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Audiology, Anywhere: Hearing Assessment Outside the Booth

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Disclosures

- **Presenter Disclosure:** Financial: James Hall received an honorarium for this course. He is a part-time professor at Drexel University. Non-financial: James Hall has no relevant non-financial relationships to disclose.
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- The interventions discussed in this course may be limited in generalizability, requiring practitioners to consider specific individual and population factors.
- The course may not cover all possible risk factors, diagnostic methods, or treatment options, and complex cases may require additional considerations.
- Healthcare providers should apply cultural competence and sensitivity to ensure effective and respectful care based on their patients' diverse needs.
- Providers should always evaluate the limitations of diagnostic and screening tools, considering their potential for false results as well as any ethical implications.
- It is the responsibility of course participants to critically evaluate the evidence from multiple sources to guide professional practice.

Learning Outcomes

After this course, participants will be able to:

- List three clinical advantages associated with automated hearing assessment outside of a sound booth.
- Describe a technique for monitoring ambient noise in a hearing test setting.
- Identify an earphone design that minimizes the impact of ambient noise on the accuracy of hearing threshold estimation.

Audiology, Anywhere: Hearing Assessment Outside the Booth

Time Ordered Agenda

- **Introduction (0 – 5 mins.)**
- Rationale for ambient noise monitoring during hearing assessment (5 – 20 mins.)
- Clinical Instrumentation for hearing assessment outside a sound treated environment (20 - 35 mins.)
- Evidence confirming the validity of hearing assessment outside a sound-treated environment (35 -55 mins.)
- Questions and Answers (55 – 60 mins.)

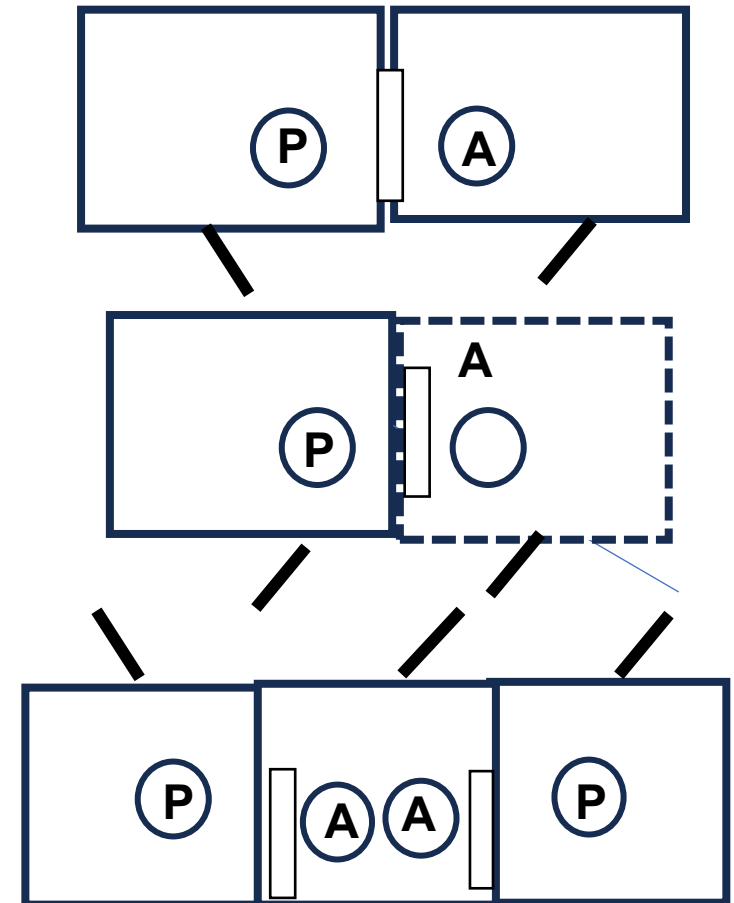
Hearing Assessment Outside the Booth



- A hallowed tradition in audiology
- Former fond memories
- Second home (4 hours/day x 5 days/week 48 weeks/year x 40 years = 38400 hours = 1600 days = 53 months = 4.4 years)
- Funny booth stories
- Reverent booth references

Sound Booths... Physical and Fiscal Challenges

- Size
 - Large footprint
 - Non portable (permanent fixed location)
- Weight (large booth > 3000 lbs.)
- Ventilation
 - Noise
 - Temperature
 - Air purity (serious problem during Covid)
- Cost
 - Large booth > \$25,000
 - Custom assembly and installation
- Step up for entry
- Compliance with ANSI MPANLs



Sound Booths... Patient-Related Challenges

- ADA compliance
 - Ramp required for wheelchair access
 - Ramp and oversize door required for gurney or bed access
- Risk management
 - Patient fall upon entry with step up
 - Patient fall upon exit with step down
 - Patient head injury upon entry or exit
- Anxiety and claustrophobia
- Clinic traffic congestion (waiting for a booth)
- Preparation for and response to a medical emergency

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Audiology, Anywhere: Hearing Assessment Outside the Booth

- Identify one important clinical application of automated pure tone audiometry outside of a sound-treated room?



