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Comparison of Hearing in Noise Test (HINT) Scores Using Three Different Transducers

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Warfighter Protection Division

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14. ABSTRACT
Army aircrew work in hostile listening environments and rely on hearing for crew coordination—a critical component of rotary-wing aviation. New technologies may require that aviators to have the ability to not only hear in noise, but to localize warning and other signals. The Hearing in Noise Test (HINT) evaluates functional hearing in noise, but has only been normalized using supra-aural headphones. Method: Sixty normal hearing students from Utah State University were equally partitioned into three groups. Each group was administered the HINT in four test conditions with one of three transducers: (a) THD-39 supra-aural, (b) ER-3A foam insert, or (c) the Communications Earplug (CEP). Results: Data analysis revealed no significant differences between scores obtained using the three transducers in any of the three noise conditions. There was a difference between the THD-39P results and those obtained from the other two insert earphones in the quiet condition that was likely due to a calibration issue. Conclusion: Insert-type earphones should be considered for administration of the HINT once a correction factor has been established.

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Introduction

The ability to hear and understand in noise is critical for U.S. Army rotary-wing aviators and aircrew members. Noise inside military helicopters can reach extremely high levels and can compromise speech intelligibility because of adverse signal-to-noise ratios (Mozo and Murphy, 1997a). In a recent study conducted at the U.S. Army Aeromedical Research Laboratory (USAARL), of 259 active duty aviators and candidates spanning many years of military service, over 30% were found to have depressed speech-in-noise test scores (unpublished observations). In order to improve hearing in noise, the U.S. Army has been conducting research for several decades into the feasibility of incorporating technology to enhance communication during aircraft operations (Houtsma, 2004).

Researchers at the USAARL are currently exploring the use of spatial hearing in rotary-wing aviation. Spatial hearing is the ability to localize sound sources or focus on sounds in a noisy environment. The ability to localize the direction of an oncoming car when crossing the street is an example of spatial hearing. This phenomenon occurs when the ears are unoccluded. In order to simulate spatial hearing under ear phones (similar to surround sound), sounds are processed using an algorithm referred to as a head related transfer function (HRTF) that gives the listener the perception that speech and other critical sounds such as warning signals are coming from various locations. This concept may improve speech intelligibility in noise and localization resulting in a safer environment for rotary-wing aircrew members (Houtsma, 2004).

One of the tests in the USAARL study mentioned above was the Hearing in Noise Test (HINT). The HINT identified the majority of those participants whose scores fell outside established norms for functional hearing in noise in the test battery. The HINT was developed at the House Ear Institute (Los Angeles, California) and uses an adaptive testing method in which the examiner presents prerecorded sentences, speech spectrum noise, and spatial separation of the signal from the noise to evaluate a person's ability to understand speech in simulated everyday listening conditions (Nilsson, Soli and Sullivan, 1994). The signal (sentences) and competing noise are presented binaurally under earphones using an HRTF that simulates a sound field environment (Houtsma, 2004). The noise is matched to the sound spectrum of the sentences to create a realistic listening environment. Listeners perceive that the sentences are being presented directly from the front (0 degrees azimuth). The competing noise is presented at perceived azimuths of 0° (front), 90° (right), and 270° (left). The noise is never presented without the accompanying sentences and is maintained at a constant presentation level of 65 dBA.

A list of 20 pre-recorded sentences is presented for each of four test conditions: (a) Quiet (Q), (b) Noise Front (NF), (c) Noise Right (NR), and (d) Noise Left (NL). The lowest intensity at which the listener correctly repeats 50% of the speech signal is recorded as the reception threshold for sentences (RTS). To date the HINT has only been administered and normalized for use in sound field or with supra-aural earphones (Figure 1).

