Naval Submarine Medical Research Laboratory

NSMRL/F1703/TR--2024-1422 **March 28, 2024**

Verification that the Naval Submarine Medical Research Laboratory Facility Meets ANSI Standards for Measuring the Effect of Hearing Protection on Horizontal Localization Performance (per ASA/ANSI S3.71-2019 Method 2)

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
19-03-2024	Technical Report	FY2021

4. TITLE AND SUBTITLE

Naval Submarine Medical Research Laboratory Facility Certification to Measure the Effect of Hearing Protection on Horizontal Localization Performance: ASA/ANSI S3.71-2019 Method 2

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6.3

6. AUTHOR(S)

Derek Schwaller, Stephanie Karch, Jeremy Federman

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

F1703

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Submarine Medical Research Laboratory
Submarine Base New London, Box 900
Groton, CT 06349-5900

8. PERFORMING ORGANIZATION REPORT NUMBER

NSMRL/F1703/TR--2024-1422

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Military Operational Medicine Research Program Headquarters
US Army Medical Research and Development Command
810 Schreider Street
Attn: FCMR-RTO, BLDG 201, Room 132
Fort Detrick, MD 21702-5000

10. SPONSOR/MONITOR'S ACRONYM(S)

MOMRP JPC-5

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

DISTRIBUTION A. Approved for public release: distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Naval Submarine Medical Research Laboratory (NSMRL) created a test facility in an anechoic room in accordance with Method 2 of the Acoustical Society of America (ASA) and the American National Standards Institute (ANSI) standard S3.71-2019 "Methods for Measuring the Effect of Head-worn Devices on Directional Sound Localization in the Horizontal Plane" (except where noted in "Procedures"). The mean open-ear (baseline) performance must be less than or equal to 10 degrees average error in order for a facility to make measures in accordance with Method 2. The results from this effort indicate that test facility at NSMRL is qualified to measure the effect of head-worn devices on horizontal localization ability.

15. SUBJECT TERMS

Hearing Protection; Localization

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			NAVSUBMEDRSCHLAB Commanding Officer
U	U	U	SAR	37	19b. TELEPHONE NUMBER *(Include area code)* 860-694-3263

Reset

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

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The views expressed in this Technical Report are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, nor the U.S. Government. This work is supported by funding work unit number F1703. The study protocol (NSMRL.2021.0003) was approved by the Naval Submarine Medical Research Laboratory Institutional Review Board in compliance with all applicable Federal regulations governing the protection of human subjects. The authors are employees of the U.S. Government. This work was prepared as part of our official duties. Title 17 U.S.C. §105 provides that 'Copyright protection under this title is not available for any work of the United States Government.' Title 17 U.S.C. §101 defines a U.S. Government work as a work prepared by a military Service Member or employee of the U.S. Government as part of that person's official duties.

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Acknowledgements

The authors would like to thank Dr. Alexa Kolias, Dr. Natalie Silvia, and Ms. Nicole Farmer for their assistance with data collection and data entry. Thanks to Mr. Joshua Ginsberg for equipment programming and set up, data collection, and data entry.

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Executive Summary

The Naval Submarine Medical Research Laboratory (NSMRL) created a test facility in an anechoic room, in accordance with Method 2 of the Acoustical Society of America (ASA) and the American National Standards Institute (ANSI) standard S3.71-2019 "Methods for Measuring the Effect of Head-worn Devices on Directional Sound Localization in the Horizontal Plane" (except where noted in "Procedures"). The aim of Method 2 is to measure the effect of head-worn devices, including hearing protection devices, on an individual's ability to spatially localize sound in the horizontal plane. This effect is quantified in degrees of error from the correct sound location. This technical report describes the open-ear (baseline) performance used to certify the test facility designed and used at NSMRL. Facility performance was measured using 25 subjects whose hearing and vision were screened and found to be within normal limits. Subject performance screening was conducted with a deviation from ASA/ANSI S3.71-2019 (described herein). The results of this effort show a mean error of 6.9 degrees for the facility performance in the open-ear (baseline) condition for Method 2. Per ASA/ANSI S3.71-2019, the mean open-ear (baseline) performance must be less than or equal to 10 degrees average error for a facility to make valid measurements in accordance with Method 2. The results from this effort indicate that test facility at NSMRL is qualified to measure the effect of head-worn devices on horizontal localization ability. Additionally, the results indicate that a review of the ASA/ANSI S3.71-2019 is required to address the shortcomings of the standard regarding the inclusion criterion for performance of the subjects.

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1. Introduction

In 2019, the Acoustical Society of America (ASA) and American National Standards Institute (ANSI) published a new standard that provides scientists and researchers with a standardized procedure for investigating the effects that hearing protection devices (HPDs) and other head-worn devices (e.g., helmets) have on the ability to spatially localize 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 second method, Method 2, is the focus of the current report. This method measures horizontal plane localization performance to reveal degradation of localization cues caused by using head-worn devices. Method 2 is an auditory search task that must take place indoors using 36 loudspeakers with 180 possible response locations, and is accomplished in 432 trials. The main metric of performance is degrees of error from the correct loudspeaker.

Regarding Method 2, NSMRL's Regional Hearing Conservation Program has created a facility in accordance with the design and technical specifications of the standard. As required by the standard, the open-ear (baseline) performance (measured in subjects' localization angular error) of the facility must be measured while following all procedures described for Method 2 (section 7.2). The group mean of those performance data, using at least 20 subjects who meet inclusion criterion for performance (section 4.1.6.2), is to be less than or equal to 10° (degrees). The aim described herein is to verify whether the test space at NSMRL is adequate for testing Method 2 of the standard. This is the second of three reports being published by NSMRL certifying its test spaces for the three different test Methods described in the standard (one report for each test Method). While the language within the three reports may be similar, the data, data analysis, results, and conclusion are unique to this report.

2. Background of Methodology

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

Table 1. ASA/ANSI S3.71-2019 Requirements Followed During NSMRL Tests.

Requirements	Section
Screening physical characteristics	4.1.1
Head, pinnae, and ear canal 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	4.1.6.3
Sound field generation by each loudspeaker	6.1
Stimulus spectrum characteristics	6.1.1
Stimulus duration	6.1.2
Loudspeakers utilized	6.2
Test space size	7.2.2.1
Loudspeaker positions	7.2.2.2
Ambient Noise in the Room Requirements	7.2.2.3
Loudspeaker construction, position, label	7.3.2
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Test stimulus presentation	8.2
Use of chin rest and Subject head position during testing	8.3
Test paradigm	8.7.1
Data analysis	8.7.2

3. Methods

3.1 Institutional Review Board (IRB) Approval

This research was conducted under the purview of the NSMRL Institutional Review Board under protocol number NSMRL.2021.0003, in compliance with all applicable Federal regulations governing the protection of human subjects. All subjects were offered compensation for their time.

3.2 Subjects

A total of 32 adults provided verbal consent to participate in the current effort. Twenty-five subjects, aged 18 to 65 years, met inclusion criteria, and completed data collection. Bilateral hearing sensitivity was confirmed via screening to be equal to 20 dB HL or better at octave band frequencies 125 to 8,000 Hz (see 4.1.6.1 in the standard). Their ear canals were clear of excessive cerumen and/or foreign debris. They were able to use insert earplugs (see 4.1.2 in the standard). Their visual acuity was better than 20/30 as measured with a Snellen test (see 4.1.5 in the standard). Gender information was collected via verbal self-report. Of the 25 subjects who completed data collection, 40% said they were female (n=10), 60% said they were male (n=15), 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 25 subjects were included in the analysis.

[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.

Four of the 32 subjects only completed the consent process and the audiometric and vision screening. One of those four subjects did not pass the audiometric screening. The remaining other three of those four subjects were lost due to subject attrition. Twenty-eight of the 32 subjects proceeded to the training and unoccluded test.

Only two of the 28 subjects met the inclusion criterion for performance in the standard (section 4.1.6.3), which requires subjects to have no greater than 5% total errors. Upon consultation with study collaborators, it was decided to reduce this performance criterion from 95% to 50% correct identification of the localization of the source loudspeaker (within 10 degrees) during the training. This 50% correct value was selected to reflect both the difficulty of correctly locating the two loudspeakers behind them (170° and 190°), and the ease of correctly locating the two loudspeakers in front of them (350° and 10°). The new performance criterion was also set at 50% correct because 50% correct is eight times the amount a subject would be expected to score if only performing at chance (6.1% correct). The full implications of this reduction in performance during initial training will be discussed in a paper critiquing the standard, which is currently in preparation. Although it was decided to continue testing any subject who scored greater than 50% correct on the training test, after data collection was complete, post-processing of the training data revealed a small anomaly with the scoring algorithm used during the testing. As a result, subjects who scored ≥ 45% correct were included in the facility certification data. With the adjusted performance criterion, 25 of the 28 subjects met the performance criterion.

3.3 Experimental Staff

The testing was conducted by the NSMRL Regional Hearing Conservation Program team. Experimental staff included Dr. Alexa Kolias, Dr. Natalie Silvia, Mr. Derek Schwaller, Ms. Nicole Farmer, Dr. Stephanie Karch, Mr. Joshua Ginsberg, and Dr. Jeremy Federman.

3.4 Dates of Data Collection:

Data were collected between February and September 2021.

3.5 Sound Field Requirements

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

The loudspeakers used were in accordance with section 6.2 of the standard.

3.6 Facility

3.6.1 Test Room

The test facility was established in an indoor anechoic laboratory space at NSMRL. A scale drawing of the space is presented in Figure 1. The test room was 10 m long by 10 m wide by 10 m high and met requirements as described in section 7.2.2.1 – 7.2.2.3 of the standard regarding dimensions, reflections, and ambient noise.