Rationale for Automated Hearing Assessment with Ambient Noise Monitoring

- Flexible test sites within a traditional audiology clinic
- Feasibility of transporting test equipment permits valid hearing assessment with one device at different times and days in multiple audiology or satellite clinics
- Valid hearing assessment by non-audiologists in a variety of settings with diverse patient populations, e.g.,
 - Public schools
 - Primary care physician offices
 - Outpatient medical clinics, e.g., VA outpatient clinics
 - Industrial settings
 - Skilled nursing facilities
 - Prisons

Rationale for Automated Hearing Assessment with Ambient Noise Monitoring

- Option for remote delivery of quality audiology services via teleaudiology
 - Urban settings
 - Remote or rural locations
 - Internationally

A Systematic Review of Telehealth Applications in Audiology

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²Callier Center for Communication Disorders, School for Behavioral and Brain Sciences, University of Texas at Dallas, Texas.

³Department of Communicative Disorders, University of Florida, Gainesville, Florida.

Abstract

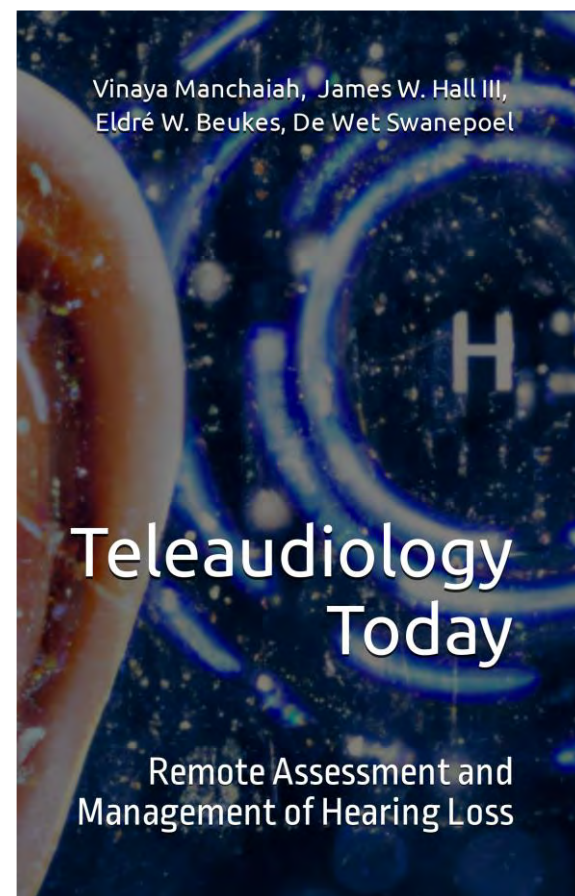
Hearing loss is a pervasive global healthcare concern with an estimated 10% of the global population affected to a mild or greater degree. In the absence of appropriate diagnosis and intervention it can become a lifelong disability with serious consequences on the quality of life and societal integration and participation of the affected persons. Unfortunately, there is a major dearth of hearing healthcare services globally, which highlights the possible role of telehealth in penetrating the underserved communities. This study systematically reviews peer-reviewed publications on audiology-related telehealth services and patient/clinician perceptions regarding their use. Several databases were sourced (Medline, SCOPUS, and CHINAL) using different search strategies for optimal coverage. Though the number of studies in this field are limited available reports span audiological services such as screening, diagnosis, and intervention. Several screening applications for populations consisting of infants, children, and adults have demonstrated the feasibility and reliability of telehealth using both synchronous and asynchronous models. The diagnostic procedures reported, including audiometry, video-otoscopy, oto-acoustic emissions, and auditory brainstem response, confirm clinically equivalent results for remote telehealth-enabled tests and conventional face-to-face versions. Intervention studies, including hearing aid verification, counseling, and Internet-based treatment for tinnitus, demonstrate

reliability and effectiveness of telehealth applications compared to conventional methods. The limited information on patient perceptions reveal mixed findings and require more specific investigations, especially post facto surveys of patient experiences. Tele-audiology holds significant promise in extending services to the underserved communities but require considerable empirical research to inform future implementation.

