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AMERICAN NATIONAL STANDARD

Methods for Measuring the Effect of Head-worn Devices on Directional Sound Localization in the Horizontal Plane

Secretariat:

Acoustical Society of America

Approved on April 30, 2019:

American National Standards Institute, Inc.

Abstract

The methods described in this standard provide data which may be used for assessment of sound localization performance open ear and with head-worn devices using human subjects. The standard describes three measurement methods: 1) a low-complexity method using 8 loudspeakers to measure location discrimination performance; 2) a more complex, more robust method to measure localization error using 36 loudspeakers; and 3) a method to measure the functional impact of degraded localization cues on visual search time with 36 loudspeakers. The standard specifies subject qualification criteria, test space acoustic requirements, details of the three methods, and reporting requirements. The standard does not provide guidance for measuring localization performance for elevation or for clinical spatial audiometry.

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ANSI/ASA S3.71-2019

Accredited Standards Committee S3, Bioacoustics

Standards Secretariat
Acoustical Society of America
1305 Walt Whitman Road, Suite 300
Melville, NY 11747

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Acoustical Society of America
Standards Secretariat
1305 Walt Whitman Road, Suite 300
Melville, New York 11747
Telephone: 1-631-390-0215
Fax: 1 631-923-2875
E-mail: asastds@acousticalsociety.org

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Foreword

[This Foreword is for information only and is not a part of the American National Standard ANSI/ASA S3.71-2019 Methods for Measuring the Effect of Head-worn Devices on Directional Sound Localization in the Horizontal Plane. As such, this Foreword may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the standard.]

This standard comprises a part of a group of definitions, standards, and specifications for use in bioacoustics. It was developed and approved by Accredited Standards Committee S3 - Bioacoustics, under its approved operating procedures. Those procedures have been accredited by the American National Standards Institute (ANSI). The Scope of Accredited Standards Committee S3 is as follows:

Standards, specifications, methods of measurement and test, and terminology in the fields of psychological and physiological acoustics, including aspects of general acoustics which pertain to biological safety, tolerance and comfort.

This standard is not comparable to any existing ISO Standard.

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U.S. Air Force	R.L. McKinley
.....	B.D. Simpson (Alt.)
U.S. Army Aeromedical Research Laboratory	W.A. Ahroon
U.S. Army CERL	D.K. Delaney
.....	M.J. White (Alt.)
U.S. Army Research Laboratory, Human Research and Engineering Directorate	A. Scharine
.....	A. Fouts (Alt.)
University of Cincinnati Animal Audiology Clinic/Bioacoustics Lab	P.M. Scheifele
.....	D.K. Brown (Alt.)

Individual Experts of the Accredited Standards Committee S3 - Bioacoustics were:

R.F. Burkard
M. Burkhard

A.J. Campanella
R.L. McKinley
P.D. Schomer

C.J. Struck
L.A. Wilber

Working Group S3/WG 94, Localization Standards, which assisted Accredited Standards Committee S3 - Bioacoustics in the development of this standard, had the following membership.

R.L. McKinley, Chair

W.A. Ahroon
E. Berger
E. Brandewie
D.S. Brungart
K. Buchanan
J. Casali
A. Dittberner
C.J. Fackler
J.S. Federman

A. Fouts
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K. Yankaskas
C. Yttri
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Introduction

Auditory situation awareness describes a person's use of auditory information, combined with other sensory information, to develop an understanding/awareness of their environment. Sound detection, distance estimation, sound localization, speech communication, and others, are commonly accepted components of auditory situational awareness. The importance of sound localization is relative to the situation and acoustical environment, and emphasis on this singular component must be balanced with other auditory needs.

