5

Note. All acronyms are as defined in section 9.1 of the standard. The standard and expanded uncertainty were calculated using the formulas and estimated values from section 9.1 of the standard. No better estimation for the uncertainty values was available at the time of writing this report.

5. Conclusion

This report describes the determination of the measured effect of the 3M™ E-A-R™ Classic™ Earplug on directional sound localization in the horizontal plane in accordance with Method 1 of ANSI S3.71-2019. The calculated overall mean (SD) percent correct (with fine resolution) values

for the 3M™ E-A-R™ Classic™ were found to be 75.4% (7.4%) for all stimuli, 68.5% (8.7%) for short stimuli, and 96.0% (7.9%) for long duration stimuli. The calculated overall mean (SD) percent of front-back reversals for the 3M™ E-A-R™ Classic™ were found to be 17.1% (5.6%) for all stimuli, 21.9% (6.8%) for short stimuli, and 2.9% (5.3%) for long duration stimuli. Taken together, these results indicate that, when properly fitted and functional, the 3M™ E-A-R™ Classic™ will cause errors in directional sound localization in the horizontal plane 24.6% of the time (21.4% higher than the facility's measured error-rate without hearing protection donned).

6. References

American National Standards Institute. (1974). *ANSI S3.19-1974: Method for the Measurement of Real-Ear Protection of Hearing Protectors and Physical Attenuation of Earmuffs.* Acoustical Society of America.

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7. Appendices

APPENDIX A: Subject Instructions

“Please face the sign that reads [INSERT THE SUBJECT’S STARTING PLACARD HERE]. This is your starting placard. You will be asked to place your chin on the chin rest and keep it there throughout the entire test session. In a few minutes, a sound will play from one of the speakers that surround you. Your job is to turn and look at the speaker where you think the sound is coming from AND then say out loud what that speaker number is. Once you have said your choice out loud, you are to turn your chair and face the starting placard. We will repeat this 24 times. You then will be told a new starting placard to face – and we will repeat the entire process another seven times. In total, this should take less than 45 minutes to complete. Let’s practice.”

APPENDIX B: Subject Information

Subject Number	1	2	3	4	5	6	7	8	9	10	11	12	13
Included in Data Analysis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No
Anthropomorphic Metric	**Measures by Subject**												
Bitragion Width (cm)	13	13.5	14	12	14	13	12	15	14	13	15	16	16
Head Height (cm)	13	14	14	14	13	12	13	14	14	13	13	14	14
Ear Canal Size	Medium	Large	Medium	Small	Medium	Medium	Medium	Large	Large	Small	Medium	Medium	Large
Hearing Sensitivity	**Passing Measure by Subject**												
125 Hz Right Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
250 Hz Right Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
500 Hz Right Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1000 Hz Right Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2000 Hz Right Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4000 Hz Right Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8000 Hz Right Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
125 Hz Left Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
250 Hz Left Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
500 Hz Left Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1000 Hz Left Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2000 Hz Left Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
4000 Hz Left Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
8000 Hz Left Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ANSI Questionnaire	**Response by Subject**												
Age (years)	50	34	48	32	18	22	45	43	20	22	37	39	38
Have you ever received one-on-one personal instruction in the fitting of head-worn devices or hearing protectors?	No	No	Yes	No	No	No	No	Yes	Yes	No	Yes	Yes	Yes
Within the past two years, have you received group instruction on, or watched videotaped or computer-based instructions about, how to fit head-worn devices or hearing protectors?	No	No	Yes	Yes	No	No	No	Yes	No	No	No	No	No
Within the past two years, have you participated in an experiment involving the use of head-worn devices or hearing protection?	No	No	Yes	No	No	No	Yes	Yes	Yes	No	No	Yes	Yes
Within the past two years, on how many occasions have you worn head-worn devices or hearing protectors because you were exposed to noise as part of your occupation, military duty, or other activity?	0	50	Many	6	0	0	6	20	>300	0	40	0	12
How many times have you worn earplugs while sleeping or swimming?	0	500	Swimming, a couple times	60	0	0	0	0	0	0	0	0	0
Within the past two years, on how many occasions have you participated in an experiment involving the localization of sound sources?	0	0	1	0	0	0	6	12	0	0	0	8	8
Within the past two years, on how many occasions have you participated in an experiment involving the localization of sound sources while wearing the head-worn device being evaluated in this experiment?	0	0	1	0	0	0	0	10	0	0	0	8	8