Introduction

The field of audiology encompasses prevention, assessment, and rehabilitation of hearing, auditory function, balance, and other related systems.^{1,2} With an estimated 642 million people in the world affected to a mild or greater degree, and 278 million to a moderate and greater degree, hearing loss is clearly a significant global healthcare concern³ with pervasive and far-reaching consequences. If not identified and treated early, children with hearing loss may suffer lifelong disability due to developmental delays in language, literacy, academic achievement, and social well-being.^{4,5} Hearing loss in adults tends to isolate and stigmatize them, leading to poor social participation and severely restricting vocational opportunities, as evidenced by significantly higher under- and unemployment.⁶ Hearing loss is therefore reported as one of the most significant contributors to the global burden of disease.⁷

Audiological diagnosis and intervention for children and adults with hearing loss offer the possibility of excellent outcomes as opposed to the negative consequences of undetected and undiagnosed hearing loss without intervention services.^{8,9} The problem in providing the necessary services, however, is the shortage of audiological professionals and services in the majority of regions in the world.^{10,11} Even in developed countries like the United States and Australia, rural and remote communities may not be able to access the necessary hearing healthcare services. Telehealth applications in audiology may offer some solutions to the mismatch in the apparent need for services and the limited capacity to deliver services.¹² Using information and communication technology in healthcare, as implied in telehealth,



Audiology, Anywhere: Hearing Assessment Outside the Booth

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Audiology, Anywhere: Hearing Assessment Outside the Booth

- In combination, an automated audiometer with an ambient noise monitoring option and appropriate circumaural earphones permits what kind of testing outside of a sound treated room?

Clinical Instrumentation for Hearing Assessment Outside a Sound Treated Environment



- Limitations of typical inexpensive options for sound level measurement
 - Noise levels are not specific to audiometric frequencies
 - Measurement of noise is static not ongoing
 - No record of noise levels during hearing assessment

Clinical Instrumentation for Hearing Assessment Outside a Sound Treated Environment

- Two components required for hearing assessment outside of a sound booth
 - Continuous frequency-specific measurement of ambient noise levels
 - Transducers with documented attenuation of ambient noise
- Third component ... automated audiometry ... permits valid hearing assessment by non-audiologists, e.g., assistants, technicians, facilitators, nurses, etc.
 - Numerous automated hearing test devices for industry
 - SHOEBOX audiometer with noise monitoring (N = 3 peer-reviewed pubs)
 - KUDUWave Pro audiometer with noise monitoring (N = 9 peer-reviewed pubs)
 - **GSI AudioStar Pro with AMTAS option** (N = > 10 peer-reviewed pubs)

Audiology, Anywhere: Hearing Assessment Outside the Booth

- Which US standard defines the requirements for an adequately quiet hearing test environment?

Clinical Instrumentation for Hearing Assessment Outside a Sound Treated Environment



KUDUwave



International Journal of Audiology 2015; 54: 777–785

*International
Journal of
Audiology*

Original Article

Pure-tone audiometry outside a sound booth using earphone attenuation, integrated noise monitoring, and automation

De Wet Swanepoel^{*,†,‡,§}, Cornelia Matthysen^{*}, Robert H Eikelboom^{*,†,‡}, Jackie L Clark[§] & James W Hall III^{*,#}

^{*}Department of Speech-Language Pathology and Audiology, University of Pretoria, South Africa, [†]Ear Sciences Centre, School of Surgery, The University of Western Australia, Nedlands, Perth, Australia, [‡]Ear Science Institute Australia, Subiaco, Australia, [§]Callier Center for Communication Disorders, University of Texas at Dallas, USA and [#]George S. Osborne College of Audiology, Salus University, Elkins Park, USA

Evidence Confirming the Validity of Hearing Assessment Outside a Sound-treated Environment



GSI AudioStar Pro Audiometer
Automated Method for Testing
Auditory Sensitivity (AMTAS)

DD 450 Headphones



Circumaural Earphones



Ambient Noise
Monitoring System (Microphone)

Evidence Confirming the Validity of Hearing Assessment Outside a Sound-treated Environment

- Maximum Permissible Ambient Noise Levels (MPANL)
- “The minimum ambient noise level that masks a pure-tone presented at 0 dB HL is the MPANL” according to ANSI S3.1-1999, R2018 (Margolis, Saly & Wilson, 2021).
- American National Standards Institute (ANSI) S3.1-1999, R2018:
 - The standard for permissible noise in audiology test rooms.
 - Measured with octave or one-third octave band noise
 - Audiometric pure tone frequencies from 125 Hz to 8000 Hz
 - Earphone specific (supra-aural, circumaural, insert, or unoccluded)

Audiology, Anywhere: Hearing Assessment Outside the Booth

- Which type of circumaural earphone provides substantial attenuation of ambient noise for hearing testing?