Many head-worn devices can affect the accuracy and time needed for a user to localize a sound and thereby affect his/her auditory situation awareness. These devices include hearing protectors, hearing aids, headphones, helmets, etc. Additionally, new technologies are being developed and marketed that claim to provide the user with the ability to monitor the ambient acoustic environment and maintain sound localization cues while protecting the user from noise. Standards exist that specify methods for measuring the attenuation properties of hearing protection devices, but at the time of the approval of this standard, there were no existing standards that addressed the impact such devices have on the user's localization performance. The ability to localize sounds is critical in many occupations including firefighting, law enforcement, emergency response, military operations, and many others in which hearing protection and/or head-worn devices must be used. The objective of this standard is to establish methods that enable accurate, repeatable, and reliable measurement of sound localization performance for human listeners.

This standard describes a set of measurement protocols for quantifying the effect of a head-worn device on one hearing-critical task: sound localization in the horizontal plane. The presence of a head-worn device will change the sound field around the user's head, and will change the sounds reaching the user's eardrums. This may lead to changes in the user's performance on hearing critical tasks, such as speech communication, or the detection, localization, and identification of sounds in the user's environment. Some of these changes are by design; for example, a hearing protector is designed to attenuate hazardous sounds, and a hearing aid is designed to amplify quiet sounds that may have been inaudible to the user. Other changes are a side effect of wearing the device. A device may enhance performance on a particular task and degrade performance on a different task. When determining whether a device is appropriate for use in a particular situation, the effect of the device on all hearing-critical tasks should be weighted by the importance of those tasks for the situation.

This standard describes three methods to assess the effects of wearing head-worn devices on the user's localization performance. Method 1 uses four pairs of loudspeakers and data are collected with the listener oriented in each of two directions and should be viewed as a simplified procedure for estimating localization performance. It provides a measure of location discrimination performance as well as an estimate of the proportion of front-back reversals. Method 2 uses an array of 36 (10-degree spacing) loudspeakers in a sound-treated environment with a high-resolution (2-degree spacing or better) response metric to measure localization performance over the full horizontal plane. Method 2 samples the localization performance at the 36 defined loudspeaker locations. Method 3 uses the same dense array of loudspeakers as Method 2 with the addition of a small cluster of four LEDs at each loudspeaker to implement an aurally guided visual search procedure for assessment of the functional impact of degraded localization cues. Each of the methods captures differing aspects of localization performance and the effects of degraded localization cues from head-worn devices.

American National Standard

Methods for Measuring Directional Sound Localization in the Horizontal Plane

1 Scope

The methods described in this standard were designed to enable accurate, repeatable, and reliable measurement of sound localization performance with or without head-worn devices. The standard is based on fundamental localization measurement paradigms that have been used in numerous laboratories. Three measurement methods are described. Method 1 should be viewed as a simplified procedure for estimating localization performance. Method 2 should be used as a robust measure of localization performance with or without head-worn devices and should identify moderate to significant degradation of localization cues. Method 3 should be used as a measure of the functional impact of degraded localization cues. Each of the methods captures differing aspects of localization performance and the effects of degraded localization cues from head-worn devices. Data from measurements detailed in this standard can be used to describe the effects of head-worn devices on localization in the horizontal plane and can be used to assess the relative performance of subjects wearing head-worn devices compared to open-ear localization performance. Users of this standard include universities, manufacturers of hearing devices (e.g., hearing protectors, communication headsets, hearing enhancement with ambient listening capability, hearing aids), commercial test laboratories, and government laboratories.

The methods described in this standard are limited to measurements of human localization performance in the horizontal plane (azimuth) only and are not intended to be used for clinical spatial audiometry or for measuring localization performance in elevation. The methods are not intended to be used for measurement of sound localization performance of devices designed to determine the location of acoustic sources.

NOTE 1 Method 1 was intentionally designed to be relatively limited in sophistication to make it more accessible to users of the standard without requiring the resources necessary for using Methods 2 and 3.

