Mobile Technology for Booth-Less Audiometry

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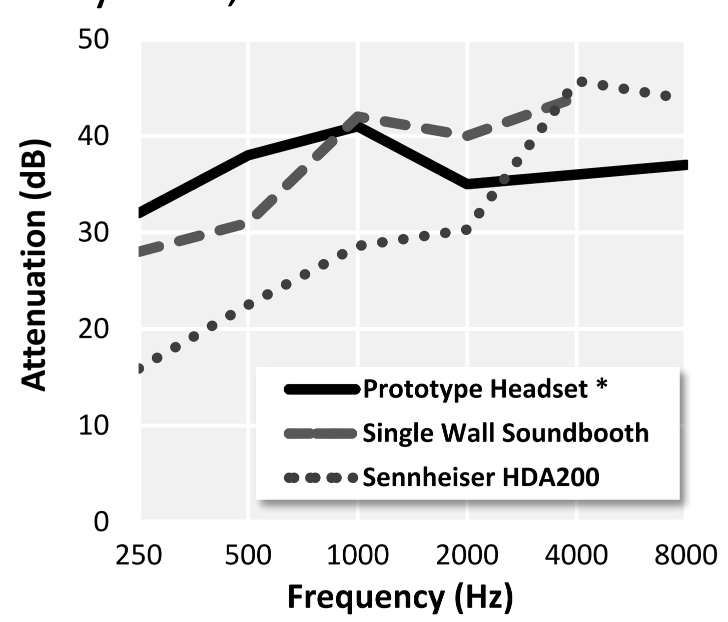
Abstract

Conducting audiometry using internet technologies is difficult because ambient noise can affect the results. We present two human studies evaluating a prototype noise attenuating, wireless audiometric headset that pairs with a mobile device to administer automated audiograms.

Wireless Audiometric Headset

Design: We designed an audiometric headset to perform automated hearing testing outside sound booths. To achieve this objective, the headset provides high levels of passive attenuation (NRS_A of 34 dB). Additionally, the headset electronics pair with mobile devices via Bluetooth. Once paired, an App serves as the user interface. For many tests, the mobile device is handed directly to the listener.



* Attenuation conducted according to ANSI 12.6-2008 Method A by Michael & Associates, Inc.

Electronics: Electronics inside the ear cups generate the stimuli and ensure calibration is *independent* of the mobile device. This approach means the headset delivers quality acoustic stimuli for Apps deployed on *any platform* (e.g., iOS, Android, Windows).

Automated threshold test: In the present studies, the headset presented pure-tone stimuli using a modified Hughson-Westlake procedure (additional details in Meinke et al. 2017). Test frequencies included 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz.

Mobile App: The headset was paired with an App developed to administer customized tests and questionnaires on mobile devices located across multiple sites (Shapiro et al. 2016).

Methods

Impact of Ambient Noise on Hearing Thresholds

The objective of this study was to control ambient noise level under laboratory conditions to determine the level at which it impacts repeatability of threshold measurements for normal hearing individuals.

Test Site & Subjects	• Audiometric booth at House Clinic, Los Angeles, CA • 21 adults (21 ears) with normal hearing (<20 dB HL)
Test Protocol	• Subjects completed seven audiograms, 250–8000 Hz o Two in quiet (before & after ambient noise conditions) o Five with brown noise played on speakers to produce A-weighted noise levels of 47, 52, 57, 62 and 67 dBA • Order of noise conditions randomized for each subject • Thresholds measured with a 2 dB step size to maximize sensitivity to effects of the noise conditions
Analysis	• Calculated within-subject differences for each of their repeated thresholds by frequency and ambient noise condition • Calculated percent of subjects that would have been incorrectly identified as having a "standard threshold shift" (STS) according to OSHA criteria (STS = average thresholds at 2–4 kHz differ from baseline by 10 dB or more [OSHA 29 CFR 1910.95])

Test-Retest Reliability for Children

The objective of this study was to evaluate test-retest reliability when children (ages 7–15 years) use the headset in target environments. Environments included an audiology clinic, a physician's office, a school, and a health clinic. Hearing tests were administered by untrained individuals such as nurses, parents, and office staff.