Subject Number	14	15	16	17	18	19	20	21	22	23	24	25
Included in Data Analysis	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
Anthropomorphic Metric	**Measures by Subject**											
Bitragion Width (cm)	14	14	16	15	15	16	15	14	15	14	15	15
Head Height (cm)	14	13.5	14	13	14	14	14.5	15	12	14	14	14
Ear Canal Size	large	medium	large	medium	large	x-large	medium	large	small	small	large	medium
Hearing Sensitivity	**Passing Measure by Subject**											
125 Hz Right Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
250 Hz Right Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
500 Hz Right Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1000 Hz Right Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2000 Hz Right Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4000 Hz Right Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8000 Hz Right Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
125 Hz Left Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
250 Hz Left Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
500 Hz Left Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1000 Hz Left Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2000 Hz Left Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4000 Hz Left Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8000 Hz Left Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
ANSI Questionnaire	**Response by Subject**											
Age (years)	29	21	28	37	37	37	33	44	43	20	54	41
Have you ever received one-on-one personal instruction in the fitting of head-worn devices or hearing protectors?	No	No	No	No	Yes	No	No	No	Yes	No	Yes	Yes
Within the past two years, have you received group instruction on, or watched videotaped or computer-based instructions about, how to fit head-worn devices or hearing protectors?	No	No	No	No	No	No	No	No	Yes	No	No	No
Within the past two years, have you participated in an experiment involving the use of head-worn devices or hearing protection?	No	No	Yes	Yes	Yes	No	No	No	Yes	No	No	Yes
Within the past two years, on how many occasions have you worn head-worn devices or hearing protectors because you were exposed to noise as part of your occupation, military duty, or other activity?	1	0	0	24	25	0	8	5	0	0	50	4-6
How many times have you worn earplugs while sleeping or swimming?	0	0	8	1	0	0	0	0	1	0	0	0
Within the past two years, on how many occasions have you participated in an experiment involving the localization of sound sources?	0	0	1	1	2	0	0	0	8	0	0	1

APPENDIX C: Independent Orientation Data

As shown in table C1, the data from the eight orientations were analyzed separately for their percent correct, with fine resolutions, without compensation for F/B reversals.

Table C1. Total Mean Correct by Orientation.

Orientation	Correct
A	72%
B	81%
C	75%
D	78%
E	73%
F	76%
H	71%
I	78%

As shown in table C2, the data from the eight orientations were also analyzed separated into the short stimulus durations. The data presented are the mean percent correct with fine resolution, without compensation for front/back reversals, for the short stimulus duration for each orientation.

Table C2. Total Mean Correct by Orientation (Short).

Orientation	Correct
A	66%
B	73%
C	69%
D	71%
E	62%
F	71%
H	64%
I	72%

As shown in table C3, the percent correct for the group from the eight orientations were also analyzed separated into the long stimulus durations. The data presented are the mean percent correct with fine resolution, without compensation for front/back reversals, for the long stimulus duration for each orientation.

Table C3. Total Mean Correct by Orientation (Long).

Orientation	Mean % Correct	Count
A	98%	11
B	98%	16
C	90%	13
D	98%	14
E	95%	12
F	96%	9
G	97%	11
H	100%	10

Presentation of long duration stimuli were pseudo-randomly selected. Each subject was presented with six blocks of long stimuli. This resulted in an uneven number of subjects who were presented with long stimuli at each orientation. The count is the total number of subjects who were presented long stimuli in that orientation and are therefore included in the mean percent correct.

APPENDIX D: Independent Loudspeaker Data

As shown in Figures D1 to D6, the data from the eight loudspeaker locations were processed separately for their percent correct, with fine resolution, without compensation for front/back reversals.