NOTE 2 Auditory localization may improve over time for individuals who wear hearing protection or other head-worn devices more than occasionally. The localization results obtained using the methods described in this standard are intended to assess localization performance before auditory learning with a specific device has occurred over a period of hours or days. For additional guidance see 4.1.6.2, 4.1.6.3, and 8.1.

2 Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ANSI/ASA S1.1, *American National Standard Acoustical Terminology*

ANSI/ASA S1.4-2014/Part 1/IEC 61672-1:2013, *American National Standard Electroacoustics – Sound Level Meters – Part 1: Specifications (a nationally adopted international standard)*

ANSI/ASA S1.11-2014/IEC 61260, Parts 1, 2, and 3, *American National Standard Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters (nationally adopted international standards)*

ANSI/ASA S3.1-1999 (R2013), *American National Standard Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms*

ANSI/ASA S3.6-2018 *American National Standard Specification for Audiometers*

ANSI/ASA S3.20, *American National Standard Bioacoustical Terminology*

ANSI/ASA S3.36-2012 (R2018), *American National Standard Specification for a Manikin for Simulated in-situ Airborne Acoustic Measurements*

ANSI/ASA S12.6-2016, *American National Standard Methods for Measuring the Real-Ear Attenuation of Hearing Protectors*

ANSI/ASA S12.42-2010, *American National Standard Methods for the Measurement of Insertion Loss of Hearing Protection Devices in Continuous or Impulsive Noise Using Microphone-in-Real-Ear or Acoustic Test Fixture Procedures*

ANSI/ASA S12.68-2007 (R2017), *American National Standard Methods of Estimating Effective A-Weighted Sound Pressure Levels When Hearing Protectors are Worn*

ISO 3382-2:2008, *Acoustics - Measurement of room acoustic parameters - Part 2: Reverberation time in ordinary rooms*

NOTE "R" stands for reaffirmed.

3 Terms and definitions

For the purposes of this standard, the terms and definitions given in ANSI/ASA S1.1, ANSI/ASA S3.20, and the following apply:

3.1.1 absolute threshold. Minimum value of a stimulus that evokes a desired response in a specific fraction of the trials.

NOTE For hearing, the sound pressure level that establishes a threshold of audibility at a specified frequency is an example of an absolute threshold.

3.1.2 auditory localization. Determination by a subject of the apparent direction and distance, direction alone, or distance alone, of a sound source.

NOTE Auditory localization in a horizontal or azimuthal plane is facilitated by interaural phase or time difference cues at lower frequencies and by interaural sound pressure level difference cues at upper frequencies. The crossover frequency for the dominance of auditory localization cues for humans is about 1500 Hz.

3.1.3 circumaural earphone. Earphone which encloses the pinna and rests on the surrounding surface of the head.

NOTE Contact with the head is normally maintained by compliant cushions. Circumaural earphones may touch but should not significantly compress the pinna.

3.1.4 clinical Spatial audiometry. Measurement of auditory acuity as a function of the direction of incoming sound to be used by audiologists in identifying auditory disfunction/s in a clinical setting.

3.1.5 earmuff. A hearing protector usually comprised of a headband and earcups with a soft cushion to seal against the head, intended to fit against the pinna (supra-aural) or the sides of the head around

the pinna (circumaural). The earcups may also be held in position by attachment arms mounted on a hard hat or hard cap.

3.1.6 earplug. A hearing protector that is inserted into the earcanal.

3.1.7 head cylinder. A defined space in the center of the loudspeaker array in which the center of the subject's head must be located during stimulus presentation. The defined diameter of the head cylinder is 20 cm. The height of the head cylinder is 30 cm $\pm$ 2 cm.

3.1.8 head tracking. Use of a device mounted on the listener's head to monitor the movements of the head in horizontal and vertical direction.

3.1.9 head-worn device. Any item—earmuff and/or earplug, communication headset, helmet, ball cap, etc.—worn on the head that may influence auditory perception.

3.1.10 helmet. A device, sometimes also functioning as a hearing protector, which usually covers a substantial portion of the head, that may include internally mounted earcups and/or earplugs.