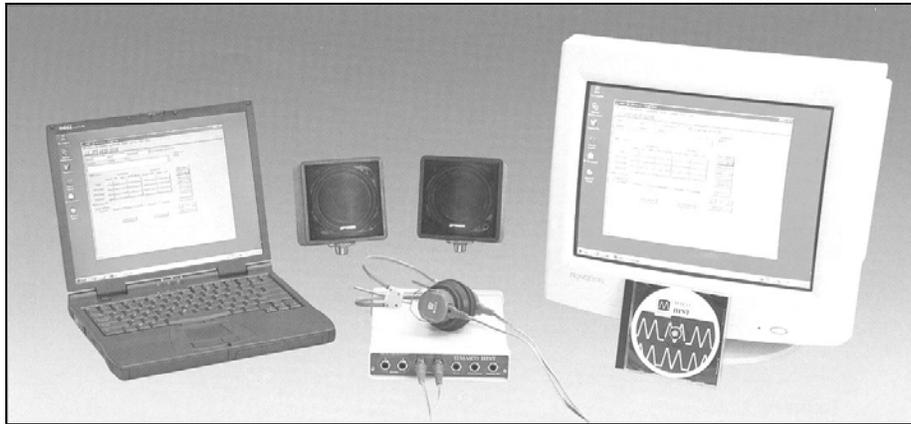


Figure 1. The HINT system consisting of laptop computer (left), optional speakers and hearing test device with TDH 39P supra-aural headphones (center) and monitor (right). Photo courtesy of Maico Diagnostics (Eden Prairie, Minnesota).

Telephonics TDH-39P 10-ohm supra-aural earphones come standard with the HINT system. This type of earphone has been used in audiometric test equipment for several decades. However, no study has evaluated the HINT performance of adults using insert earphones. In a study conducted at Utah State University, researchers tested volunteer participants ages 6-11 using a children's version of the HINT presented through insert earphones. Results showed that for all test conditions in noise there was no difference in results obtained from insert phones and sound field normative data (Dr. Mindy Norris, personal communication, June 2006).

Insert earphones are relatively new as transducers for audiometric testing. The foam ear tips are comfortable and allow increased attenuation of ambient noise. Insert phones are becoming a popular transducer in audiological practices throughout the United States and are preferred by many clinicians because of the increased inter-aural attenuation the phones provide, often reducing the need for masking (Lilly & Purdy, 1993). The EARTone ER-3A insert phone system, manufactured by Aearo (Indianapolis, Indiana), is comprised of a transducer, a delivery tube, and foam disposable ear tips (Figure 2).



Figure 2. EARTone ER-3A 10-ohm insert earphones with foam ear tips. Photo courtesy of Aearo Company (Indianapolis, Indiana).

The Communications Earplug (CEP) falls into the category of new technology designed to enhance communication in noise while providing hearing protection. The CEP (Figure 3) was conceived, developed, and evaluated at the USAARL. The CEP is a device that uses a miniature earphone transducer adapted to a foam earplug with a screw-on tip. The CEP fits into the ear canal and connects into the intercommunications system (ICS) of Army helicopters as well as other electronic devices. A 2.5 mm diameter hole from tip to base of the earplug provides a path for sound generated by the transducer to enter the occluded portion of the ear canal (Mozo and Murphy, 1997a; Mozo and Murphy, 1997b).

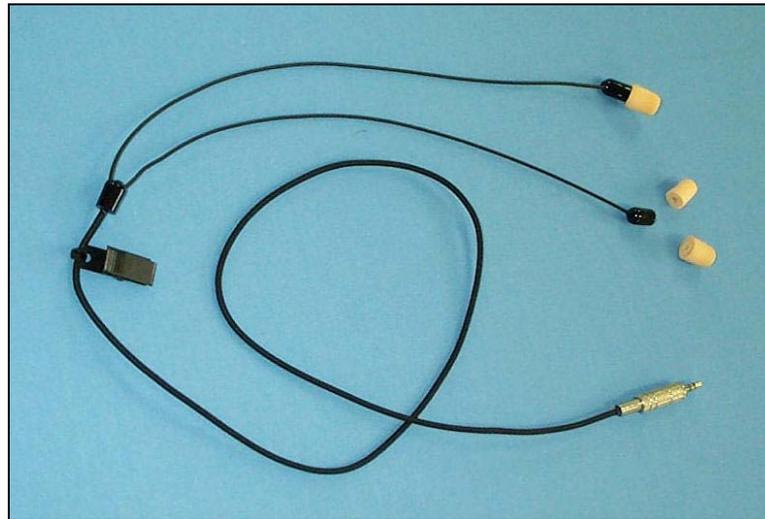


Figure 3. Communications Ear Plug (CEP) with foam tip. Photo courtesy of CEP, Enterprise, Alabama.