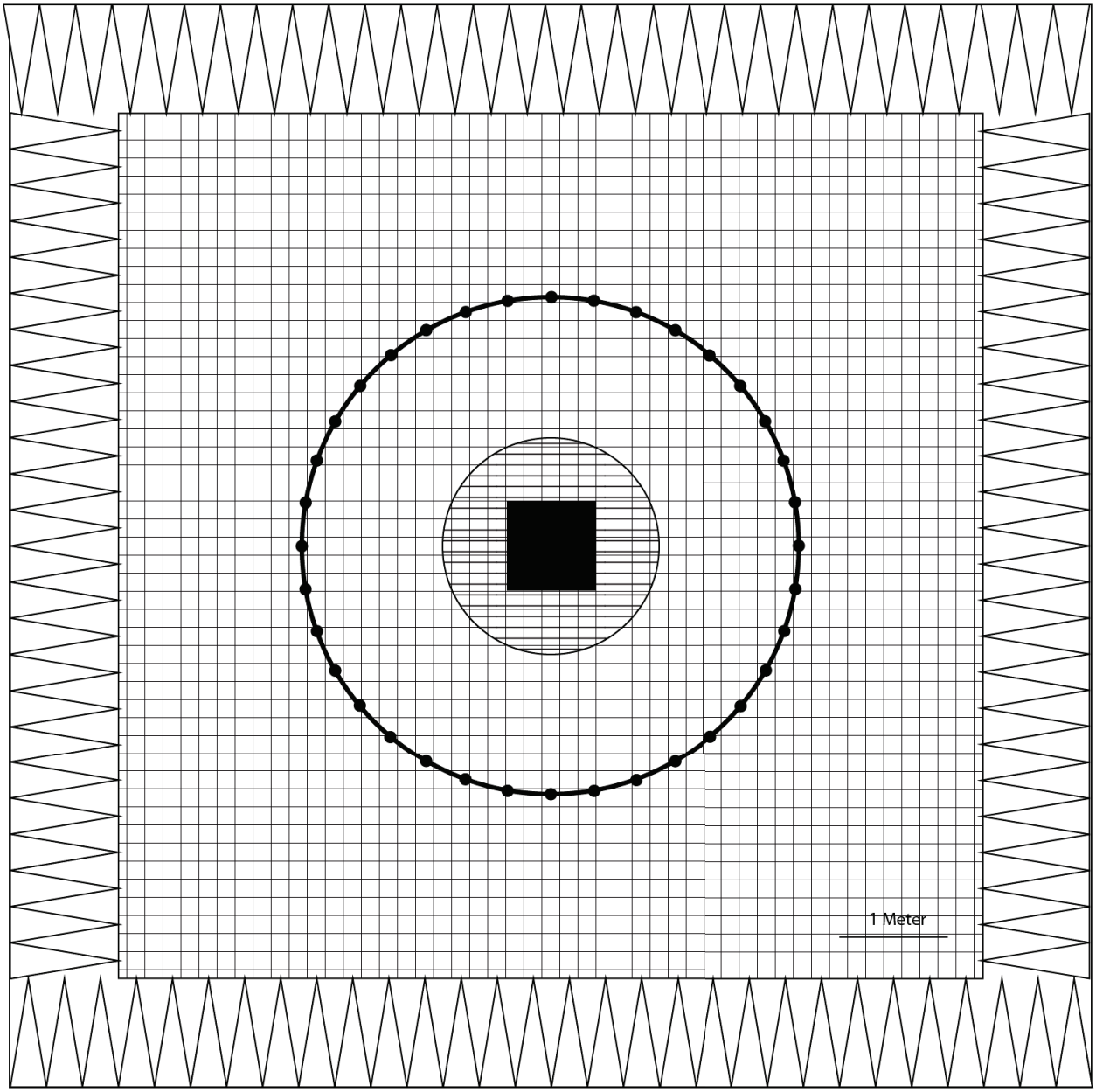

Figure 1. Scale Drawing of the Test Space - Method 2. This figure depicts the anechoic test room as viewed from above with the walls, ceiling, and floor covered with one-meter-deep acoustic traps. The thick black circle with the smaller dots on it represents the loudspeaker array. The array had a radius of 2.3 m. The loudspeakers (array dots) were spaced every 10°. The smaller circle with the line pattern represents a rigid platform in the middle of the room. The black square represents the subject's chair. Apart from the rigid platform, the floor was a suspended wire mesh. Entrance to the space was accessed via a double-hinged door in the top-left corner of the room (not shown). The door was closed during testing.

3.6.2 Loudspeaker Spacing

In accordance with section 7.3.2 of the standard, the front of each loudspeaker was 2.3 m from the center of the head cylinder and spaced such that the loudspeakers were 10º apart when viewed from the perspective of the subject. The loudspeakers were visually obscured by acoustically transparent cloth. Above the cloth were 180 placards spaced 2º apart when viewed from the perspective of the position of the subject. Each placard had a pair of capital letters. The letters were randomly assigned to each placard without letter pair duplication. The acrylic placards were 7.75 cm wide and 13.25 cm tall with letters presented in a 3.75 cm tall black Arial font and a white backing. The placards were mounted on the same custom fiber loudspeaker stands used for the loudspeakers. The vertical visual angle (in arc-minutes) was calculated using the four-digit approximation formula of visual angle:

Equation 1. $$Visual\ Angle = 3438 \times \frac{object\ height}{object\ distance}$$

To calculate visual angle, the object height and object distance must be in the same units (Howett, 1983). Using an object height of the letters (3.75 cm) and an object distance of the radius of the array (230 cm) results in 56 arc-minutes, which is greater than the minimum visual angle of 20/30 vision (7.5 arc-minutes or 0.125º [Howett, 1983]). This ensured that the placard writing would be legible by the subject from the subject's chair.

3.6.3 Subject Chair

The subject's chair was installed in accordance with section 7.3.3 of the standard in relation to loudspeaker height. The subject chair was used without its footrest (Collins, Model 8060S). If the subject could not comfortably put their feet on the floor, a removable square wooden frame was placed around the subject's chair. In accordance with section 8.3 of the standard requiring maintenance of the subject head location inside the head cylinder, a subject chin rest (Veatch Ophthalmic Instruments, SLRI01-001) was attached to the right armrest during testing and was modified to mount on a custom-made swingarm. The height was adjustable and was suitable for all subjects.

3.6.4 Instrumentation

Otoscopic inspection of subjects' ears was completed using a diagnostic otoscope (Welch-Allyn 25020). Physical measures of the subjects' anatomical features, required by section 4.1.2 of the standard, were made with an ear gauge (3M Eargage, Ear Measure 85099-00000) and head calipers (Baseline, 12-1230). Acquisition of subjects' hearing thresholds was completed in a double walled sound booth (Industrial Acoustics Company Inc.; 109906) using a calibrated, FDA approved clinical audiometer (GSI 61; Grason-Stadler, 1761).

Digital stimuli were generated in accordance with section 6.1 of the standard, with a computer (New Tech Solutions Inc.) operating with Windows 10 Pro (Microsoft, Version# 1607) running LabVIEW 2019 (National Instruments Corp., Version #19.0) and MATLAB 2019a (Mathworks, Version# 9.6.0.1072779). The computer, using MADI mixer software (RME Audio, TotalMix

FX, Version# 1.40), output the digital stimuli to a MADI interface (RME Audio, MADIFace XT USB). The signal was then routed to a MADI digital-to-analog interface (RME Audio, M32-DA). The analog signal from the interface was sent to nine audio amplifiers (Crown Audio, CT8150) and then to the loudspeakers (ORB Audio, Mod1X). The loudspeakers were mounted on customized loudspeaker stands of carbon fiber tubes and connectors (DragonPlate Carbon Fiber).

To ensure stimuli were presented at the required sound levels in accordance with section 8.3 of the standard, the sound field was measured using a sound level meter (Bruel & Kjaer, Type 2270). The sound level meter used a microphone (Bruel & Kjaer, Type 4192) and a microphone preamplifier (Bruel & Kjaer, Type ZC 0032). The sound level meter was calibrated with a pistonphone (Bruel & Kjaer, Type 4230) prior to each day of measurement.

Data were processed using signal and data processing software (Matlab 2019a; Mathworks, Version# 9.6.0.1072779) and Excel 2016 32-bit (Microsoft, Version# 16.0.5356.1000).

3.7 Stimuli

In accordance with section 6.1.1 of the standard, randomly generated pink noise samples were used as the stimuli. Specifically, 200 Hz to 14 kHz pink noise within ± 3 dB at every octave band of the measured sound pressure level (SPL) at 1 kHz. In accordance with section 6.1.2 of the standard, short-duration stimuli were 250 ms in total 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; specifically, on for 250 ms then off for 250 ms until the subject responded or for a total duration of 7 s, whichever was shorter. The stimuli were randomly presented in accordance with section 8.2 of the standard at 65, 70, or 75 dBA for a given trial.

3.8 Procedure

Subjects were screened for inclusion in the testing by completing the subject screening test described in the standard (section 4.1.6.3). Following screening, qualified subjects' unoccluded localization performance was measured.

The auditory localization task for Method 2 was conducted in accordance with section 8.7.1 of the standard. The experimenter visually monitored the subject with a video camera. The experimenter used the open two-way monitor to communicate with the subject (i.e., initiate data collection, instruct the subject when the session ended, and clarify responses). The timing data of the subject responses were recorded using a hand-held pushbutton. The letter pairs of the subject responses were given verbally through an open two-way monitor and then manually entered into the test computer by the experimenter. In addition to the standard's requirements, scripted instructions were used to instruct every subject consistently (see Appendix A).

3.9 Analysis Plan

In accordance with section 8.7.2 of the standard, the data were analyzed for:

1) Localization Angular Error (mean and standard deviation)
    a. With and without corrections for front-back (F/B) reversals
    b. For each subject, across all loudspeaker locations
    c. For each loudspeaker location, across all subjects
2) Proportion of F/B reversals
    a. With and without corrections for guessing (as described in the standard)
    b. For each subject, across all loudspeaker locations
    c. For each loudspeaker location, across all subjects

The mean and standard deviation of the angular error were calculated both with and without correcting for F/B reversals, for each of the 36 source locations for each subject and the group of subjects and plotted as mean localization angular error per location. Data from the anthropomorphic measures are reported but were not statistically analyzed.

4. Results

4.1 Room Acoustics

For Method 2, the standard requires that ambient noise levels in each of the seven octave bands between 125 Hz and 8000 Hz be less than 35 dB SPL. The test space met that requirement each day of testing. The maximum measured sound levels for each octave-band are presented in Table 2.

Table 2. Maximum Measured Sound Levels.

Octave-Band Center Frequency (Hz)	Maximum Measured Sound Level (dB SPL)
125	24.1
250	16.3
500	15.2
1000	16.5
2000	13.9
4000	12.8
8000	13.8

4.2 Subject Information

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

4.3 Facility Performance

Table 3 shows localization angular error calculated means and standard deviations (SDs) for open-ear (n = 25) for all stimulus durations (Overall – All Stimuli), for short stimulus duration

(Short Stimulus), and for long stimulus duration (Long Stimulus) in the Method 2 test space at NSMRL as well as the means and standard deviations of the Proportion of F/B Reversals. Facility performance tabular data are reported in Appendix C. Facility performance graphical data are reported in Appendix D.

Table 3. Group Mean and SD (N = 25) for Facility Performance.

All Stimuli	**Mean – Across Subjects**	**SD – Across Subjects**
Localization Error (Mean - Absolute Degrees)	6.9	3.3
Localization Error (Mean - Corrected for F/B Reversals)	6.4	2.7
Localization Error (SD - Absolute Degrees)	10.9	7.5
Localization Error (SD - Corrected for F/B Reversals)	9.1	5.7
Proportion of F/B Reversals	0.5%	0.8%
Proportion of F/B Reversals (Corrected for Guessing)	-18.1%	1.0%
Short Stimuli	**Mean**	**SD**
Localization Error (Mean - Absolute Degrees)	8.4	4.1
Localization Error (Mean - Corrected for F/B Reversals)	7.8	3.3
Localization Error (SD - Absolute Degrees)	11.8	8.2
Localization Error (SD - Corrected for F/B Reversals)	9.6	6.3
Proportion of F/B Reversals	0.6%	1.1%
Proportion of F/B Reversals (Corrected for Guessing)	-17.9%	1.3%
Long Stimuli	**Mean**	**SD**
Localization Error (Mean - Absolute Degrees)	2.4	1.9
Localization Error (Mean - Corrected for F/B Reversals)	2.4	1.8
Localization Error (SD - Absolute Degrees)	3.8	5.2
Localization Error (SD - Corrected for F/B Reversals)	3.7	4.9
Proportion of F/B Reversals	0.0%	0.2%
Proportion of F/B Reversals (Corrected for Guessing)	-18.6%	0.2%

Note. As described in section 8.7.2 of the standard, the data presented are the Localization angular error. The data are the means and standard deviations across all subjects' means and standard deviations of angular error and all subjects' proportions of F/B Reversals. All Localization Error data are presented both uncorrected and corrected for F/B reversals, as per 8.7.2 of the standard. All Proportion of F/B Reversals are presented both uncorrected and corrected for guessing, as per 8.7.2 of the standard.

4.4 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 shown 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
AE	$\overline{AE}$	5	Normal	1	5
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
AE	5.6	11.2

Note. All acronyms presented in Table 4 are defined in section 9.2 of the standard. The standard uncertainty and expanded uncertainty were calculated using the formulas and estimated values from section 9.2 of the standard. No better estimation for the uncertainty values were available at the time of writing this report.

5. Conclusion

All requirements of the standard for conducting baseline, open-ear condition testing indoors in accordance with the Method 2 procedures are satisfied except for the inclusion criterion for training performance, which was set at 45% accuracy rather than the standard's stated requirement of 95%. The full implications of this change in procedures will be discussed in a paper critiquing the standard, which is currently in preparation. All the means of the performance metrics for the 25 subjects who passed the initial screening (in accordance with sections 4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5, and 4.1.6.1) were better than 10 degrees of error on all performance metrics. The individual subject means of the Localization angular error output metrics ranged from 3.4 degrees to 17.4 degrees. Performance metrics for the room performance meet the required maximum value of 10 degrees of error. Altering the training performance requirement may have introduced error that is not accounted for in the performance limits in section 4.1.6.3. However, since the performance result is a mean value of 6.9 degrees of localization angular error overall, without F/B corrections, it is unlikely that the introduced error would have altered the performance measures to above the required 10%. Taken together, these results indicate that the test space at NSMRL meets the performance requirements to conduct Method 2 testing of head-worn devices in accordance with the standard. As a result, Method 2 testing according to the standard is permissible. Additionally, the results indicate that a review of the ASA/ANSI

S3.71-2019 is required to address the shortcomings of the standard regarding the inclusion criterion for performance of the subjects.