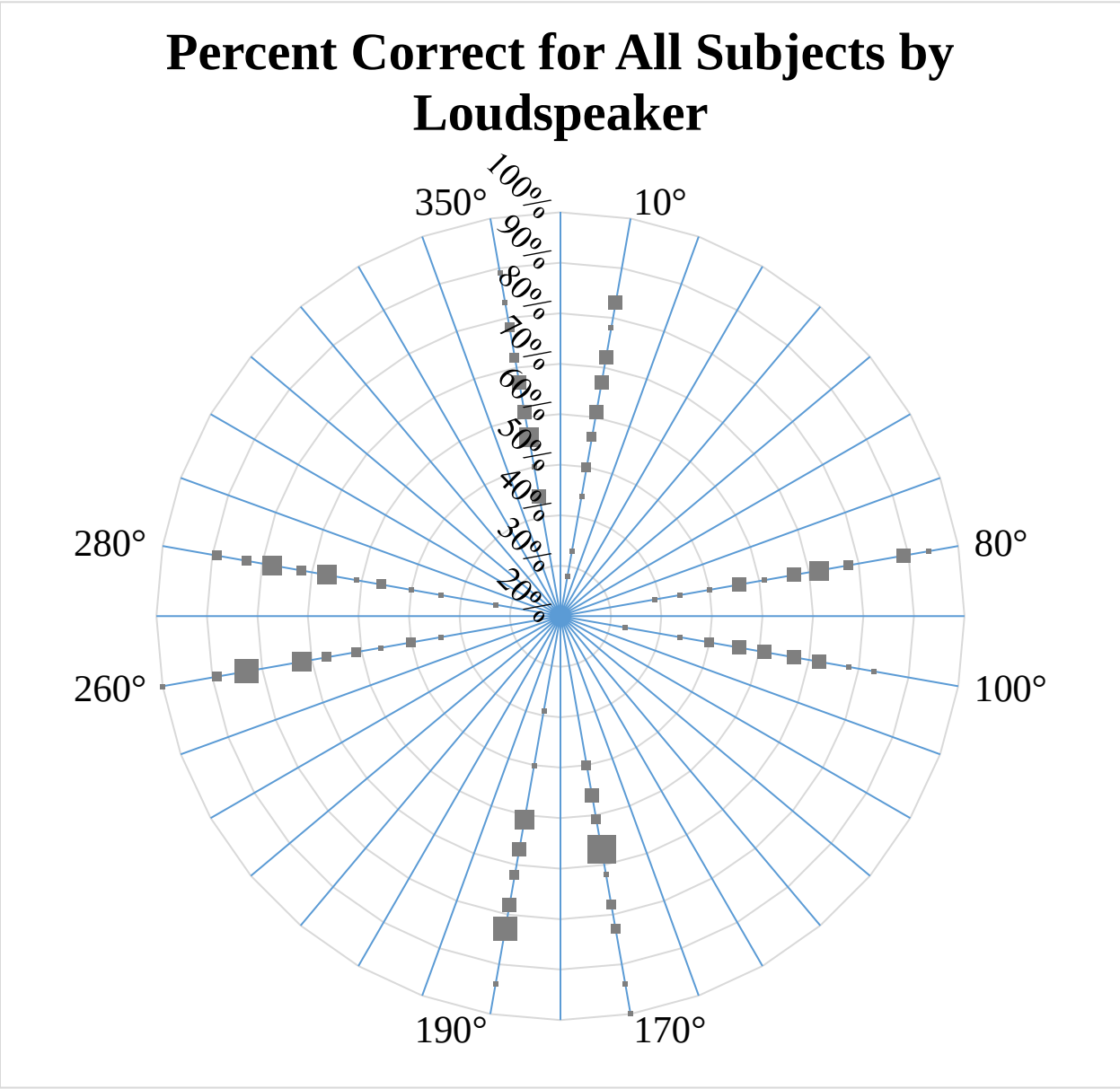

Figure D1. Percent Correct for Each Subject. Percent correct data, with fine resolution, without compensation for front/back reversals for each subject. The angles (in degrees (º)) are shown for the eight loudspeakers, referenced with the midpoint between loudspeakers 1 and 2 as 0º. The radius is the percent correct (0 to 100%). The squares are a subject's percent correct. The marker size of the squares is proportional to the number of subjects who scored that value.