Clinical Instrumentation for Hearing Assessment Outside a Sound Treated Environment



GSI AudioStar Pro with AMTAS

Clinical Instrumentation for Hearing Assessment Outside a Sound Treated Environment

DD 450 Headphones



Ambient Noise Monitoring during Pure-Tone Audiometry

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² Division of Speech and Hearing Science, College of Health Solutions, Arizona State University, Tempe, Arizona^{Q4}

Address for correspondence: Robert H. Margolis, (e-mail: Rhmargo001@gmail.com).^{Q5}

J Am Acad Audiol 2021;00:1–11.

Audiology, Anywhere: Hearing Assessment Outside the Booth

- Which feature of ambient noise monitoring is essential during pure tone audiometry?

Clinical Instrumentation for Hearing Assessment Outside a Sound Treated Environment

Frequency (Hz)	Maximum (dB SPL)				
	Supra-aural (C, D, F, G, H)	Ear canal	Circumaural		
			00450	100/200Hz	1000/2000
	AD51	AD51	AD51		
125	39	39	40	40	41
250	25	25	37	37	37
500	21	16	39	28	42
800	24	15	42	29	43
1,000	26	13	43	30	46
1,600	30	14	45	36	48
2,000	34	14	47	41	58
3,150	36	13	52	38	52
4,000	37	11	58	39	55
6,300	37	13	58	36	59
8,000	37	14	58	32	60
12,000	37	14	58	24	65

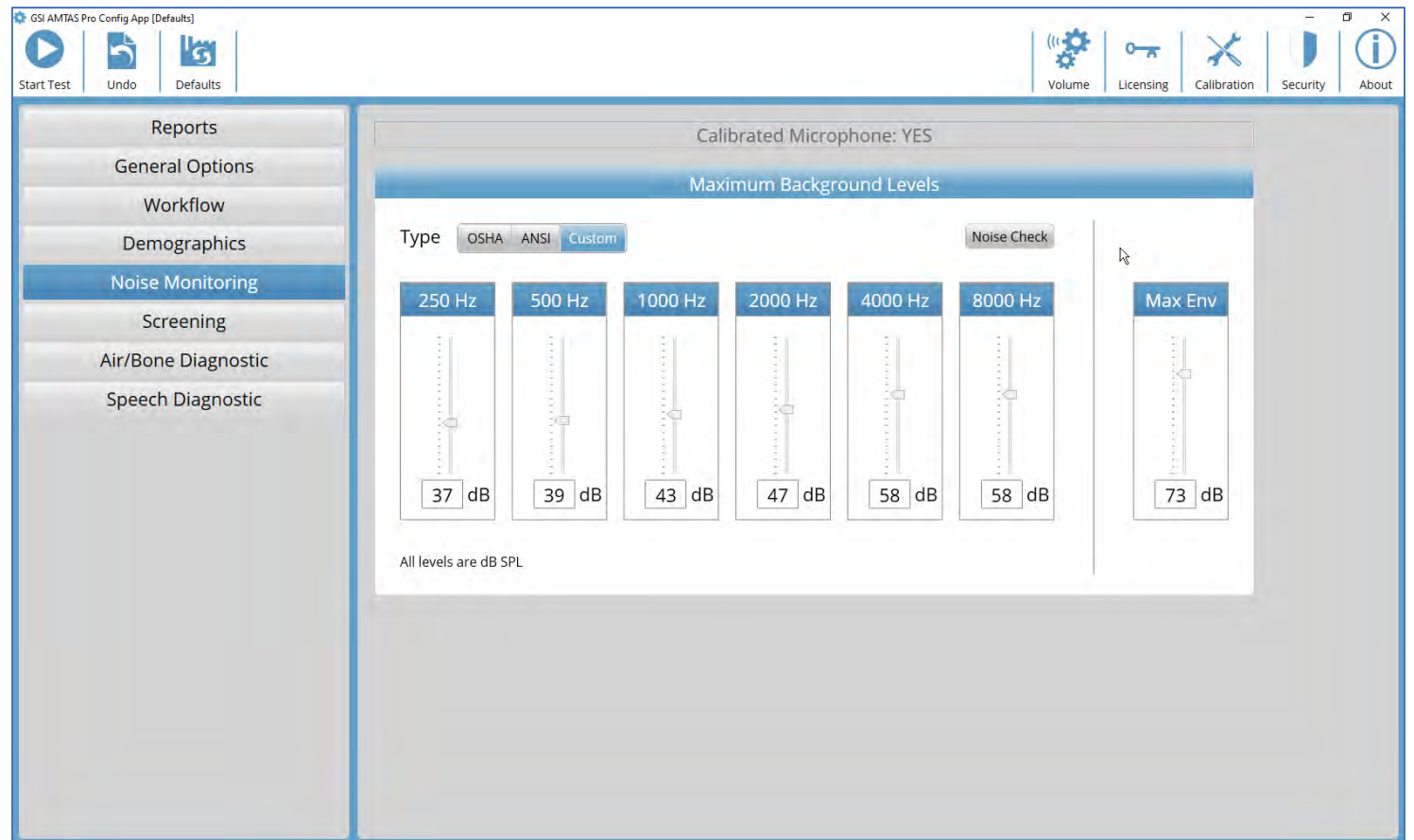
Maximum Permissible Ambient Noise Levels (MPANLs)