6. References

American National Standards Institute. (2019). Methods for measuring the effect of head-worn devices on directional sound localization in the horizontal plane (ANSI/ASA S3.71-2019). In. New York: American National Standards Institute.

Howett, G. L. (1983). Size of Letters Required for Visibility as a Function of Viewing Distance and Observer Visual Acuity. National Bureau of Standards Technical Note #1180.

7. APPENDIX A: Subject Instructions

"You will be listening for a noise, either a single short noise or pulse train <demonstrate signal>. Once you hear the noise, rotate your chair, keeping your chin on the chin rest, to face the direction from where you think the noise came. Once you have identified the correct letter placard, depress and hold the button. Say the two-letters on the placard using the NATO phonetic alphabet. The NATO alphabet is posted on each wall. Continue depressing the button until you finish saying the placard letters. After you have responded, rotate your chair back so you are facing placard 'Victor Bravo.' In total, this should take less than 60 minutes to complete."

8. APPENDIX B: Subject Information

Subject Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Included in Data	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	Yes	No	Yes	Yes
Bitragion Width (cm)	15	12	14	16	14	15	13	16	13	15	N/A	14	16	13	15	14
Head Height (cm)	14	13	13.5	13	15	14	14	14	13	15	N/A	12	14.5	12	13	15
Ear Canal Size	Medium	Medium	Large	Medium	Large	XLarge	Large	Medium	Medium	Large	N/A	Large	Large	Medium	Medium	Large
125 Hz Right Ear <=20HL	Yes	Yes	Yes	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	Yes	Yes	Yes
500 Hz Right Ear <=20HL	Yes	Yes	Yes	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	Yes	Yes	Yes
2000 Hz Right Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
4000 Hz Right Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
8000 Hz Right Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
125 Hz Left Ear <=20HL	Yes	Yes	Yes	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	Yes	Yes	Yes
500 Hz Left Ear <=20HL	Yes	Yes	Yes	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	Yes	Yes	Yes
2000 Hz Left Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
4000 Hz Left Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
8000 Hz Left Ear <=20HL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes

Subject Number	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Included in Data	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Bitragion Width (cm)	12	15	12	12	14	16	15	15	15.5	13.5	15	15	14	13.5	13	15
Head Height (cm)	13	14	13	13	14	15	12	14	14.5	14.5	14.5	15	14	14.5	15	14
Ear Canal Size	Small	Large	XSmall	Large	Large	Large	Medium	Large	Medium	Medium	Medium	Large	Medium	Large	Medium	Large
125 Hz Right Ear <=20HL	Yes	Yes	Yes	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	Yes	Yes	Yes
500 Hz Right Ear <=20HL	Yes	Yes	Yes	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	Yes	Yes	Yes
2000 Hz Right Ear <=20HL	Yes	Yes	Yes	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	Yes	Yes	Yes
8000 Hz Right Ear <=20HL	Yes	Yes	Yes	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	Yes	Yes	Yes
250 Hz Left Ear <=20HL	Yes	Yes	Yes	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	Yes	Yes	Yes
1000 Hz Left Ear <=20HL	Yes	Yes	Yes	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	Yes	Yes	Yes	Yes
4000 Hz Left Ear <=20HL	Yes	Yes	Yes	Yes	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	Yes	Yes	Yes	Yes	Yes	Yes

9. APPENDIX C: Tabular Performance Data

As shown in Table C1, the data from each subject were analyzed separately for the mean and standard deviation of localization angular error, with and without compensation for F/B reversals. Also, the data were analyzed for proportion of front-back (F/B) reversals, with and without compensation for guessing. The data were analyzed for both stimulus types (Overall), the short stimuli (Short), and the long stimuli (Long).

Table C1. Localization Angular Error and Proportion of F/B Reversals for Each Subject (Collapsed Across Loudspeaker Location).

	Subject Number	1	2	3	4	5	6	7	8	10	13	15	16	17	18	20	21	22	23	24	27	28	29	30	31	32
Overall	Localization Error (Mean - Absolute Degrees)	7.2	5.4	3.4	7.7	5.6	5.4	5.5	5.8	3.9	3.9	5.6	5.6	7.5	5.7	6.9	17.4	6.7	9.4	4.6	5.9	7.1	16.2	4.4	7.3	8.3
	Localization Error Mean - Corrected for F/B Reversals	7.0	5.4	3.4	7.5	5.6	5.4	5.3	5.8	3.9	3.9	5.4	5.6	5.9	5.7	6.9	15.3	6.5	7.5	4.6	5.9	6.9	14.0	4.2	7.3	6.2
	Localization Error (SD - Absolute Degrees)	7.4	9.0	3.3	7.5	6.1	6.0	8.7	8.4	6.8	3.6	14.2	6.3	16.9	5.6	7.5	27.2	10.2	21.9	11.8	9.5	8.8	31.7	5.8	5.4	22.2
	Localization Error SD - Corrected for F/B Reversals	6.6	9.0	3.3	5.5	6.1	6.0	6.7	8.4	6.8	3.6	13.7	6.3	6.8	5.6	7.5	22.7	8.6	13.6	11.8	9.5	7.8	27.8	3.8	5.4	13.6
	Proportion of F/B Reversals	0.2%	0.0%	0.0%	0.5%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.2%	0.0%	1.4%	0.0%	0.0%	2.5%	0.2%	1.9%	0.0%	0.0%	0.2%	2.5%	0.2%	0.0%	1.6%
	Proportion of F/B Reversals - Corrected for Guessing	- 18.4%	- 18.7%	- 18.7%	- 18.1%	- 18.7%	- 18.7%	- 18.4%	- 18.7%	- 18.7%	- 18.7%	- 18.4%	- 18.7%	- 17.0%	- 18.7%	- 18.7%	- 15.7%	- 18.4%	- 16.5%	- 18.7%	- 18.7%	- 18.4%	- 15.7%	- 18.4%	- 18.7%	- 16.8%
	Subject Number	1	2	3	4	5	6	7	8	10	13	15	16	17	18	20	21	22	23	24	27	28	29	30	31	32
Short	Localization Error (Mean - Absolute Degrees)	9.0	6.6	4.0	8.1	7.0	6.6	6.3	7.1	4.8	4.5	6.9	7.0	9.6	6.7	8.4	20.3	8.5	12.2	5.7	7.3	8.9	20.7	5.4	8.1	9.6
	Localization Error Mean - Corrected for F/B Reversals	8.8	6.6	4.0	7.7	7.0	6.6	6.0	7.1	4.8	4.5	6.8	7.0	7.5	6.7	8.4	17.5	8.2	9.7	5.7	7.3	8.7	17.7	5.2	8.1	7.1
	Localization Error (SD - Absolute Degrees)	7.6	10.1	3.4	8.2	6.4	6.4	8.3	8.3	7.6	3.9	16.1	6.6	19.1	6.1	8.1	28.6	11.2	24.7	13.4	10.5	9.5	35.4	6.3	5.5	23.0
	Localization Error SD - Corrected for F/B Reversals	6.6	10.1	3.4	5.7	6.4	6.4	5.3	8.3	7.6	3.9	15.6	6.6	7.1	6.1	8.1	23.1	9.3	15.1	13.4	10.5	8.2	31.2	3.9	5.5	12.1
	Proportion of F/B Reversals	0.3%	0.0%	0.0%	0.6%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.3%	0.0%	1.9%	0.0%	0.0%	3.4%	0.3%	2.5%	0.0%	0.0%	0.3%	3.4%	0.3%	0.0%	1.9%
	Proportion of F/B Reversals - Corrected for Guessing	- 18.3%	- 18.7%	- 18.7%	- 17.9%	- 18.7%	- 18.7%	- 18.3%	- 18.7%	- 18.7%	- 18.7%	- 18.3%	- 18.7%	- 16.5%	- 18.7%	- 18.7%	- 14.7%	- 18.3%	- 15.8%	- 18.7%	- 18.7%	- 18.3%	- 14.7%	- 18.3%	- 18.7%	- 16.5%
	Subject Number	1	2	3	4	5	6	7	8	10	13	15	16	17	18	20	21	22	23	24	27	28	29	30	31	32
Long	Localization Error (Mean - Absolute Degrees)	1.5	1.7	1.5	6.7	1.2	1.7	3.3	1.7	1.3	2.3	1.5	1.2	1.1	2.8	2.4	8.6	1.4	1.1	1.4	1.6	1.7	2.7	1.3	5.1	4.1
	Localization Error Mean - Corrected for F/B Reversals	1.5	1.7	1.5	6.7	1.2	1.7	3.3	1.7	1.3	2.3	1.5	1.2	1.1	2.8	2.4	8.6	1.4	1.1	1.4	1.6	1.7	2.7	1.3	5.1	3.4
	Localization Error (SD - Absolute Degrees)	1.2	1.7	1.5	4.7	1.3	1.4	9.5	7.3	1.2	1.8	1.3	1.8	1.3	1.8	2.0	20.0	1.4	1.0	1.5	1.5	1.4	3.7	1.3	4.2	19.0
	Localization Error SD - Corrected for F/B Reversals	1.2	1.7	1.5	4.7	1.3	1.4	9.5	7.3	1.2	1.8	1.3	1.8	1.3	1.8	2.0	20.0	1.4	1.0	1.5	1.5	1.4	3.7	1.3	4.2	17.0
	Proportion of F/B Reversals	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%
	Proportion of F/B Reversals - Corrected for Guessing	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 18.7%	- 17.6%

The data from the 36 orientations were also analyzed for mean and standard deviation of localization angular error, with and without compensation for F/B reversals. Also, the data were analyzed for proportion of F/B reversals, with and without compensation for guessing. The data were analyzed for both stimulus types (Overall; Table C2), the short stimuli (Short; Table C3), and the long stimuli (Long; Table C4).

Table C2. Localization Angular Error and Proportion of F/B Reversals for Each Loudspeaker Location (Collapsed Across Subjects) for Both Stimulus Types.