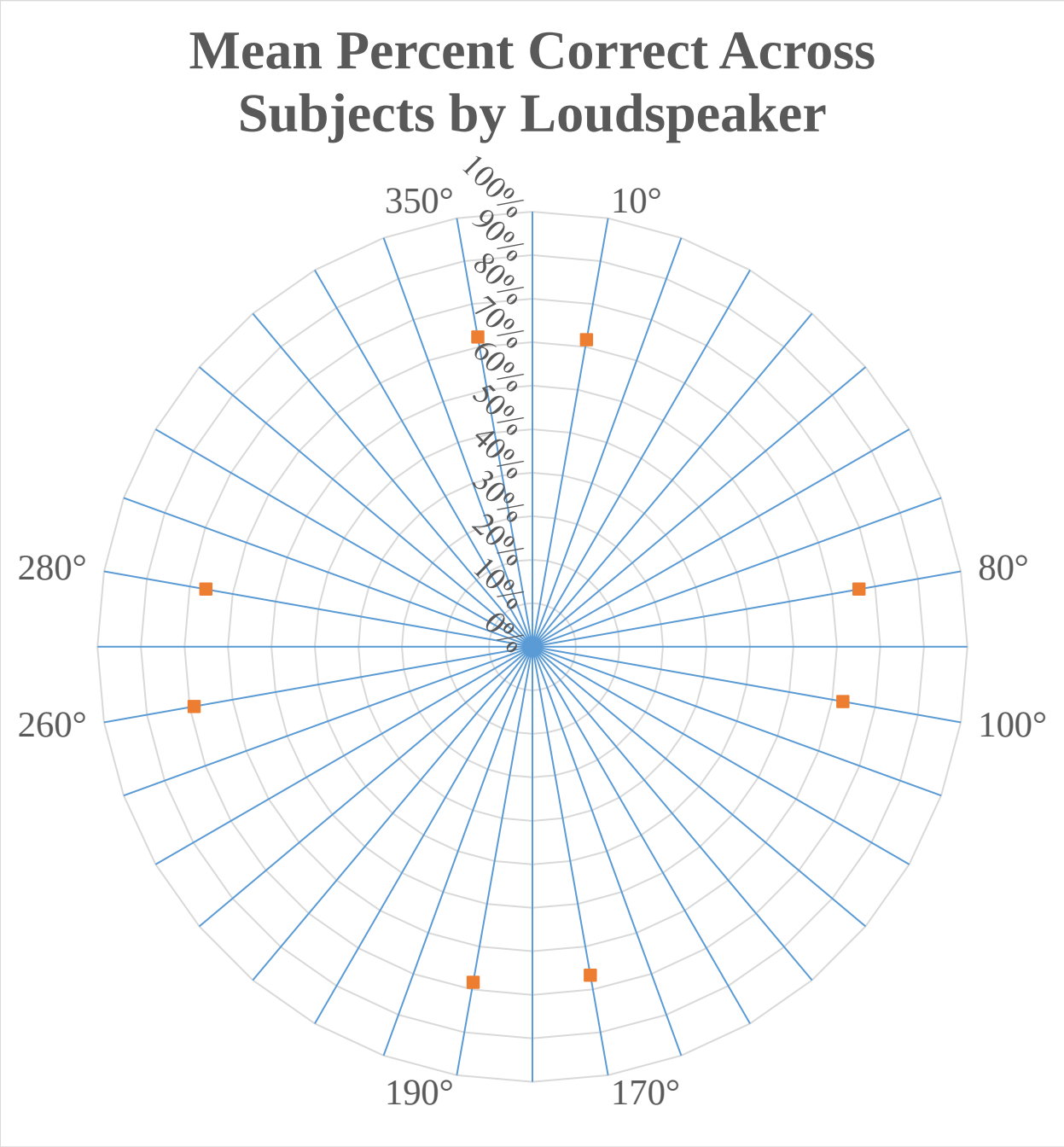

Figure D2. Mean Percent Correct Across Subjects. Mean percent correct data, with fine resolution, without compensation for front/back reversals for each loudspeaker averaged across subjects. The angles (in degrees (º)) are shown for the eight loudspeakers, referenced with the midpoint between loudspeakers 1 and 2 as 0º. The radius is the percent correct (0 to 100%). The mean percent correct data for each loudspeaker location are marked with an orange square.

The data from the eight loudspeaker locations were also processed separately for their percent correct, with fine resolution, without compensation for front/back reversals separately for the long and short stimuli durations. The results are in Figures D3 and D4 for the short duration and Figures D5 and D6 for the long duration.