Octave Band SPLs in dB

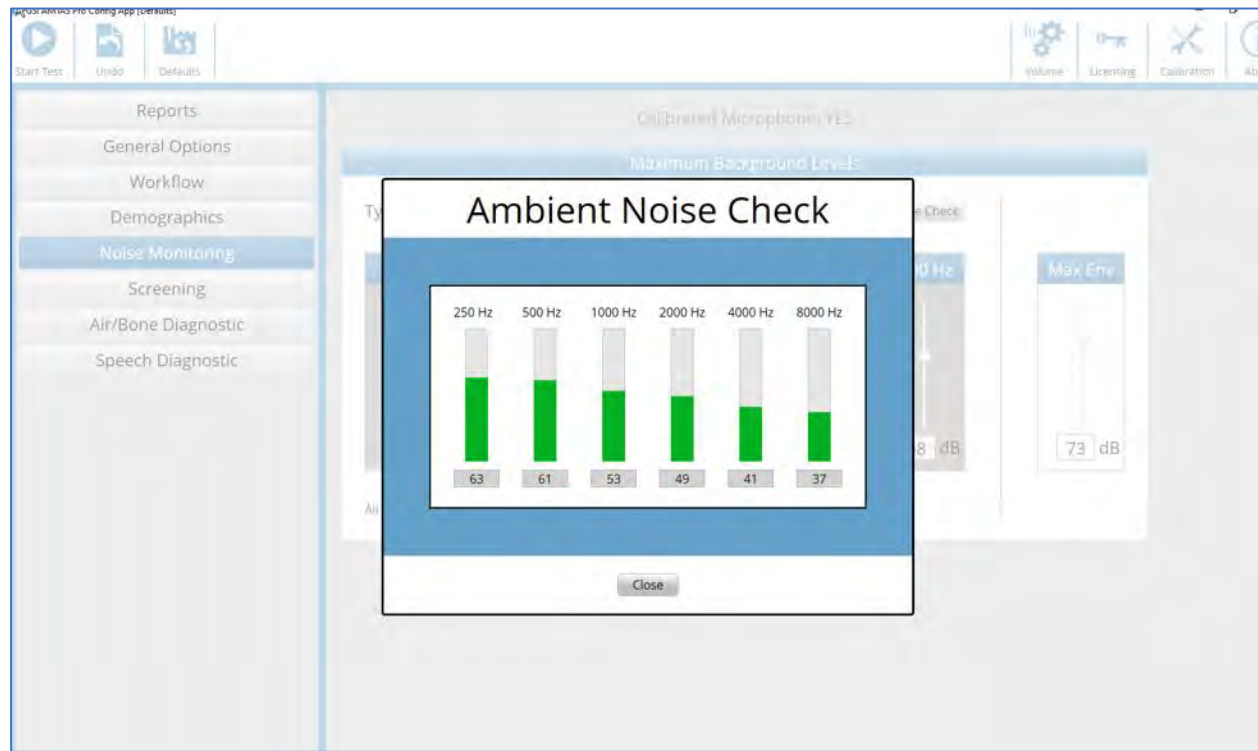
ANSI 3.1 1999

(From: Margolis, Saly & Wilson, 2021)

Noise Monitoring



Noise Monitoring



- Real time dynamic octave band noise levels
- Confirms the microphone is working
- Can be used to confirm environment is appropriate for testing
- Testing can be temporarily paused if noise is too high



Noise Monitoring

Ambient Noise Monitoring Report

gsi
Grason-Stadler

Patient Name: TV ANS1

Environmental Noise Report
Any noise level that may have had an impact on the threshold is indicated on the audiogram with an 'Y' next to the audiometric symbol