Overall	All Subjects					
Loudspeaker	Localization Error (Mean - Absolute Degrees)	Localization Error Mean - Corrected for F/B Reversals	Localization Error (SD - Absolute Degrees)	Localization Error SD - Corrected for F/B Reversals	Proportion of F/B Reversals	Proportion of F/B Reversals - Corrected for Guessing
0	2.7	2.1	6.5	4.3	0.4%	-18.3%
10	3.2	3.2	3.2	3.2	0.0%	-18.7%
20	2.6	2.6	1.0	1.0	0.0%	-18.7%
30	2.9	2.9	2.8	2.8	0.0%	-18.7%
40	4.2	3.6	3.4	2.5	0.7%	-18.0%
50	3.4	3.4	1.8	1.8	0.0%	-18.7%
60	4.6	4.6	4.0	4.0	0.0%	-18.7%
70	4.8	4.8	2.8	2.8	0.0%	-18.7%
80	4.5	4.5	2.4	2.4	0.0%	-18.7%
90	4.6	4.6	3.3	3.3	0.0%	-18.7%
100	7.0	7.0	2.6	2.6	0.0%	-18.7%
110	8.6	8.6	3.4	3.4	0.0%	-18.7%
120	9.9	9.6	4.8	4.5	0.4%	-18.3%
130	9.7	9.4	5.7	4.8	0.4%	-18.3%
140	8.6	8.6	4.1	4.1	0.0%	-18.7%
150	9.7	9.2	3.7	3.2	0.7%	-18.0%
160	10.4	8.2	7.1	3.3	2.2%	-16.5%
170	9.1	6.6	11.1	4.1	2.2%	-16.5%
180	6.0	4.8	7.2	4.1	0.7%	-18.0%
190	8.3	6.8	6.3	2.6	1.1%	-17.6%
200	7.2	6.9	3.0	2.5	0.4%	-18.3%
210	7.4	7.4	3.2	3.2	0.0%	-18.7%
220	9.0	8.4	4.6	4.3	0.7%	-18.0%
230	8.1	8.1	4.1	4.1	0.0%	-18.7%
240	9.5	9.5	3.4	3.4	0.0%	-18.7%
250	8.8	8.8	2.9	2.9	0.0%	-18.7%
260	6.4	6.4	3.0	3.0	0.0%	-18.7%
270	3.7	3.7	2.0	2.0	0.0%	-18.7%
280	5.9	5.7	4.3	4.0	0.4%	-18.3%
290	5.4	5.4	3.1	3.1	0.0%	-18.7%
300	4.9	4.9	3.3	3.3	0.0%	-18.7%
310	5.2	4.9	2.2	1.7	0.4%	-18.3%
320	3.4	3.4	1.8	1.8	0.0%	-18.7%
330	3.2	3.2	3.2	3.2	0.0%	-18.7%
340	2.4	2.4	0.9	0.9	0.0%	-18.7%
350	2.0	2.0	1.4	1.4	0.0%	-18.7%

Table C3. Localization Angular Error and Proportion of F/B Reversals for Each Loudspeaker Location (Collapsed Across Subjects) for Short Stimulus Types.

Short	All Subjects					
Loudspeaker	Localization Error (Mean - Absolute Degrees)	Localization Error Mean - Corrected for F/B Reversals	Localization Error (SD - Absolute Degrees)	Localization Error SD - Corrected for F/B Reversals	Proportion of F/B Reversals	Proportion of F/B Reversals - Corrected for Guessing
0	3.3	2.6	8.7	5.7	0.5%	-18.2%
10	3.5	3.5	4.1	4.1	0.0%	-18.7%
20	2.8	2.8	1.1	1.1	0.0%	-18.7%
30	3.2	3.2	3.2	3.2	0.0%	-18.7%
40	4.8	4.0	4.4	3.3	1.0%	-17.7%
50	4.0	4.0	2.3	2.3	0.0%	-18.7%
60	4.8	4.8	3.5	3.5	0.0%	-18.7%
70	5.0	5.0	2.3	2.3	0.0%	-18.7%
80	5.0	5.0	2.4	2.4	0.0%	-18.7%
90	5.4	5.4	4.4	4.4	0.0%	-18.7%
100	8.4	8.4	3.5	3.5	0.0%	-18.7%
110	10.9	10.9	4.7	4.7	0.0%	-18.7%
120	12.4	12.0	6.1	5.9	0.5%	-18.2%
130	11.6	11.6	6.3	6.3	0.0%	-18.7%
140	10.8	10.8	5.4	5.4	0.0%	-18.7%
150	12.4	11.7	4.9	4.3	1.0%	-17.7%
160	13.1	10.2	9.6	4.5	2.9%	-15.8%
170	11.5	8.2	14.8	5.5	2.9%	-15.8%
180	7.5	6.0	9.6	5.3	1.0%	-17.7%
190	10.2	8.3	8.5	3.4	1.4%	-17.2%
200	8.8	8.5	4.0	3.3	0.5%	-18.2%
210	9.3	9.3	4.2	4.2	0.0%	-18.7%
220	11.3	10.5	6.0	5.6	1.0%	-17.7%
230	10.0	10.0	5.0	5.0	0.0%	-18.7%
240	11.9	11.9	4.2	4.2	0.0%	-18.7%
250	10.9	10.9	3.4	3.4	0.0%	-18.7%
260	7.9	7.9	4.1	4.1	0.0%	-18.7%
270	4.5	4.5	2.7	2.7	0.0%	-18.7%
280	7.2	7.0	5.5	5.2	0.5%	-18.2%
290	6.7	6.7	4.1	4.1	0.0%	-18.7%
300	6.0	6.0	4.2	4.2	0.0%	-18.7%
310	6.0	5.7	2.7	1.9	0.5%	-18.2%
320	3.9	3.9	2.3	2.3	0.0%	-18.7%
330	3.8	3.8	3.9	3.9	0.0%	-18.7%
340	2.7	2.7	1.1	1.1	0.0%	-18.7%
350	2.3	2.3	1.6	1.6	0.0%	-18.7%

Table C4. Localization Angular Error and Proportion of F/B Reversals for Each Loudspeaker Location (Collapsed Across Subjects) for Long Stimulus Types.

Long	All Subjects					
Loudspeaker	Localization Error (Mean - Absolute Degrees)	Localization Error Mean - Corrected for F/B Reversals	Localization Error (SD - Absolute Degrees)	Localization Error SD - Corrected for F/B Reversals	Proportion of F/B Reversals	Proportion of F/B Reversals - Corrected for Guessing
0	0.8	0.8	1.0	1.0	0.0%	-18.7%
10	2.3	2.3	1.1	1.1	0.0%	-18.7%
20	2.0	2.0	1.5	1.5	0.0%	-18.7%
30	2.0	2.0	2.3	2.3	0.0%	-18.7%
40	2.5	2.5	1.5	1.5	0.0%	-18.7%
50	1.7	1.7	1.3	1.3	0.0%	-18.7%
60	4.0	4.0	12.3	12.3	0.0%	-18.7%
70	4.1	4.1	7.1	7.1	0.0%	-18.7%
80	3.1	3.1	5.3	5.3	0.0%	-18.7%
90	1.9	1.9	1.4	1.4	0.0%	-18.7%
100	2.8	2.8	1.5	1.5	0.0%	-18.7%
110	1.8	1.8	2.0	2.0	0.0%	-18.7%
120	2.3	2.3	2.7	2.7	0.0%	-18.7%
130	3.9	2.6	6.5	1.7	1.4%	-17.2%
140	2.1	2.1	2.6	2.6	0.0%	-18.7%
150	1.7	1.7	2.5	2.5	0.0%	-18.7%
160	2.3	2.3	1.6	1.6	0.0%	-18.7%
170	1.9	1.9	1.5	1.5	0.0%	-18.7%
180	1.5	1.5	1.5	1.5	0.0%	-18.7%
190	2.5	2.5	1.3	1.3	0.0%	-18.7%
200	2.1	2.1	2.0	2.0	0.0%	-18.7%
210	1.8	1.8	1.9	1.9	0.0%	-18.7%
220	2.0	2.0	3.0	3.0	0.0%	-18.7%
230	2.4	2.4	3.3	3.3	0.0%	-18.7%
240	2.1	2.1	3.0	3.0	0.0%	-18.7%
250	2.7	2.7	3.1	3.1	0.0%	-18.7%
260	2.0	2.0	1.5	1.5	0.0%	-18.7%
270	1.4	1.4	0.8	0.8	0.0%	-18.7%
280	2.1	2.1	2.2	2.2	0.0%	-18.7%
290	1.6	1.6	1.6	1.6	0.0%	-18.7%
300	1.8	1.8	1.7	1.7	0.0%	-18.7%
310	2.7	2.7	1.6	1.6	0.0%	-18.7%
320	1.7	1.7	1.5	1.5	0.0%	-18.7%
330	1.4	1.4	1.6	1.6	0.0%	-18.7%
340	1.6	1.6	1.0	1.0	0.0%	-18.7%
350	1.3	1.3	1.5	1.5	0.0%	-18.7%

10. APPENDIX D: Graphical Performance Data

As shown in Figures D1 to D6, the data from the 36 loudspeaker locations were processed separately for their localization angular error.

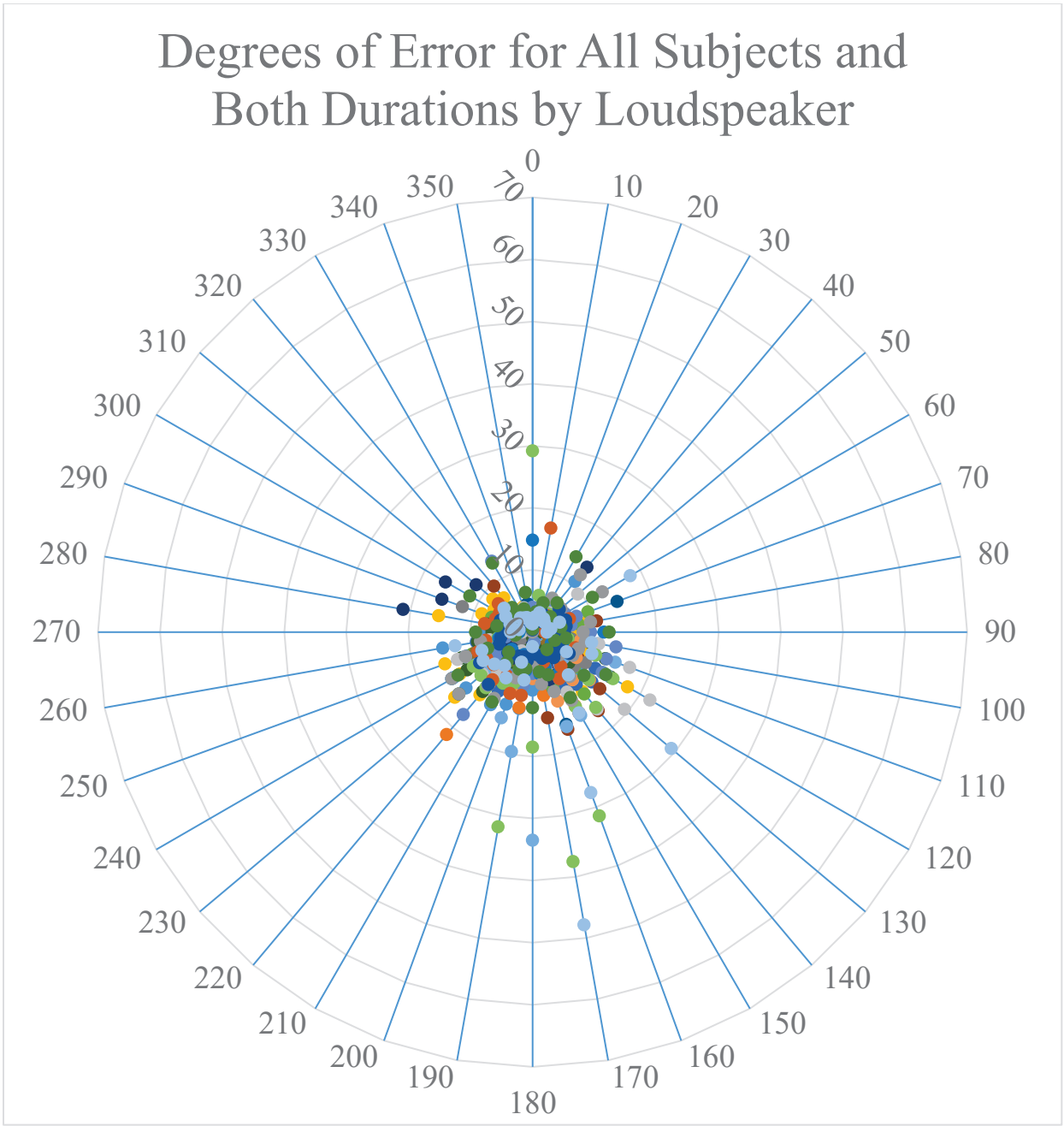

Figure D1. Localization Angular Error for Each Subject. Mean localization angular error data, without compensation for front-back (F/B) reversals for each subject, for both short and long durations combined. The angles [in degrees (º)] are shown for the 36 loudspeakers, referenced with the loudspeaker in front of the subject as 0º. The radius is the localization angular error (0 to 70 degrees). The circles are a subject's score. Each subject is represented by a different color. This plot shows the general shape of distribution of the data and presents the few outlying data points.