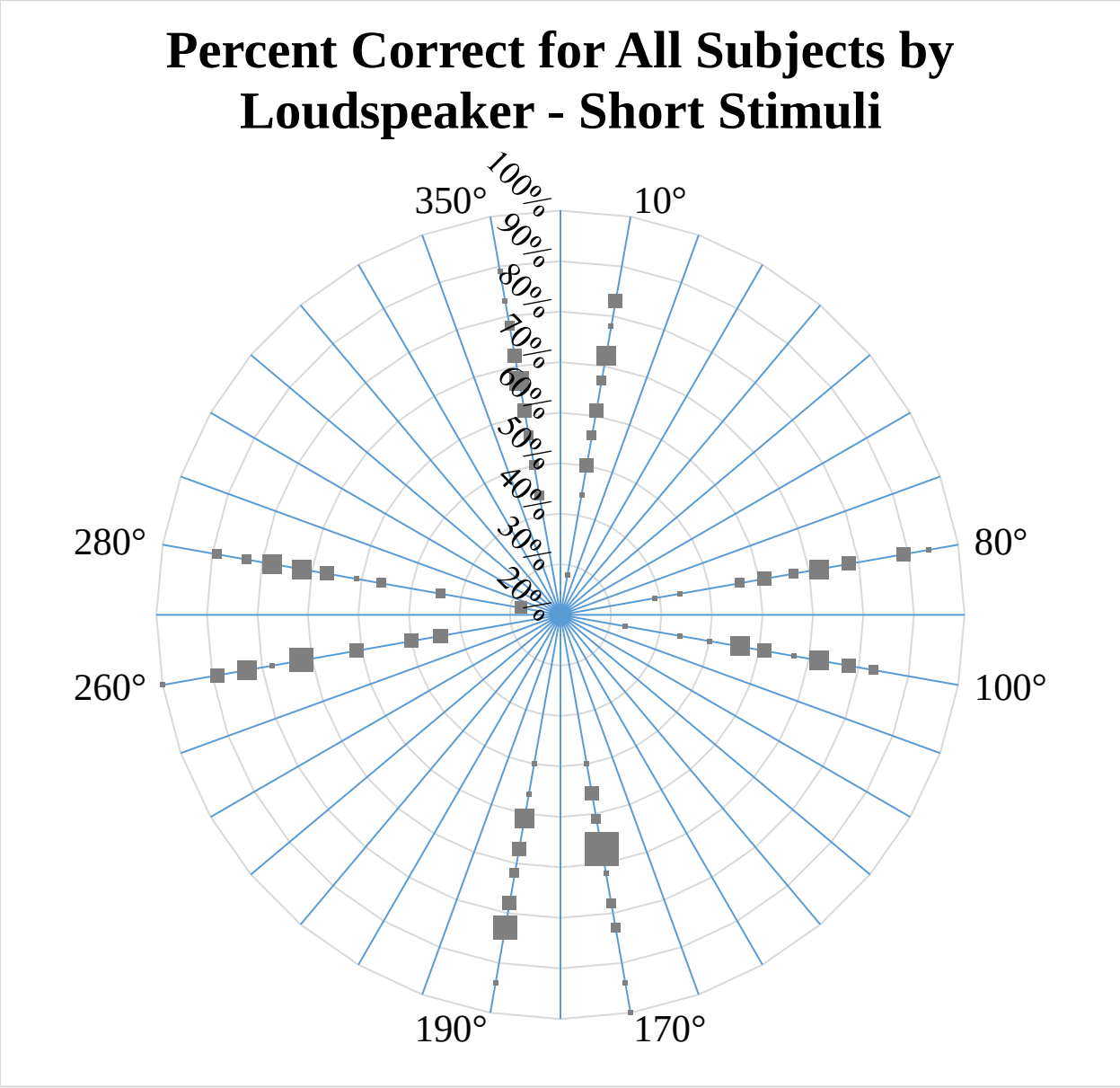

Figure D3. Percent Correct for Short Stimuli for Each Subject. Percent correct data, with fine resolution, without compensation for front/back reversals for each loudspeaker for all subjects of the short duration stimuli data. The angles (in degrees (º)) are shown for the eight loudspeakers, referenced with the midpoint between loudspeakers 1 and 2 as 0º. The radius is the percent correct (0 to 100%). The squares are a subject's percent correct. The marker size of the squares is proportional to the number of subjects who scored that value.