Test Sites & Subjects	• Audiology clinic, 20 children (40 ears) • Physician's office, 6 children (12 ears) • School, 3 children (6 ears) • Health clinic, 12 children (24 ears)
Test Protocol	• Subjects completed two audiograms from 250–8000 Hz • Between the audiograms, the test proctor removed and replaced the headset
Analysis	• Calculated within-subject differences for each of their repeated audiograms • Calculated percentages of repeated thresholds that were (1) equivalent to, (2) within 5 dB of, and (3) within 10 dB of their initial threshold

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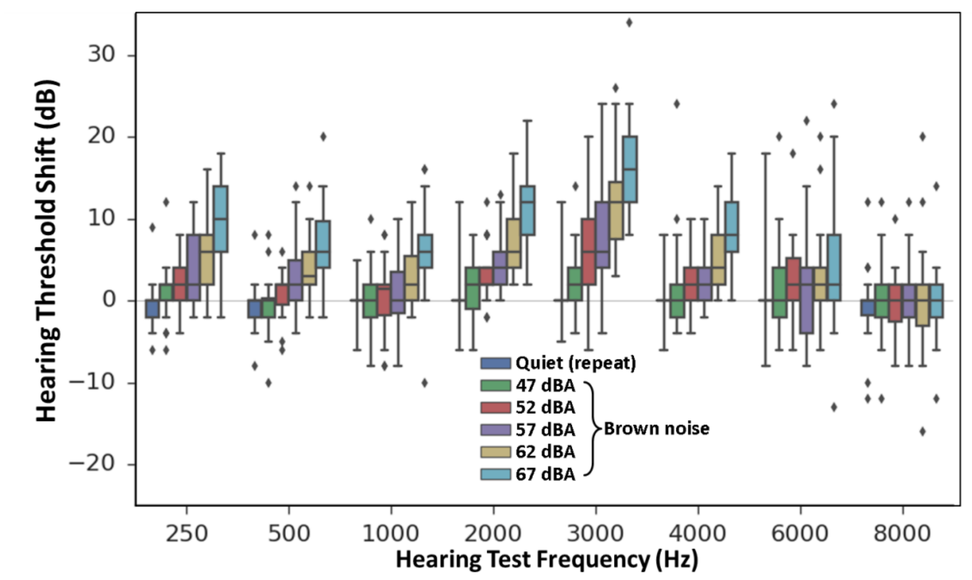
Content does not necessarily represent views of NIH or Army.

Results

Impact of Ambient Noise on Thresholds

Increased levels of ambient brown-noise introduced artificial threshold shifts at 250 through 4000 Hz. When applying OSHA criteria, false positives were not observed until noise level reached 57 dBA.

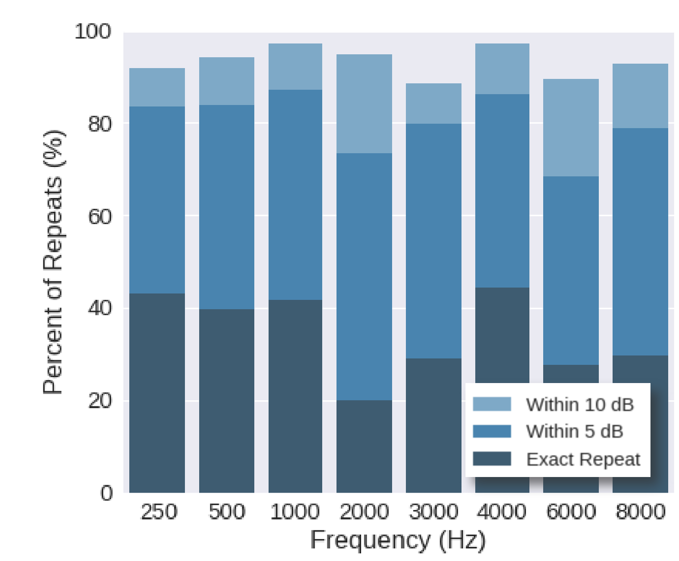


OSHA STS Criteria	
Condition	**% of subjects**
Quiet	0
47 dBA	0
52 dBA	0
57 dBA	4.8
62 dBA	28.6
67 dBA	71.4

Test-Retest Reliability for Children

More than 80% of the time, subjects repeated their automated threshold measurement to within 5 dB (or better).

Additionally, although most children reacted positively to the technology, the App interface could be improved to reliably engage children under age 9.



Conclusions

Using a prototype wireless, audiometric headset with significant passive noise attenuation permits:

- Normal thresholds (down to 0 dB HL) can be reliably measured in brown-shaped noise of up to ~55 dBA with only 5–10% of false positives according to OSHA STS guidelines
- Screening at 20 dB HL could occur at even higher ambient noise levels
- Test-retest reliability in children is consistent with outcomes reported using other transducers (Stuart et al. 1991)

Future work will continue to expand on techniques to ensure reliable measurements in the varied environments outside sound booths and expanding application to TeleHealth.

References & Acknowledgements

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