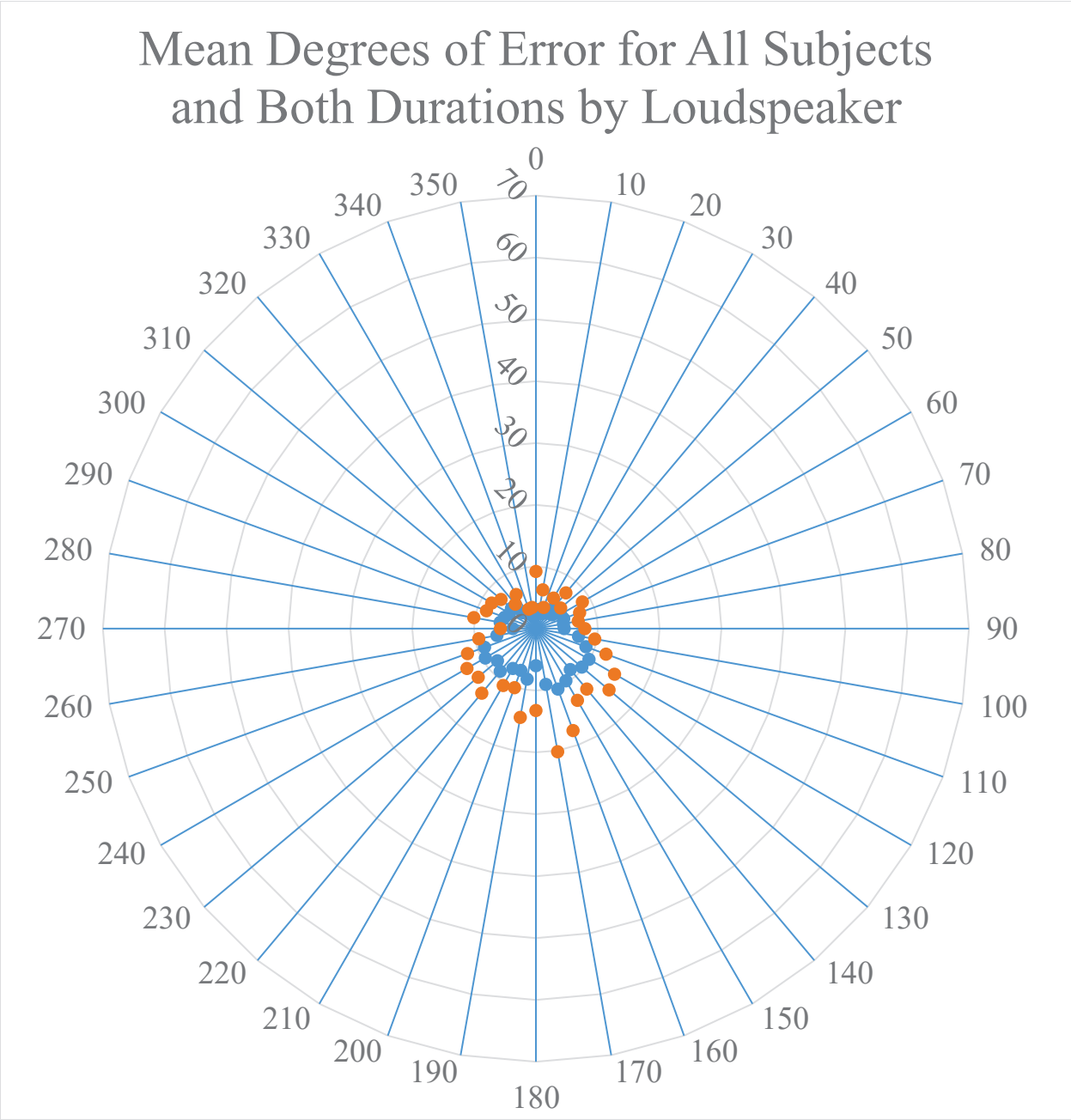

Figure D2. Mean Localization Angular Error Across All Subjects. Mean localization angular error data, without compensation for F/B reversals averaged across all subjects, for both short and long durations combined. The angles (in degrees) are shown for the 36 loudspeakers, referenced with the loudspeaker in front of the subject as 0º. The radius is the localization angular error (0 to 70 degrees). The blue circles are the mean subjects' localization angular error. The orange circles are the mean plus one standard deviation of the subjects' localization angular error.

The data from the 36 loudspeaker locations were also processed separately for their localization angular error without compensation for F/B reversals separately for the long and short stimulus durations. The results are in Figures D3 and D4 for the short duration and Figures D5 and D6 for the long duration.

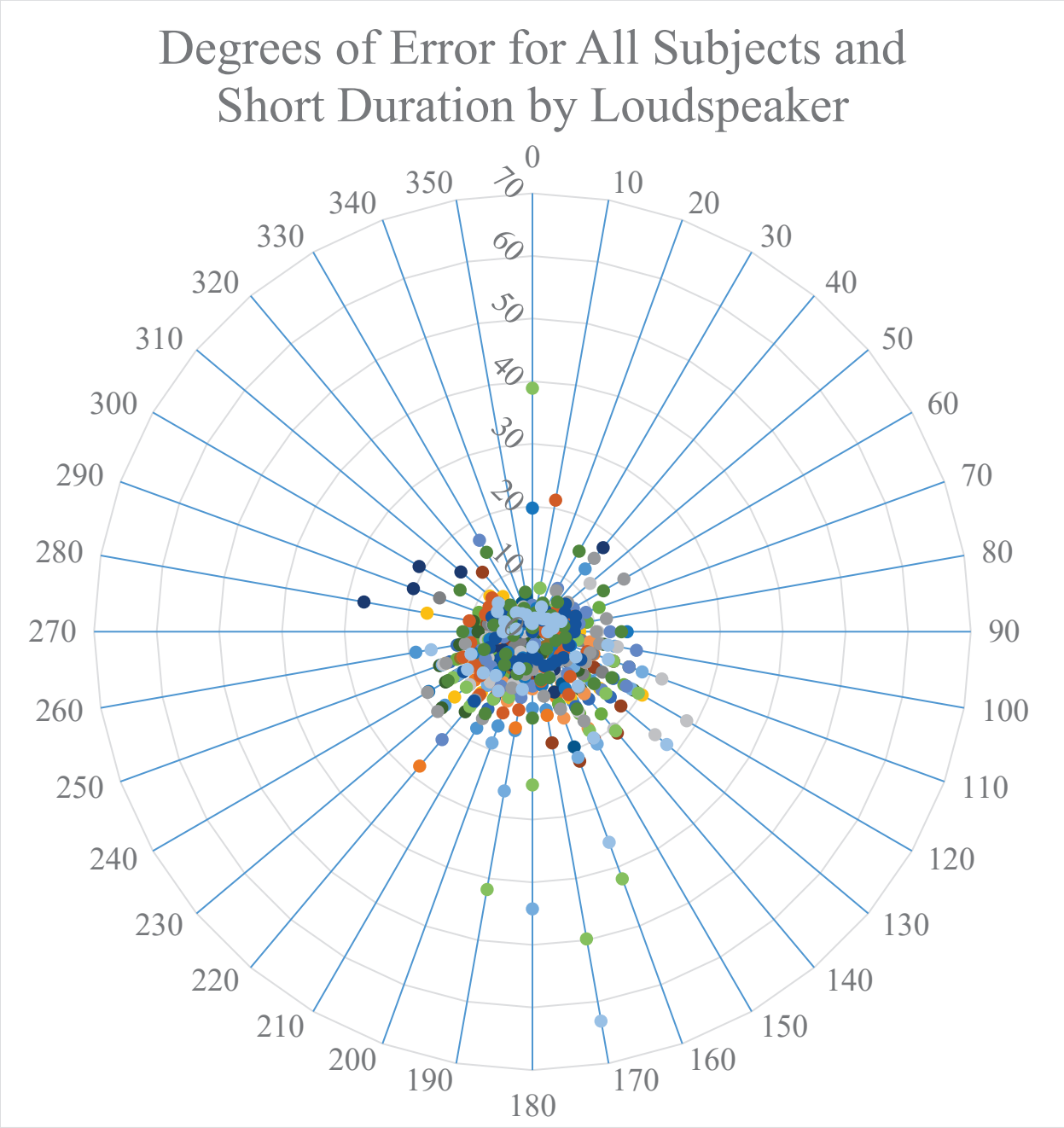

Figure D3. Localization Angular Error for Each Subject – Short Duration. Mean localization angular error data, without compensation for F/B reversals for each subject, for short duration stimuli. The angles (in degrees) are shown for the 36 loudspeakers, referenced with the loudspeaker in front of the subject as 0º. The radius is the localization angular error (0 to 70 degrees). The circles are a subject's score. Each subject is represented by a different color. This plot shows the general shape of distribution of the data and presents the few outlying data points.

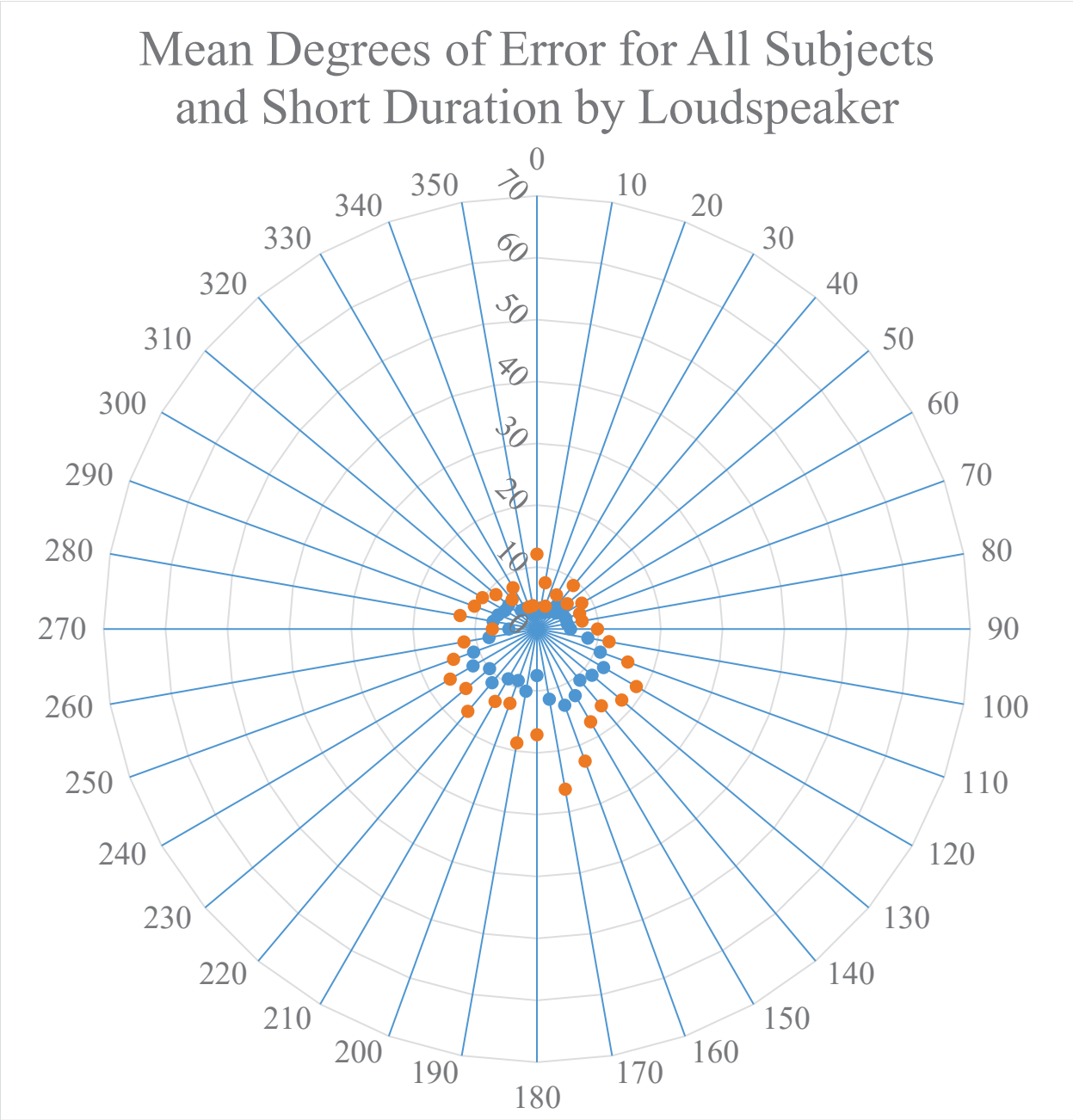

Figure D4. Mean Localization Angular Error Across All Subjects – Short Duration. Mean localization angular error data, without compensation for F/B reversals averaged across all subjects, for short duration stimuli. The angles (in degrees) are shown for the 36 loudspeakers, referenced with the loudspeaker in front of the subject as 0º. The radius is the localization angular error (0 to 70 degrees). The blue circles are the mean subjects' localization angular error. The orange circles are the mean plus one standard deviation of the subjects' localization angular error.