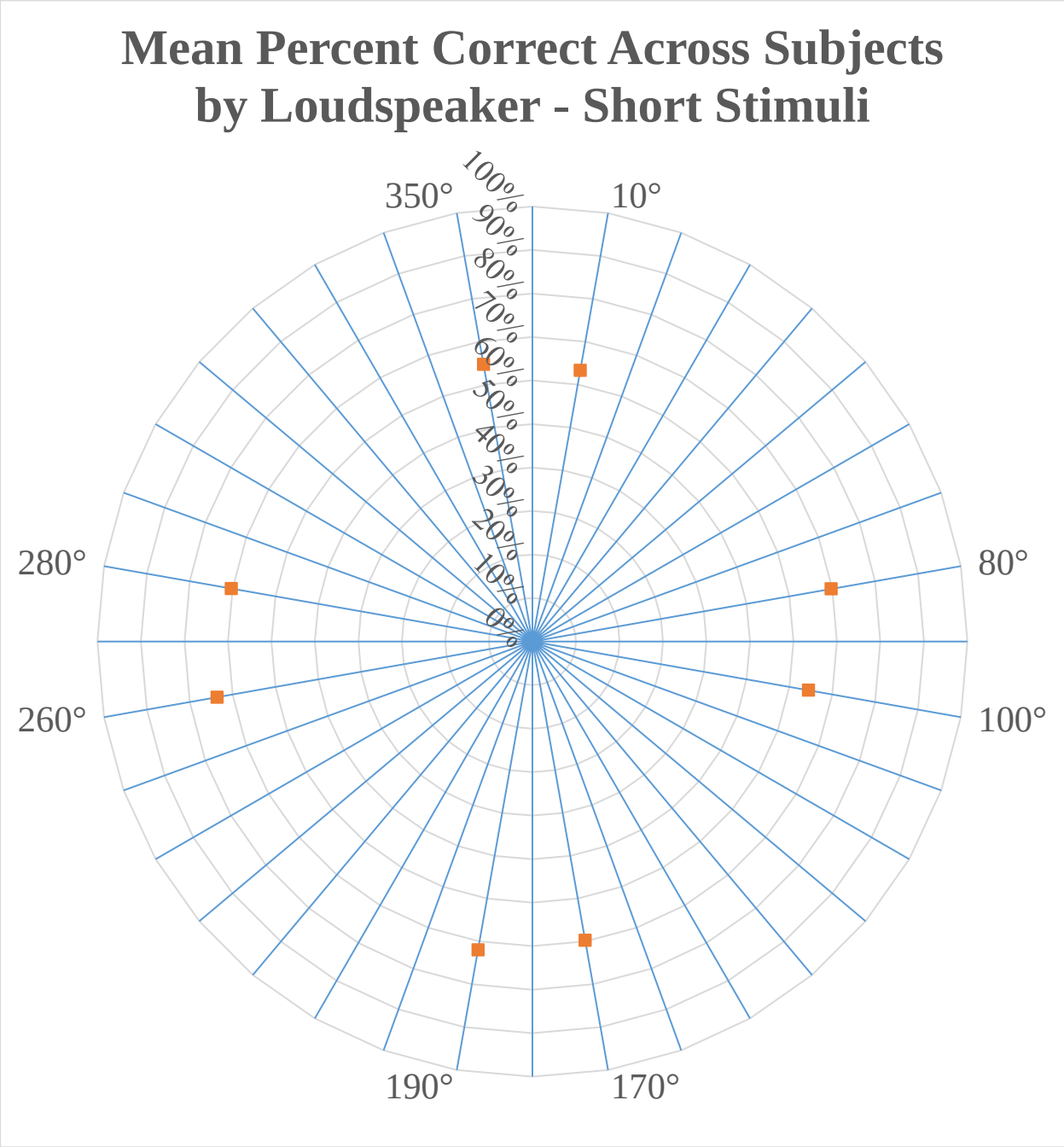

Figure D4. Mean Percent Correct for Short Stimuli Across Subjects. Mean percent corrects, with fine resolution, without compensation for front/back reversals for each loudspeaker averaged across subjects of the short duration stimuli data. The angles (in degrees, (º)) are shown for the eight loudspeakers, referenced with the midpoint between loudspeakers 1 and 2 as 0º. The radius is the percent correct (0 to 100%). The mean percent correct data for each loudspeaker location are marked with an orange square.

