Wireless Automated Hearing Test System

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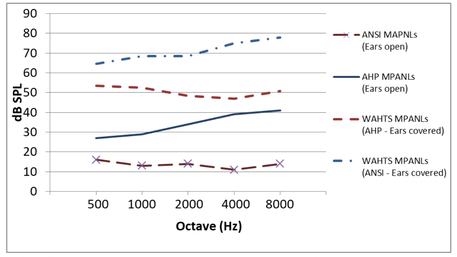
Technology

Worldwide, increasing access to hearing health care will require enabling currently available commodities (Internet, smartphones) to conduct surveillance of hearing loss beyond traditional clinical environments. In military settings, there is an urgent need to monitor hearing downrange, especially in settings where no sound booth is available. To address this need, Creare developed a noise attenuating audiometric headset that pairs with a mobile device for easy assessment outside the clinic. The Wireless Automated Hearing Test System (WAHTS) integrates calibrated electronics inside highly attenuating ear cups. The headphones are calibrated according the ANSI S3.6-2004 standard for audiometers.

The WAHTS uses TabSINT as the user interface and data management system. TabSINT also communicates with a Bluetooth dosimeter to monitor ambient noise during testing. Because of its high noise attenuation, the WAHTS allows testing reliably outside of the booth, in relatively noisy settings.

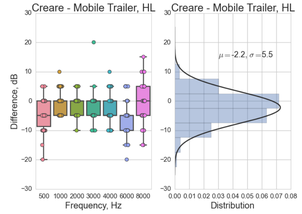


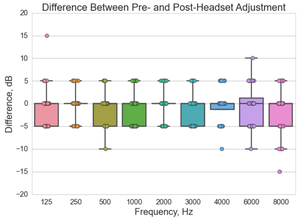
In this figure, we show the maximum permissible ambient noise levels (MPANLs) according to the ANSI S3.1-R2008 standard for ears open or ears covered with the WAHTS, and the Army Public Health MPANLs for ears open or ears covered with the WAHTS

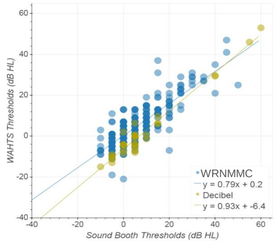
Validation Studies

	Evaluation of hearing thresholds at an industrial plant
Test Site & Subjects	• Mobile trailer audiometry conducted with Benson CCA-200m audiometer (TDH 39 earphones) with in-line sound level meter monitoring for OSHA compliance. Setting: single-walled test booth. • WAHTS automated audiometry measured twice, after removal and replacement of headset between each hearing test. Setting: 6 rooms at brewery plant selected by the EH&S staff with regard to available plant space that could be used for hearing tests if on-site testing were feasible. • 20 adults (20 ears) with normal hearing (a few with some hearing loss)
Test Protocol	Subjects completed three audiograms, • One in the mobile trailer using standard occupational hearing conservation testing protocol, 500–8000 Hz • Two with the WAHTS in standard rooms (remove and replace between each audiogram), 125–8000 Hz
Analysis	• Calculated within-subject differences for each paired thresholds by frequency for one WAHTS test and the standard test (for frequencies up to 4 kHz) • Calculated within-subject differences for each paired thresholds by frequency for test-retest sequence with the WAHTS

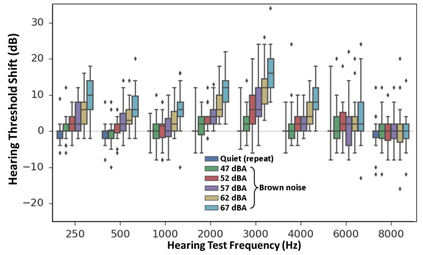
	Comparison of 4 kHz thresholds to Manual Audiometry
Test Site & Subjects	• National Military Audiology and Speech Pathology Center (NMASC) at Walter Reed National Military Medical Center • 173 adults (345 ears)
Test Protocol	Subjects completed two tests at 4000 Hz • One measured in a sound booth using manual audiometry (he modified Hughson-Westlake method) • One measured with the WAHTS using an automated modified Hughson-Westlake method
Analysis	• Calculated within-subject differences for each of their repeated thresholds by frequency



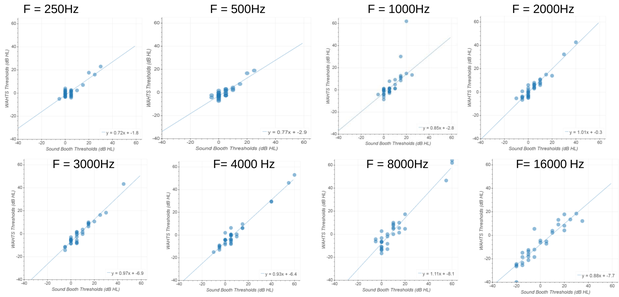




	Effect of ambient noise on measured threshold
Test Site & Subjects	• Audiometric booth at House Clinic, Los Angeles, CA • 21 adults (21 ears) with normal hearing (<20 dB HL)
Test Protocol	Subjects completed seven audiograms, 250–8000 Hz • Two in quiet (before & after ambient noise conditions) • Five 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])



	Comparison of thresholds to manual audiometry across full frequency range
Test Site & Subjects	• Standard audiometric sound booth located at Decibel Therapeutics facility in Boston, MA • 17 adults (34 ears) with normal hearing
Test Protocol	Subjects completed two audiograms, 250 Hz - 16,000 Hz • One in the sound booth using manual audiometry on a commercially available audiometer • One with the WAHTS in the sound booth
Analysis	• Calculated within-subject differences for each paired thresholds by frequency



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Conclusions And Future Work

Using a Creare WAHTS resulted in the following key outcomes:
- The WAHTS yields reliable thresholds, and is comparable to other audiometric earphones or headphones
- The noise attenuation of the headset enables valid hearing threshold measurements outside of a sound booth
- Normal thresholds (down to 0 dB HL) can be reliably measured in brown-shaped noise of up to ~55 dBA
- Screening at 20 dB HL could occur at even higher ambient noise levels

Other ongoing studies evaluated the reliability of the WAHTS in measuring speech in noise with the Hearing In Noise Test and found very similar results to an existing computer-based system. Future studies should evaluate the accuracy of the device on individuals with various degrees of hearing loss to further validate the results. Planned studies include testing of individuals exposed to high noise levels during weapons training to identify potential changes to hearing thresholds after exposure.

Future developments with the headset include earplug fit testing under the ear cups and the addition of bone conduction integrated with the WAHTS.