Average Noise Levels
Average noise levels for each octave band during testing

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
ANSI Limit (dB SPL)*	37	39	43	47	50	50
Measured	67	74	63	60	50	53

* Maximum Permissible Ambient Noise Levels (MPANL) used by AMTAS are adjusted for the additional attenuation provided by the circumaural earphones

ANSI Limits
Number of times the octave band noise exceeded the maximum limits during the test

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Limit (dB SPL)	37	39	43	47	50	50
Alerts Count	335	335	335	332	109	97
Alert Percent	100%	100%	100%	99%	33%	29%

Maximum Noise Level during testing
Number of times the noise level exceeded the overall maximum

Maximum Limit (dB SPL)	Exceeded Max Count	Exceeded Max Percent	Total Test Time (min:sec)	Total Test Count
73	372	100%	05:43	372

Distraction Alert
Overall likelihood that distractions affected patient responses

HIGH

- **Average Noise Levels (dB SPL):** OSHA, ANSI or Custom Average Noise Levels during entire test
- **Limits Table:** Count # of times limit was exceeded and % of time exceeded
- **Maximum Noise Level:** Times overall peak level (max env) was exceeded
- **Distraction Alert:** High when 50% or greater of the peak levels exceed 72.5 dB SPL.

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Evidence Confirming the Validity of Hearing Assessment Outside a Sound-treated Environment



Long-Term Impact of **M**military-Relevant
Brain Injury **C**onsortium—**C**hronic
Effects of **N**eurotrauma **C**onsortium
(**LIMBIC-CENC**)

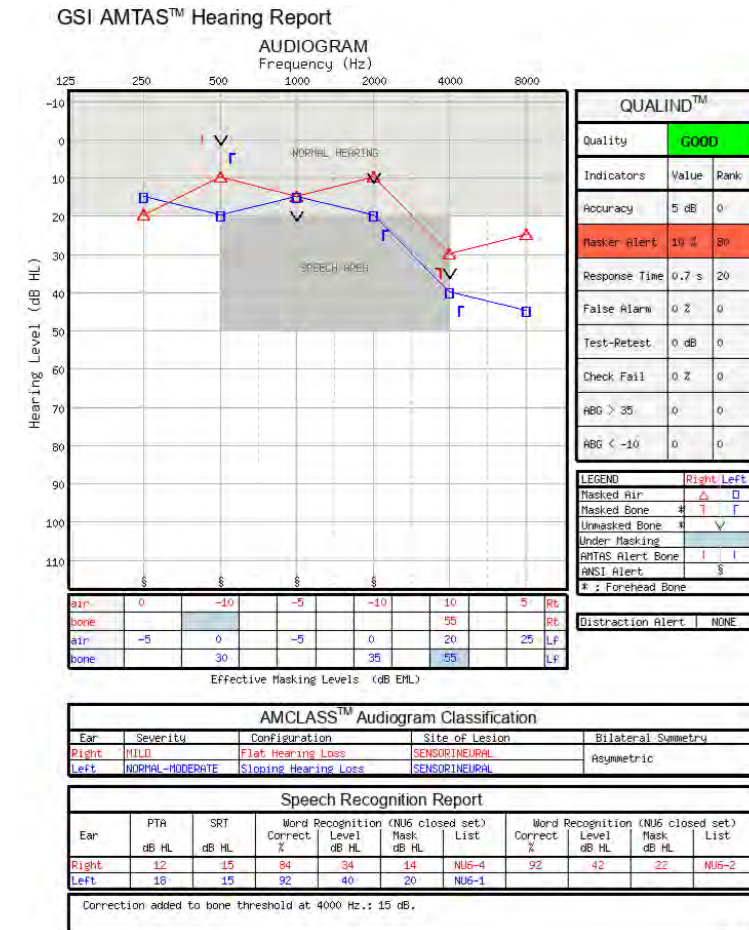
LIMBIC-CENC Prospective Longitudinal Study