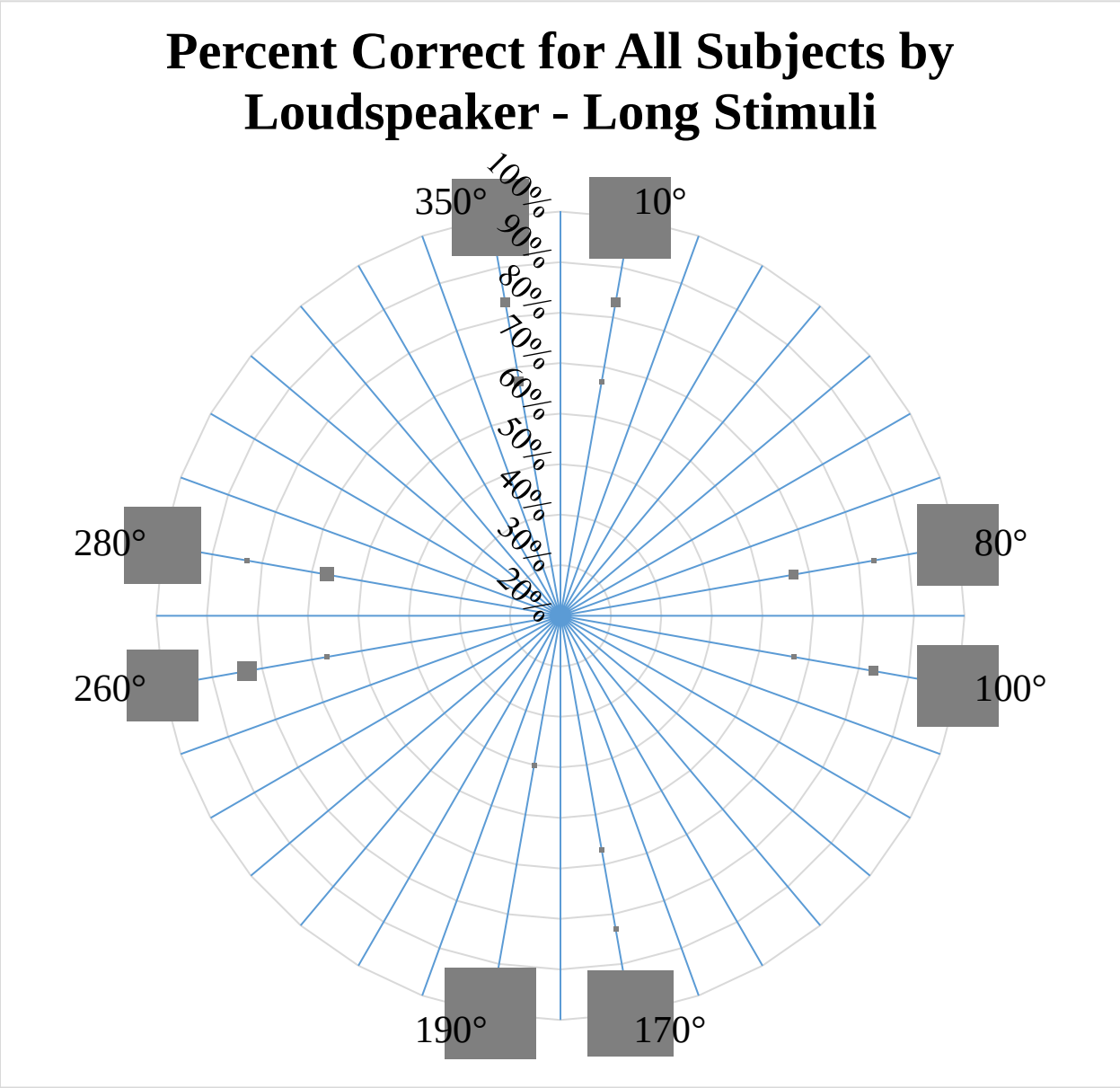

Figure D5. Percent Correct for Long Stimuli for Each Subject. Percent corrects, with fine resolution, without compensation for front/back reversals for each loudspeaker for all subjects of the long duration stimuli data. The angles (in degrees (º)) are shown for the eight loudspeakers, referenced with the midpoint between loudspeakers 1 and 2 as 0º. The radius is the percent correct (0 to 100%). The squares are a subject's percent correct. The marker size of the squares is proportional to the number of subjects who scored that value.