The purpose of this study was to compare the HINT responses of normal, healthy, young adults using three different acoustic transducers (TDH-39P, ER-3A insert phones, and the CEP). The research question was this: Is there a difference in HINT scores when the test is presented through insert-type phones versus supra-aural headphones?

Methods

This protocol was approved by the USAARL Scientific Review Committee at Fort Rucker, Alabama, and the Institutional Review Board at Utah State University (USU) in Logan, Utah.

Volunteer Participants

Sixty volunteer participants (30 male and 30 female) were recruited from students at Utah State University (18-30 years of age, with a mean age of 24). Each participant was a volunteer and was fully informed of the purpose of the study and also read and signed an approved consent form. Participants completed a survey that included general demographic information, general health, and history of noise exposure.

Equipment

Instrumentation consisted of a Dell Latitude 800C laptop computer, Maico HINT version 6.2, and the HINT Hearing Test Device (HTD) connected through the wall of the sound treated booth using each of the three earphone systems under investigation. Calibration of transducers was conducted prior to the beginning and after the completion of the study. Supra-aural transducers were calibrated according to the HINT manufacturer's instructions using an NBS 9A 6 cc coupler, a Larson-Davis 800 B precision sound level meter, and a Larson-Davis 1 inch microphone (Maico Diagnostics, 2001). The ER-3A insert phones were calibrated in like manner; however, a custom modified HA-1 coupler was used in lieu of the NBS coupler. The CEP was calibrated using a modified HA-2 coupler. A Grason-Stadler GSI-33 Middle Ear Analyzer was used for tympanometry and acoustic reflex data collection. Pure-tone air conduction audiograms were obtained using a Madsen ORBITER 922 diagnostic audiometer (GN Otometrics, Taastrup, Denmark).

Procedure

As part of the screening for potential participants, an otoscopic examination (visual inspection) of the outer ear canals was performed to rule out pathology or anomalies that might affect test results. An immittance test battery of tympanograms and ipsilateral acoustic reflexes at 500, 1000, and 2000 Hz with a probe tone of 220 Hz was used to verify that participants had normally functioning middle ear systems. Normal tympanograms were classified as those where the peak of the tympanogram occurred between +/- 100 daPa. The acoustic reflex was also evaluated. Reflexes had to be present at 500, 1000, and 2000 Hz for inclusion in the study.

Pure-tone behavioral thresholds were obtained using a modified Hughson-Westlake search method (Carhart and Jerger, 1959), at the following frequencies: 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000Hz. Testing was conducted in a sound treated booth meeting ANSI specifications (ANSI, 1991) for ambient noise levels. In order to be included in the study, volunteer participants had to be native English speakers and have pure-tone air conduction thresholds of no more than 20 dBHL at all test frequencies from 250 Hz to 8000 Hz.

Once selected, participants were randomly assigned to one of three groups. Each group consisted of 20 members (10 males and 10 females). All groups were tested using the HINT. Group #1 was tested using supra-aural earphones, Group #2 was tested using Aearo ER-3A insert earphones, and Group #3 was tested with the CEP.

Presentation sequence of all speech materials was randomized using a Latin Squares design to reduce learning effects. Total test time was approximately 1 hour. Participants were given rest breaks as needed to reduce fatigue effects and were paid for their participation.