3.1.11 insert earphone. Earphone inserted in the outer ear or earcanal.

3.1.12 masking. (a) The process by which the threshold of hearing for one sound is raised by the presence of another (masking) sound. (b) The amount by which the threshold of hearing for one sound is raised by the presence of another (masking) sound, expressed in decibels.

3.1.13 pink noise. A signal or process with a frequency spectrum such that the power spectral density (energy or power per Hz) is inversely proportional to the frequency of the signal. In pink noise, each octave band (halving/doubling in frequency) carries an equal amount of noise power.

3.1.14 pinna. Ovoid-formed, skin-covered, fibro-cartilaginous plate that is attached to the head around the opening of the external auditory meatus; the most visible part of the ear.

3.1.15 RT60. reverberation time. The time (in seconds) it takes sound reflected from surfaces to decay 60 dB.

3.1.16 supra-aural earphone. Earphone applied externally to the outer ear and intended to rest on the pinna.

3.1.17 transfer function. The input-to-output response characteristics of a device, expressed either mathematically or graphically.

4 Subject qualifications

4.1 Test subjects

All subjects shall meet the requirements of clauses under 4.1 unless the requester of the measurement can indicate that the device is intended for use by specific optional populations (e.g., children). The specifics of that optional population shall be described in the reporting of the results in 10.3.

4.1.1 Anatomical features

Subjects shall be selected without respect to sizes and shapes of heads, pinnae, or earcanals. The subjects shall have no physical abnormalities of the pinnae and earcanal. However, subjects shall be excluded for features or physical disabilities adversely affecting the fitting of hearing protectors and other head-worn devices, such as might arise from birth defects, ear surgery, or personal adornments.

4.1.2 Otoscopic inspection

At the time of initial audiometric testing, subject's ears, as determined by an otoscopic inspection, shall be free from excessive cerumen, irritation, or infection that would affect the fit and/or performance of the device. This requirement shall also apply to areas of the pinna and head that would be contacted by the head-worn device being tested.

NOTE Subsequent otoscopic inspections may be required if testing occurs over the course of more than a few days.

4.1.3 Measurement of head dimensions

The bitrignon width, head height, and earcanal diameter (when testing insert devices) of the test subject shall be measured per the procedure of Annex C.

4.1.4 Gender balance

Unless specifically designated by the requester, the ratio of male to female subjects shall be between and including 60/40 and 40/60.

4.1.5 Visual acuity

Subjects participating in measurements shall have uncorrected or corrected visual acuity equal to or better than 20/30 measured with a Snellen or other similar test procedure.

NOTE Good vision is required for response methods used in all three methods.

4.1.6 Hearing sensitivity

4.1.6.1 Minimum sensitivity

Subjects shall have unaided pure-tone air-conduction hearing threshold levels at the octave-band center frequencies from 125 Hz to 8 kHz, as measured using a standard audiometer, that are ≤ 20 dB HL (ANSI/ASA S3.6).

4.1.6.2 Minimum localization performance – Method 1

During subject qualification, subjects for Method 1 using short stimuli, as defined in 6.1.1 and 6.1.2, a qualified Method 1 facility as defined in Clause 7, and using methods described in 8.6, shall demonstrate at least 90% correct over a minimum of 100 trials. The subjects may train for a period of time, at the discretion of the experimenter, prior to demonstrating this performance.

4.1.6.3 Minimum localization performance – Methods 2 and 3

For Methods 2 and 3, subjects shall demonstrate no greater than 5% total errors (front-back and left-right) measured using a minimum of 100 short-stimulus trials when using the four speakers located at 10, 170, 190, and 350 degrees. For this subject screening test, an error shall be defined as a response a response that is greater than 10 degrees from the stimulus location. The subjects may train for a period of time, at the discretion of the experimenter, prior to demonstrating this performance.