**Audiology Standard Operating Procedures
(SOP)**

Version 5.2

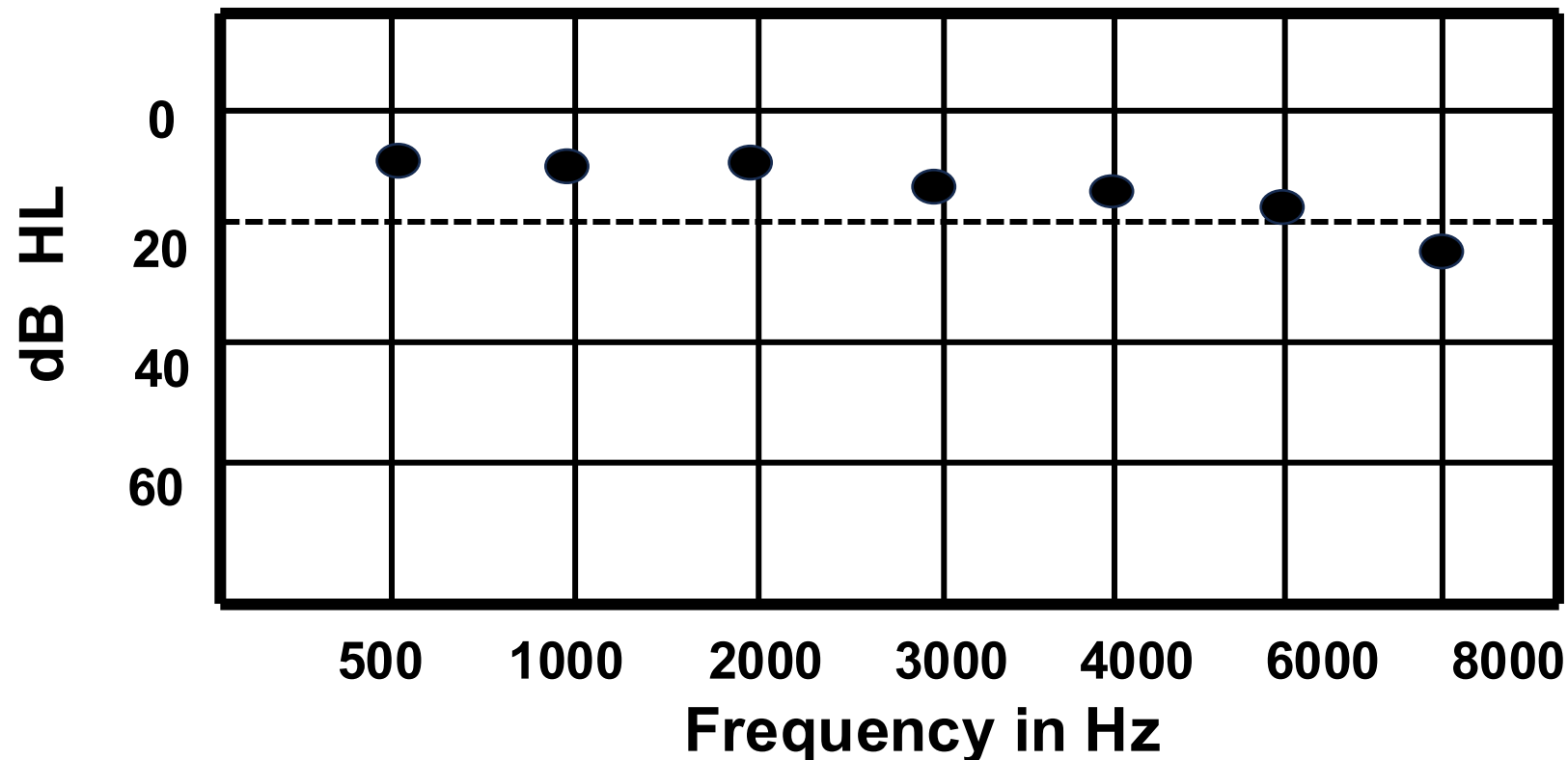
- Auditory data collected from > 3000 participants (Veterans or military personnel) in 10 different sites in the United States
- Data collected in quiet but not sound treated rooms by non-audiologists
- Pure tone audiometry (air conduction and bone conduction as indicated)
- SCAN-3 Subtests
 - Gap detection test
 - Auditory figure ground test
 - Competing words test

Evidence Confirming the Validity of Hearing Assessment Outside a Sound-treated Environment



Evidence Confirming the Validity of Hearing Assessment Outside a Sound-treated Environment

N = 1840 Age = 43 years (mean) Gender = 14% female; 86% male



Evidence Confirming the Validity of Hearing Assessment Outside a Sound-treated Environment



Photographs Courtesy of GSI

Environmental Noise Report

Any noise level that may have had an impact on the threshold is indicated on the audiogram with an '!' next to the symbol

Average Noise Levels

Average noise levels for each octave band during testing

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
ANSI Limit (dB SPL)*	37	39	43	47	58	58
Measured	41	39	30	25	26	24

* Maximum Permissible Ambient Noise Levels (MPANL) used by AMTAS are adjusted for the additional attenuation of the circumaural earphones