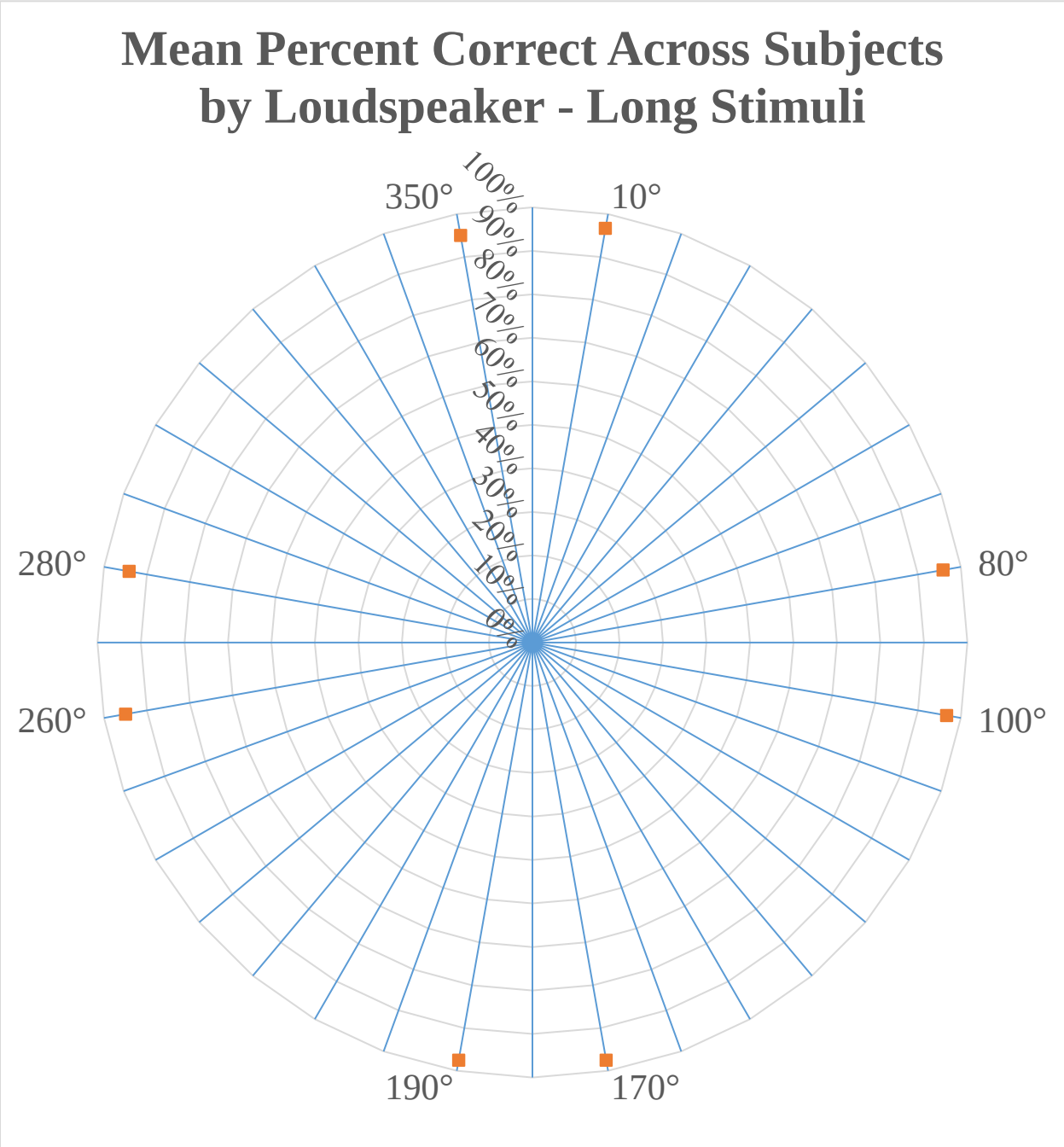

Figure D6. Mean Percent Correct for Long Stimuli Across Subjects. Mean percent corrects, with fine resolution, without compensation for front/back reversals for each loudspeaker averaged across subjects of the long duration stimuli data. The angles (in degrees (º)) are shown for the eight loudspeakers, referenced with the midpoint between loudspeakers 1 and 2 as 0º. The radius is the percent correct (0 to 100%). The mean percent correct data for each loudspeaker location are marked with an orange square.