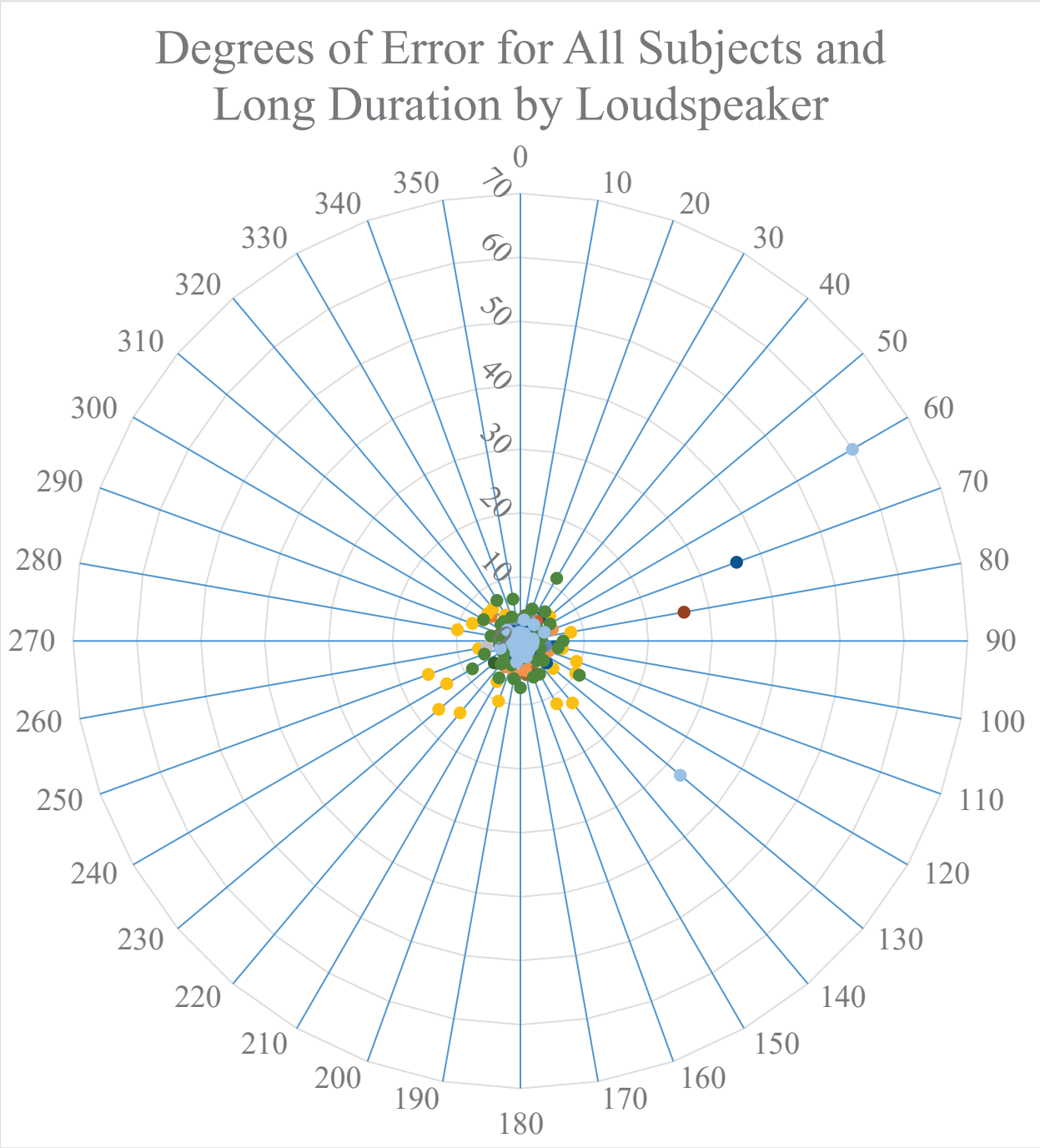

Figure D5. Localization Angular Error for Each Subject – Long Duration. Mean localization angular error data, without compensation for F/B reversals for each subject, for long duration stimuli. The angles (in degrees) are shown for the 36 loudspeakers, referenced with the loudspeaker in front of the subject as 0º. The radius is the localization angular error (0 to 70 degrees). The circles are a subject's score. Each subject is represented by a different color. This plot shows the general shape of distribution of the data and presents the few outlying data points.

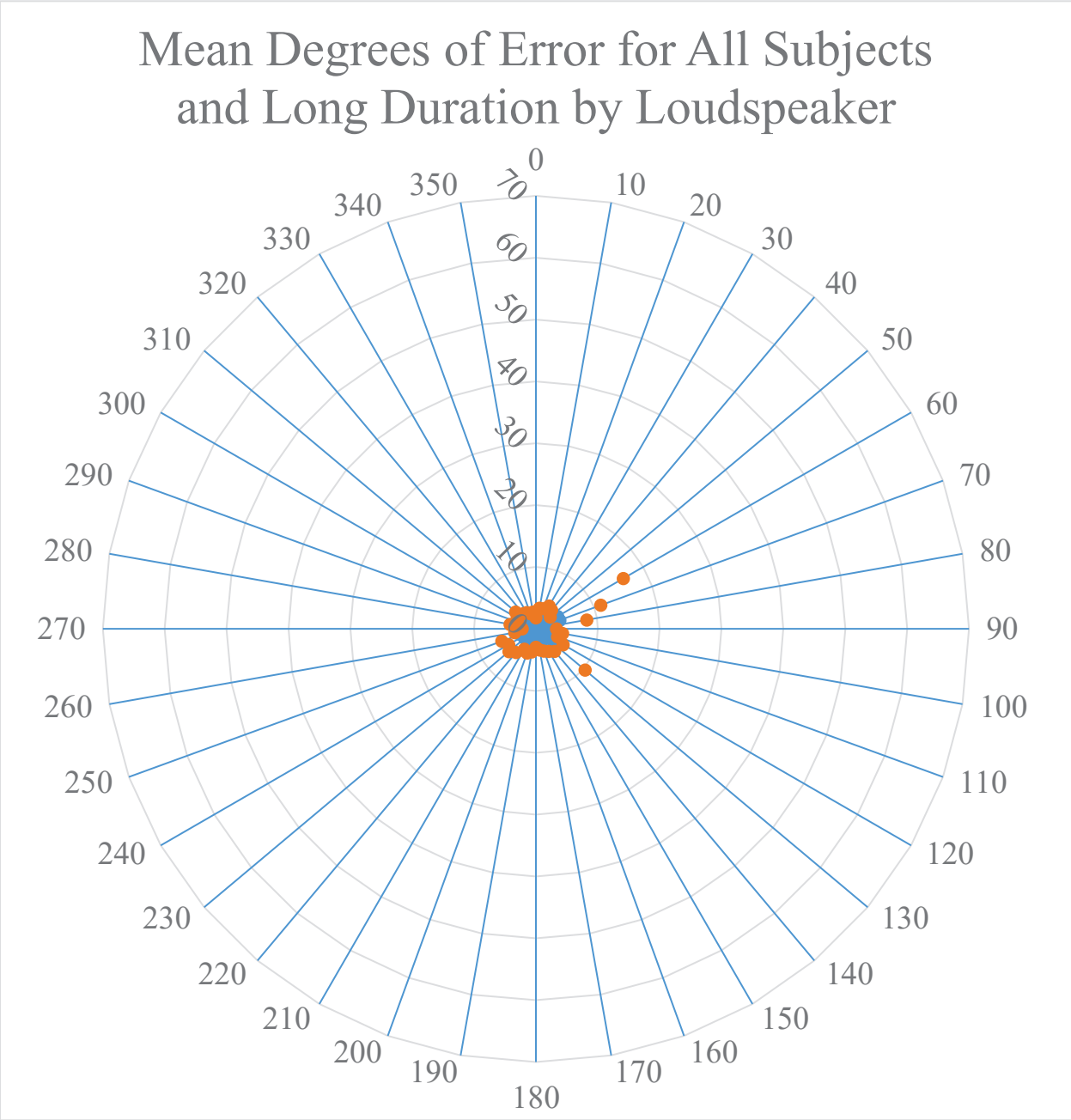

Figure D6. Mean Localization Angular Error Across All Subjects – Long Duration. Mean localization angular error data, without compensation for F/B reversals averaged across all subjects, for long duration stimuli. The angles (in degrees) are shown for the 36 loudspeakers, referenced with the loudspeaker in front of the subject as 0º. The radius is the localization angular error (0 to 70 degrees). The blue circles are the mean subjects' localization angular error. The orange circles are the mean plus one standard deviation of the subjects' localization angular error.

As shown in Figures D7 to D12, the data from the 36 loudspeaker locations were processed separately for localization angular error, with compensation for F/B reversals.