ANSI Limits

Number of times the octave band noise exceeded the maximum limits during the test

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Limit (dB SPL)	37	39	43	47	58	58
Alerts Count	572	214	7	1	0	0
Alert Percent	100%	37%	1%	0%	0%	0%

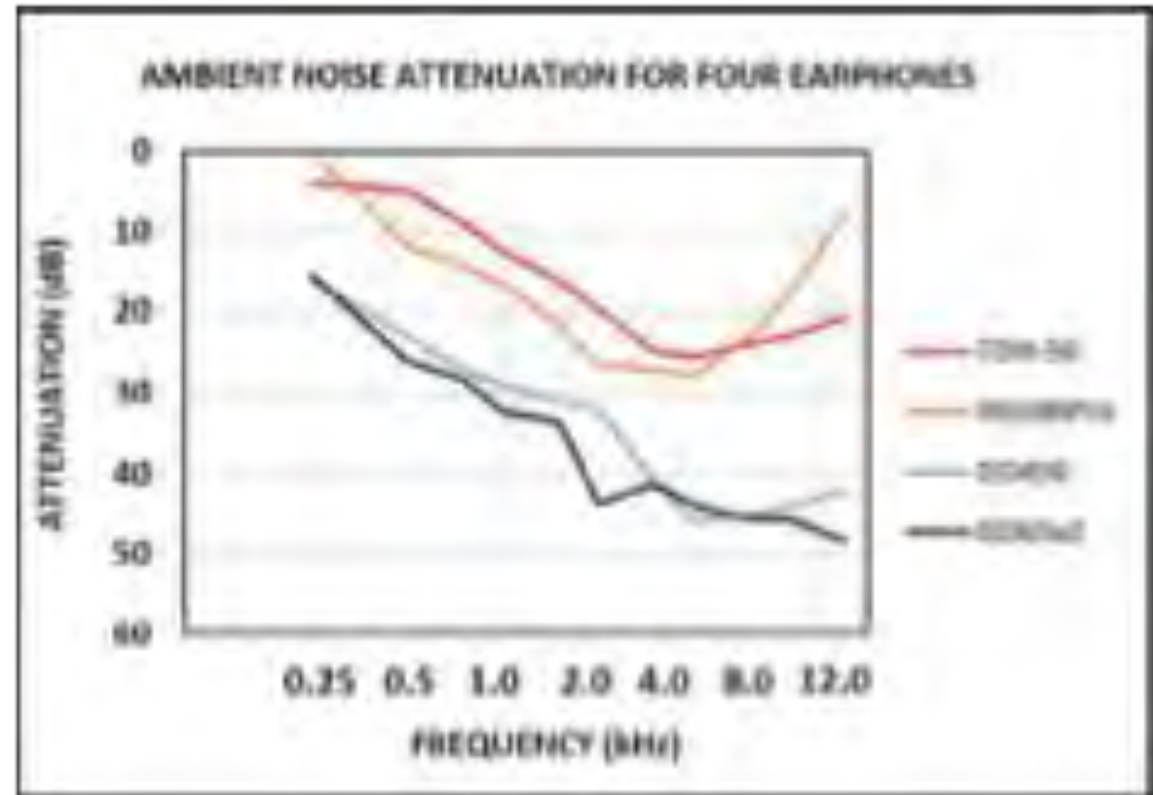
Maximum Noise Level during testing

Number of times the noise level exceeded the overall maximum

Maximum Limit (dB SPL)	Exceeded Max Count	Exceeded Max Percent	Total Test Time (min:sec)	Total Test Count
73	9	1%	10:37	637

Evidence Confirming the Validity of Hearing Assessment Outside a Sound-treated Environment

DD 450 Headphones



From: Margolis, Saly & Wilson, 2021

Evidence Confirming the Validity of Hearing Assessment Outside a Sound-treated Environment

Table 2. Ambient noise data (N = 401) and maximum permissible ambient noise levels (MPANLs) with DD-450 circumaural earphones.

Noise Levels (dB SPL)	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Ambient Noise Mean (SD)	29.7 (13.4)	30.0 (12/1)	28.1 (11.2)	25.2 (10.3)	23.4 (9.9)	23.8 (9.9)
Ambient Noise Range	0 - 61	0 - 61	0 - 61	0 - 61	0 - 78	0 - 83
MPANL (ANSI) Octave-Band	37	39	43	47	58	58
MPANL (ANSI) 1/3 Octave	32	34	38	42	53	53

NOTE: MPANL data with circumaural (DD-450) earphones

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