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Research paper

The effect of sensorineural hearing loss and tinnitus on speech recognition over air and bone conduction military communications headsets

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ABSTRACT

Military personnel are at risk for hearing loss due to noise exposure during deployment (USACHPPM, 2008). Despite mandated use of hearing protection, hearing loss and tinnitus are prevalent due to reluctance to use hearing protection. Bone conduction headsets can offer good speech intelligibility for normal hearing (NH) listeners while allowing the ears to remain open in quiet environments and the use of hearing protection when needed. Those who suffer from tinnitus, the experience of perceiving a sound not produced by an external source, often show degraded speech recognition; however, it is unclear whether this is a result of decreased hearing sensitivity or increased distractibility (Moon et al., 2015). It has been suggested that the vibratory stimulation of a bone conduction headset might ameliorate the effects of tinnitus on speech perception; however, there is currently no research to support or refute this claim (Hoare et al., 2014). Speech recognition of words presented over air conduction and bone conduction headsets was measured for three groups of listeners: NH, sensorineural hearing impaired, and/or tinnitus sufferers. Three levels of speech-to-noise (SNR = 0, −6, −12 dB) were created by embedding speech items in pink noise. Better speech recognition performance was observed with the bone conduction headset regardless of hearing profile, and speech intelligibility was a function of SNR. Discussion will include study limitations and the implications of these findings for those serving in the military.

1. Introduction

1.1. Hearing loss and the military

Military personnel are at high risk for noise-induced hearing loss due to the acoustic trauma experienced during deployment from high-level impulsive blasts (i.e., weaponry, improvised explosive devices) and continuous noise (i.e., air and ground vehicles, engine equipment) (USACHPPM, 2008). In fact, noise-induced hearing loss is the most prevalent injury of United States Soldiers returning from Afghanistan and Iraq (Cave et al., 2007). Ear injuries, including tympanic membrane perforation, sensorineural hearing loss, and tinnitus, affect a warfighter's hearing acuity and, as a result, reduce situational awareness and readiness (Dougherty et al., 2013).

1.2. Tinnitus

Moreover, noise-induced hearing loss is highly associated with tinnitus, the experience of perceiving sound that is not produced by a source outside of the body (Henry et al., 2010). ‘Clinically-significant,’ or chronic, tinnitus is when it has been experienced for at least 3 to 6 months and may become problematic for an individual and their quality of life (Tunkel et al., 2014). Intervention and management are the only options for those individuals suffering from chronic tinnitus as there is no cure for this condition. ‘Clinically-significant’ tinnitus affects an individual's sleep, daily tasks,

Abbreviations: ANCOVA, Analysis of Covariance; ANSI/ASA, American National Standards Institute/Acoustical Society of America; FY, Fiscal Year; IRB, Institutional Review Board; KEMAR, Knowles Electronic Manikin for Auditory Research; MRT, Modified Rhyme Test; NH, Normal Hearing; RAU, Rationalized Arcsine Unit; SNHL, Sensorineural Hearing Loss; SNR, Speech to Noise Ratio; SNHL+T, Clinically Significant Tinnitus; TCAPS, Tactical Communication and Protective Systems; TFI, Tinnitus Functional Index

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relaxation, and conversation (Moon et al., 2015). Tinnitus is the primary service-connected disability, affecting 1,450,462 Veterans in Fiscal Year (FY) 2015 (Veterans Administration, 2015).