A list of 20 pre-recorded sentences was presented for each of the four test conditions (Q, NF, NR, and NL). Each participant was asked to repeat the sentences as he/she heard them. The lowest intensity at which the listener correctly repeated 50% of the speech signal was recorded as the reception threshold for sentences (RTS). In the Q condition, RTSs were reported in dBA. In all other conditions, noise thresholds were reported in dB signal-to-noise ratio (SNR). The noise was held at a constant level of 65 dBA. Each participant's RTS for each test condition was compared with established normative scores.

Results

A repeated-measures analysis of variance was computed using SPSS v.12 software. All statistics were computed at a significance level of 0.05. The sphericity test was significant; therefore, a Wilk's Lambda multivariate test was used. The following effects were noted: (a) Test main effect ($F_{(3, 52)} = 1502.94, p < .001$), (b) Test \times Transducer interaction ($F_{(6, 104)} = 7.552, p < .001$), and (c) between-subjects Transducer effect ($F_{(2, 54)} = 308.76, p = .001$). There were no other significant main effects or interactions: (a) Test \times Gender ($F_{(3, 52)} = 2.018, p = .123$), (b) Test \times Transducer \times Gender ($F_{(6, 104)} = .193, p = .978$), (c) Gender ($F_{(1, 54)} = 8.461, p = .656$), and (d) Transducer \times Gender ($F_{(2, 54)} = 1.073, p = .349$).

Post hoc multiple comparisons were computed for the transducer effect using Fisher's Least Significant Differences (LSD). There were significant differences between the TDH-39P earphone and the insert phones: CEP ($p = .001$) and ER-3A ($p = .001$). There was no significant difference between the CEP and the ER-3A phones ($p = .806$). The greatest differences were noted in the quiet condition. The mean differences for the quiet condition were as follows: (a) Supra – CEP = 5.2 dB, (b) Supra – ER-3A = 3.6 dB, and (c) ER-3A – CEP = 1.57 dB.

Figure 4 plots the mean scores for the three devices as a function of test condition. Also included in the graph are the mean and standard deviation of scores from normal listeners as published by the manufacturer (Maico Diagnostics, 2001). The mean score in quiet for supra-aural earphones obtained from normative data was $15.60 \pm$ one standard deviation of 3.1 dB (range 12.5 to 18.7). The CEP fell outside the normal criterion for the Q condition where the threshold mean was almost 4 dB better than that obtained from the supra-aural phones. There was a similar finding in the Q condition in the HINT version for children study mentioned earlier (Dr. Mindy Norris, personal communication, June 2006).