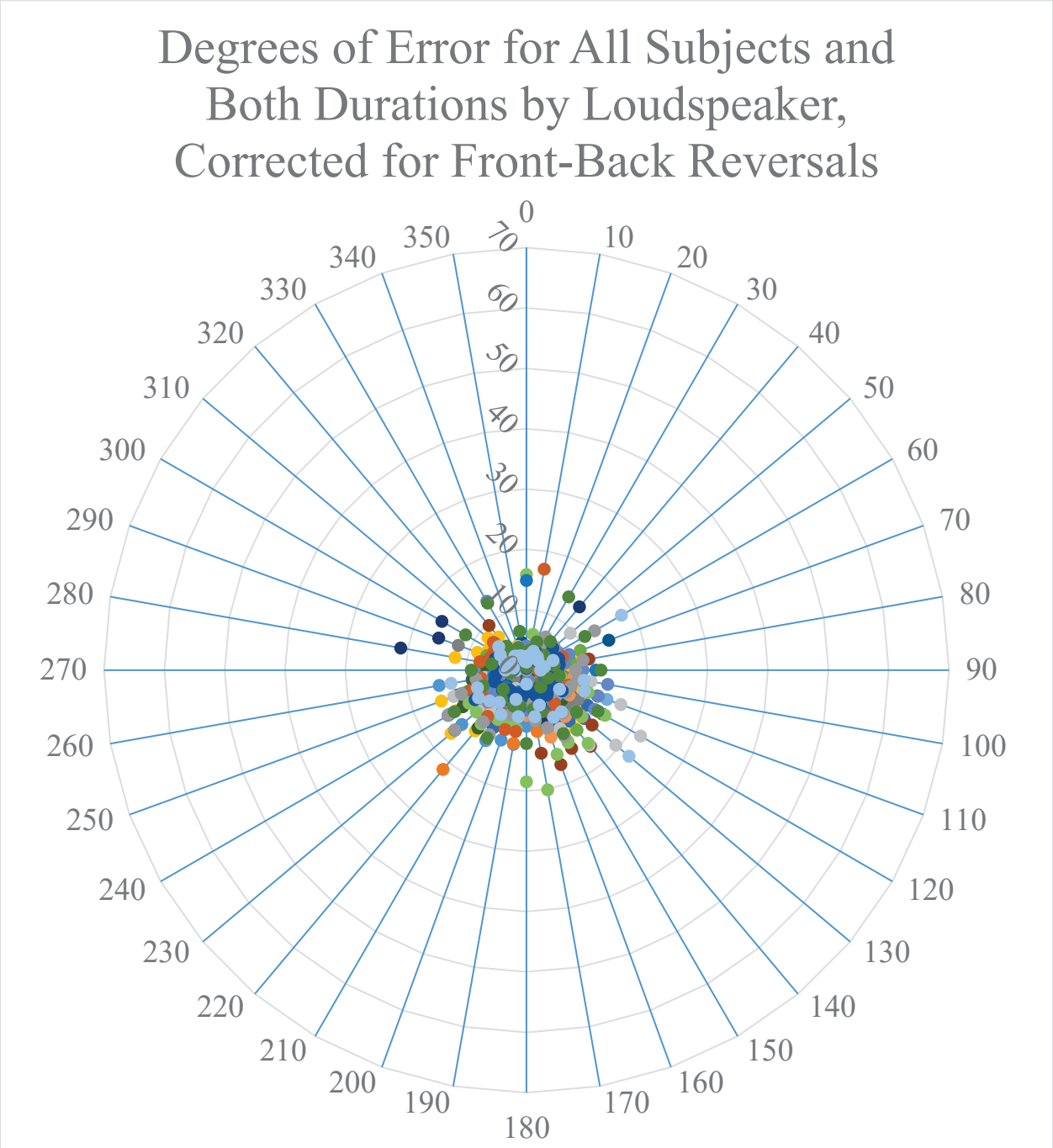

Figure D7. Localization Angular Error for Each Subject, Compensated for F/B Reversals. Mean localization angular error data, with compensation for F/B reversals for each subject, for both short and long durations combined. The angles (in degrees) are shown for the 36 loudspeakers, referenced with the loudspeaker in front of the subject as 0º. The radius is the localization angular error (0 to 70 degrees). The circles are a subject's score. Each subject is represented by a different color. This plot shows the general shape of distribution of the data and presents the few outlying data points.

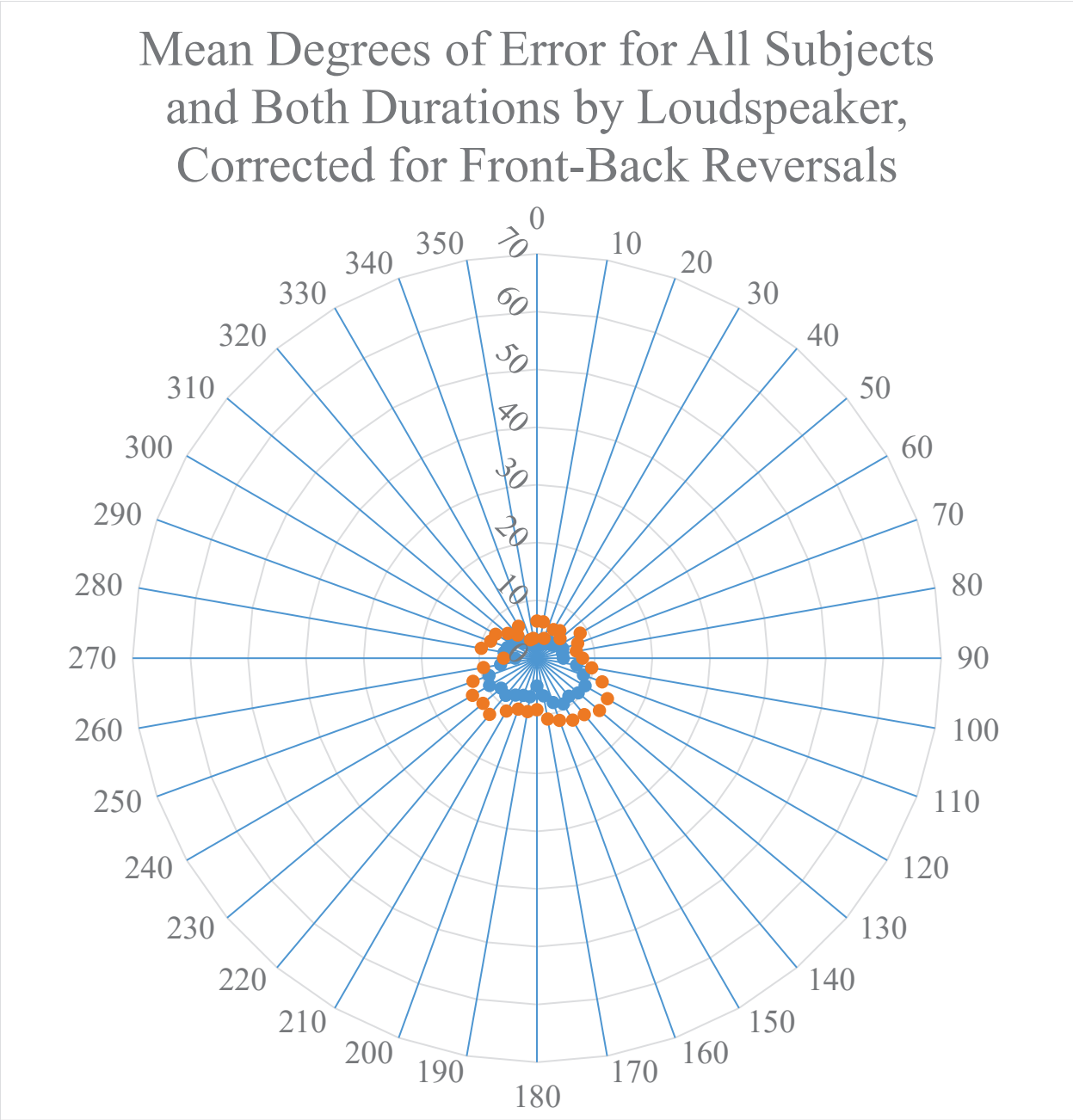

Figure D8. Mean Localization Angular Error Across All Subjects, Compensated for F/B Reversals. Mean localization angular error data, with compensation for F/B reversals averaged across all subjects, for both short and long durations combined. The angles (in degrees) are shown for the 36 loudspeakers, referenced with the loudspeaker in front of the subject as 0º. The radius is the localization angular error (0 to 70 degrees). The blue circles are the mean subjects' localization angular error. The orange circles are the mean plus one standard deviation of the subjects' localization angular error.

The data from the 36 loudspeaker locations were also processed separately for their localization angular error with compensation for F/B reversals separately for the long and short stimulus durations. The results are in Figures D9 and D10 for the short duration and Figures D11 and D12 for the long duration.

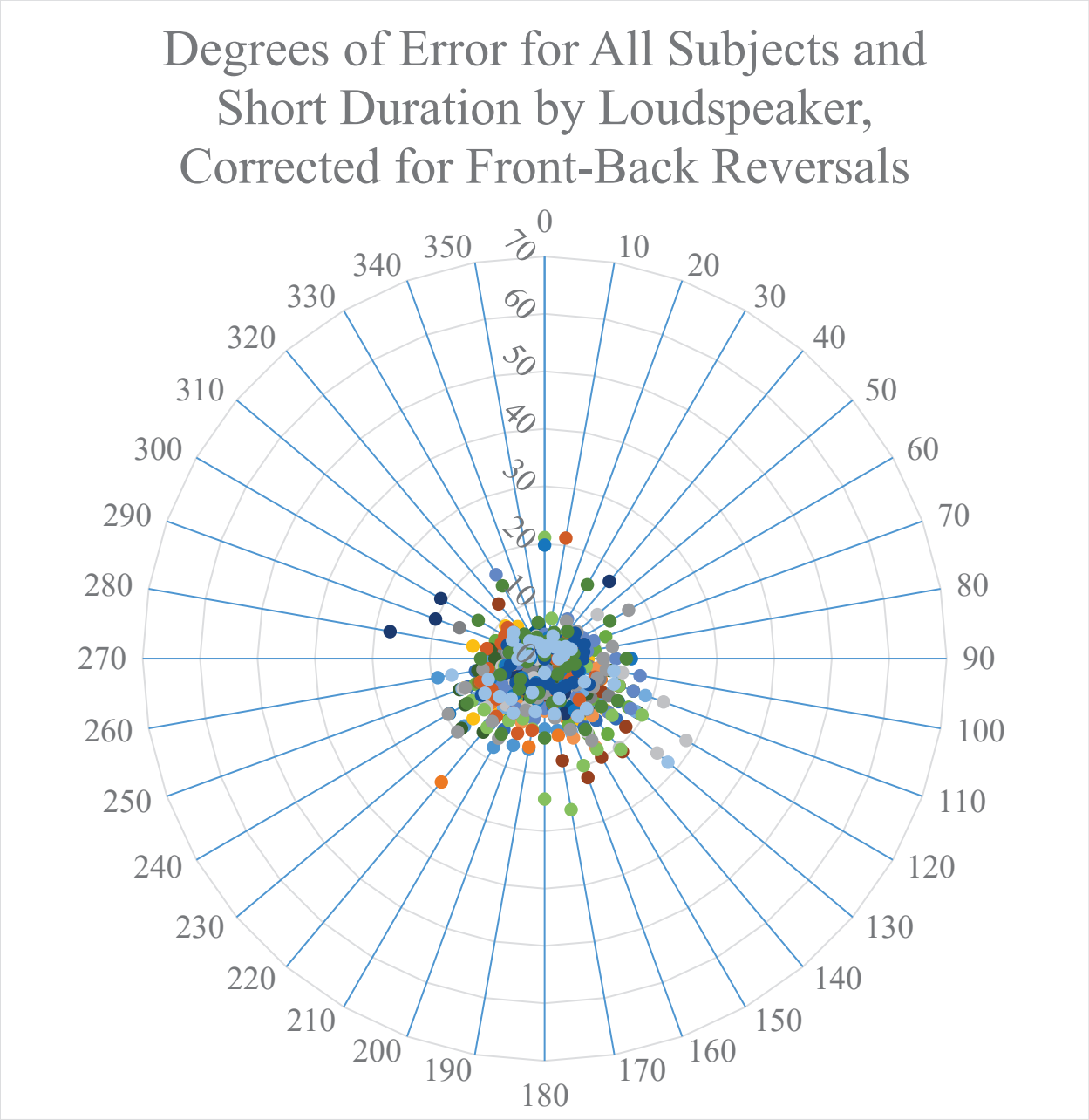

Figure D9. Localization Angular Error for Each Subject – Short Duration, Compensated for F/B Reversals. Mean localization angular error data, with compensation for F/B reversals for each subject, for short duration stimuli. The angles (in degrees) are shown for the 36 loudspeakers, referenced with the loudspeaker in front of the subject as 0º. The radius is the localization angular error (0 to 70 degrees). The circles are a subject's score. Each subject is represented by a different color. This plot shows the general shape of distribution of the data and presents the few outlying data points.

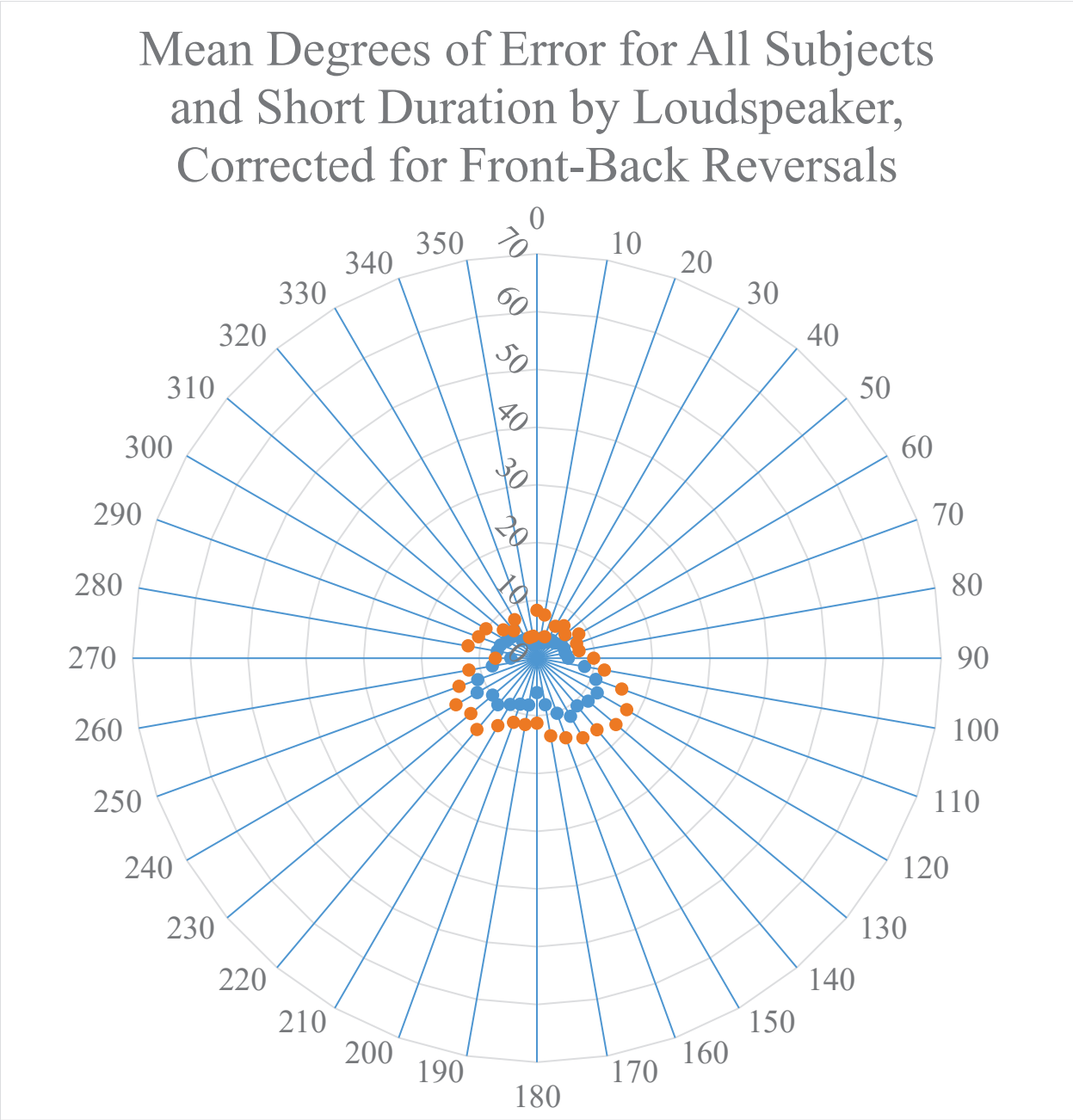

Figure D10. Mean Localization Angular Error Across All Subjects – Short Duration, Compensated for F/B Reversals. Mean localization angular error data, with compensation for F/B reversals averaged across all subjects, for short duration stimuli. The angles (in degrees) are shown for the 36 loudspeakers, referenced with the loudspeaker in front of the subject as 0º. The radius is the localization angular error (0 to 70 degrees). The blue circles are the mean subjects' localization angular error. The orange circles are the mean plus one standard deviation of the subjects' localization angular error.

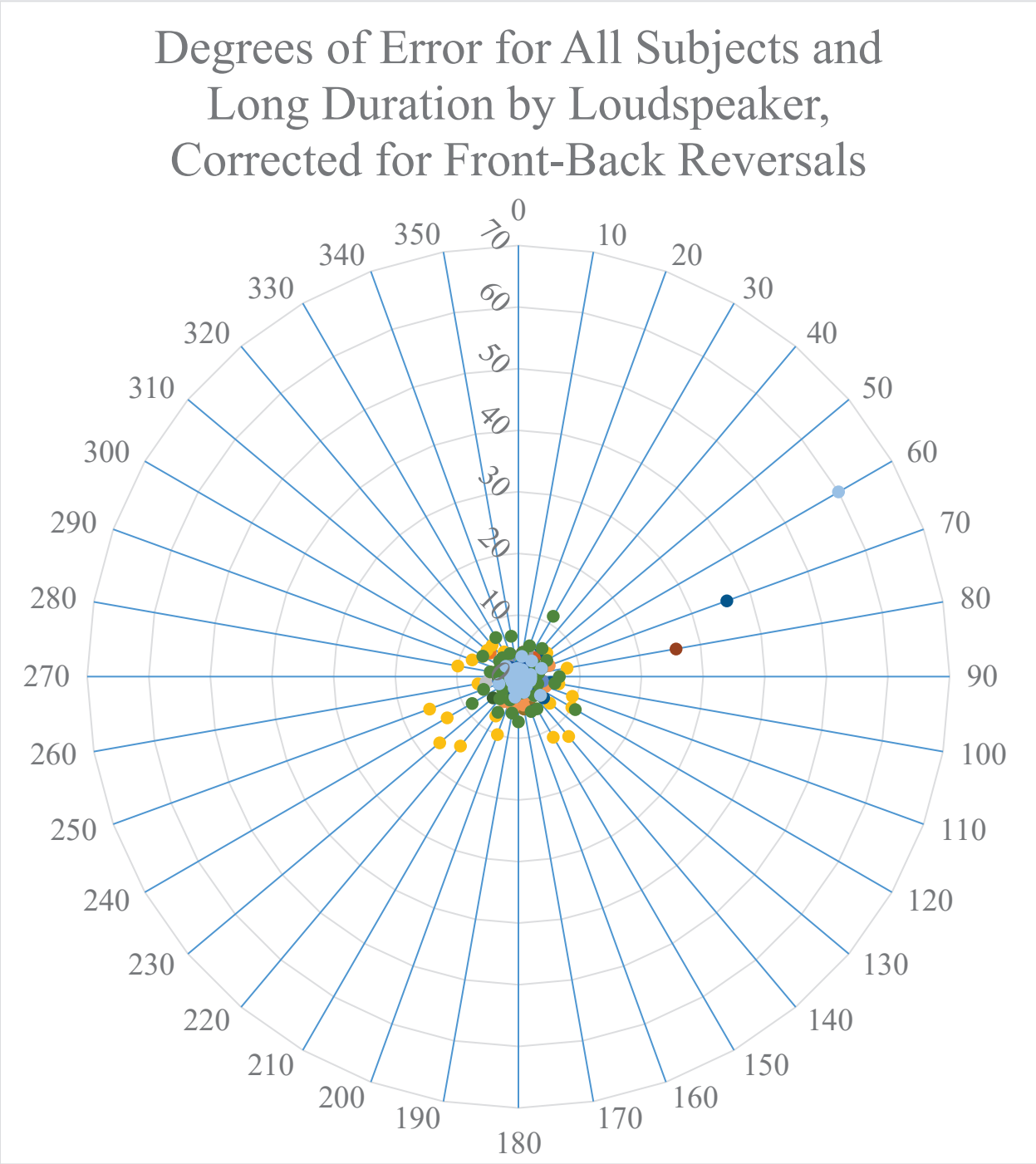

Figure D11. Localization Angular Error for Each Subject – Long Duration, Compensated for F/B Reversals. Mean localization angular error data, with compensation for F/B reversals for each subject, for long duration stimuli. The angles (in degrees) are shown for the 36 loudspeakers, referenced with the loudspeaker in front of the subject as 0º. The radius is the localization angular error (0 to 70 degrees). The circles are a subject's score. Each subject is represented by a different color. This plot shows the general shape of distribution of the data and presents the few outlying data points.

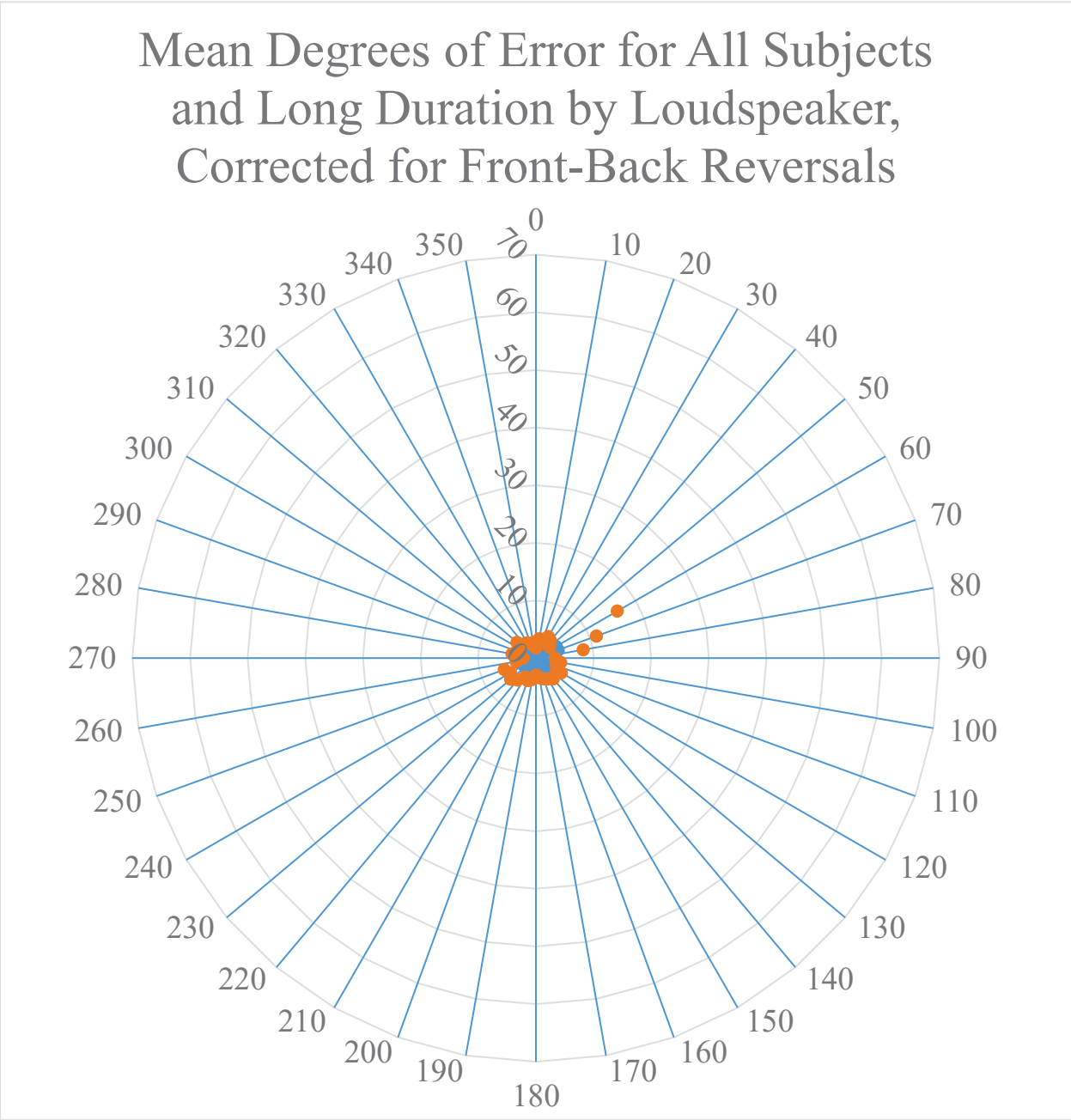

Figure D12. Mean Localization Angular Error Across All Subjects – Long Duration, Compensated for F/B Reversals. Mean localization angular error data, with compensation for F/B reversals averaged across all subjects, for long duration stimuli. The angles (in degrees) are shown for the 36 loudspeakers, referenced with the loudspeaker in front of the subject as 0º. The radius is the localization angular error (0 to 70 degrees). The blue circles are the mean subjects' localization angular error. The orange circles are the mean plus one standard deviation of the subjects' localization angular error.