HINT Comparison of Transducers

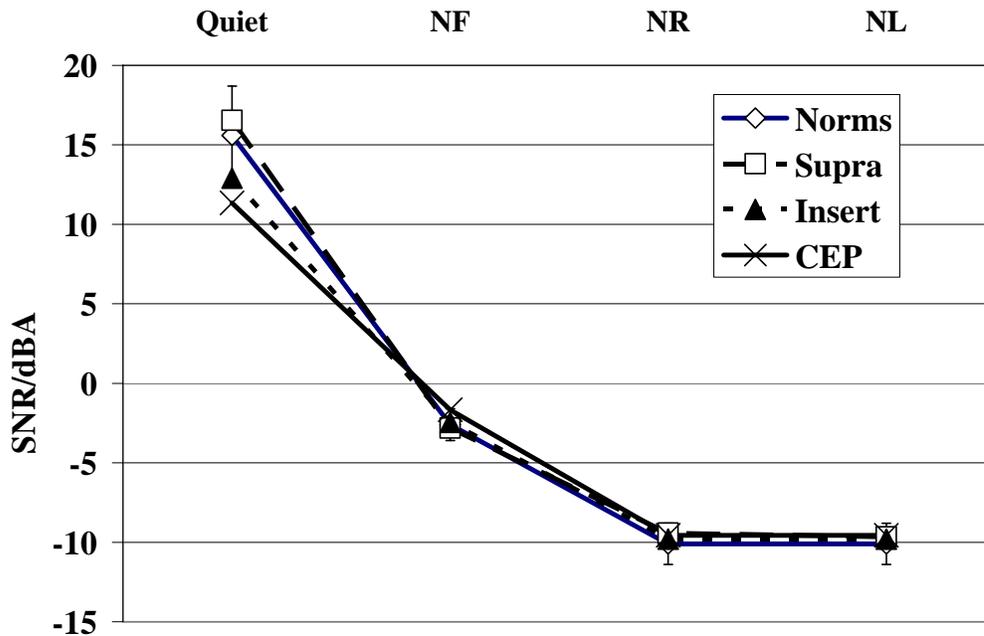


Figure 4. HINT mean scores as a function of test condition. Quiet is reported in dBA; all other conditions are reported in dB signal-to-noise ratio (SNR). Normative data (means and standard deviation) are included for comparison purposes.

Discussion

Both types of insert phones had better (lower) RTSs in quiet than the supra-aural phones. One reason for this finding is likely an acoustical calibration issue. Moving the transducers closer to the tympanic membrane and sealing off the external auditory meatus increases the intensity of the signal reaching the ear. This is evident when calibration standards for both supra and insert earphones are compared (ANSI, 2004). Based on data in this study, a correction factor will need to be developed for responses when the HINT is administered using the CEP or ER-3A-type earphones in order to be equivalent to those obtained via supra-aural ear phones.

The HINT can be administered either by supra-aural or insert/CEP earphones. These findings may be significant for development of communications systems in rotary-wing aircraft. For instance, the CEP has already been modified for use in military aviation communication systems to include aircrew helmets (Mozo and Murphy, 1997a; Mozo and Murphy, 1997b). This study supports the possibility of incorporating the CEP or similar insert device for use in 3-D audio environments such as those currently under investigation at the USAARL. In addition, the HINT might be considered as part of a test battery for predicting how well aviators will do in noise and in a 3-D audio environment.

Conclusions

Based on findings from this study, there is strong evidence that the HINT can be successfully administered using insert-type earphones and that the results will be comparable to those obtained using supra-aural earphones once a correction factor is established for the Q condition. No evidence of gender differences was found. Insert phones, such as the CEP, currently available to military aviators through supply channels, may be considered as a transducer for use in new 3-D auditory display systems. This is important because advanced auditory displays in new and upgraded aircraft may include spatialized communication signals in which communications from a source (e.g., tower, ground commander, wingman) may be perceived in virtual (3-D) auditory space corresponding to the actual position of the transmitter. Correct perception of these spatialized communications signals will be essential for the safety and operational effectiveness of the aircrew.

References

- ANSI. 2004. American National Standards Specification for Audiometers S3.6-2004. New York: American National Standards Institute. 24-29.
- ANSI. 1991. Maximum permissible ambient noise levels for audiometric test rooms S3.1- 1991. New York: American National Standards Institute.
- Carhart, R. and Jerger, J. 1959. Preferred method for clinical determination of pure-tone thresholds. J Speech Hear Disord. 16: 340-345.
- Houtsma, A. 2004. Spatial hearing, hearing impairments and hearing protection. U.S. Army Medical Department Journal. April - June 17-23.
- Lilly, D. and Purdy, J. 1993. On the routine use of tubephone insert earphones. Am J Audiol. 17-20.
- Maico Diagnostics. 2001. HINT for Windows Operating Instructions. Minnesota: Maico Diagnostics.
- Mozo, B. and Murphy, B. 1997. Assessment of sound attenuation and speech intelligibility of selected active noise reduction devices and the Communications Earplug when used with the HGU-56/P Aviator Helmet. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report No. 97-08.
- Mozo, B. & Murphy, B. 1997. Evaluation of the Communications Earplug in the H-53 and CH-46 Helicopter environments. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report No. 97-36.
- Nilsson, M., Soli, S. D., and Sullivan, J. A. 1994. The development of the Hearing in Noise Test for the measurement of speech reception thresholds in quiet and in noise. J Acoust Soc Am 95(2): 1085-1099.