1.3. Hearing protection

The exposure that causes hearing loss could be greatly reduced by the proper and consistent use of hearing protection. The Army Hearing Conservation Program (Army Pamphlet 40–501, 2015) mandates the use of hearing protection for steady-state noise above 85 dBA, and for impulsive noise above 140 dB peak. However, the prevalence of hearing loss and tinnitus within the military population suggests that Soldiers are failing to use their hearing protection despite its being mandatory. Warfighters are commonly exposed to unsafe levels of noise; however, in many instances, proper use of hearing protection would reduce exposure to safe levels. For example, a tracked vehicle noise can exceed 115 dB A (an Abrams M1A2 tank driven at 63 mph measures at 117 dBA), and an M16A2 measures 157 dB peak at the shooter's position (Robertson et al., 1978). Assuming hearing protection of approximately 20 dB from earmuffs, and up to 30 dB from properly inserted earplugs, the noise exposure to these can be reduced to safe levels. Although there are sources of noise exposure for which 20 dB attenuation would not be sufficient, in many cases special operational procedures and equipment are in place to reduce their impact. For example, there are locations on Navy flight decks where steady-state levels exceeding 145 dB C have been measured (Webster, 1971). However, these shipmen use specialized cranial helmets with communications capability and although there are still issues with proper fit, use of these devices compliance is higher. In contrast, Infantry Soldiers and other ground troops, still at great risk for hearing loss, often forego the use of protection believing it may decrease circumstantial responsiveness during combat (Abel et al., 2011).

1.4. Increasing compliance

The unpredictable nature of the noise threat and the reasonable need to shoot, move, and communicate during combat makes it difficult to gain full compliance with hearing protection mandates. Having communication technology that does not interfere with either hearing protection or communication is essential for increasing compliance. One strategy is to incorporate hearing protection into reliable communication devices (Palca, 2016). It is presumed that the desirability of radio communications will encourage the use of a headset incorporating hearing protection. Another strategy is to offer communications through bone-conduction headsets that allow the warfighter to have full communications capability that does not interfere with the use of hearing protection when needed and allows unhindered hearing when not needed.

1.4.1. TCAPS

The integration of communications with hearing protection has been given the name, "Tactical Communication and Protective Systems (TCAPS)", and refers to any device that provides two-way audio communications through a headset and a microphone, passive protection via earplugs or earmuffs, and active protection via electronic compression or shut-offs. The passive protection of air-conduction TCAPS headsets provides protection from high ambient noise levels, and active talk-through microphones allow the user to engage in face-to-face conversation and hear ambient environmental sounds, preserving situation awareness. In order to prevent the transmission of ambient noises exceeding safe levels, levels beyond a certain threshold level are either compressed or limited by the active circuitry, thus restoring hearing protection. Similar devices designed to work without a radio have also been developed under the moniker, TCAPS Lite (AUSA – Silynx Offering ANR Ear Pro, 2014; Jahner, 2015).

1.4.2. Bone conduction

The second option, bone conduction, presents radio transmissions by converting electric signals into mechanical vibrations, sending sound to the internal ear through the cranial bones. Because headsets with bone conduction transducers do not cover the ears, they allow the user to hear the surrounding environment and the option to communicate over a radio network (Walker et al., 2005). When hearing protection is required, the closed ear canal serves as a resonant chamber to amplify the bone conducted signal (Henry and Letowski, 2007). Worn with or without hearing protection, bone conduction devices are inconspicuous and fit easily under the helmet (Tran et al., 2013). Bone conduction communication devices have been used in the past; however, they have not been widely adopted for military applications. Further, because the use of bone conduction communication devices is still relatively new, there are still many complaints about the fit, sound quality, and sound transmission obtained from these devices (Ganesh, 2016; Kuchera, 2009). Consequently, there have been reports of devices not working for certain people (e.g., poor design and fit), or that the sound transmission is weak (e.g., insufficient power) (Kuchera, 2009); however, issues reported are most likely due to design failures. There are no physiological reasons that bone conduction should fail to work for a user, assuming that the transducer is sufficiently powerful, has good placement, and has appropriate contact with the user's head (Henry and Letowski, 2007). By identifying the optimal design characteristics required for bone conduction transducer implementation, recent psychophysical studies have contributed significantly (Mcbride et al., 2005; Myles et al., 2015; Pollard et al., 2015; Tran et al., 2008, 2013). Therefore, while bone conduction technology is not as commonly used currently, for some it may be the preferred option. Further, since it is a relatively new technology, more research is needed to understand how it functions for different user populations.

1.5. Hearing loss and military service

Although near normal hearing is a requirement for entry to military service (Department of the Army, 2008; Headquarters: Department of the Army., 2011; U.S. Department of Defense, 2011; U.S. Department of the Air Force, 2009), many military personnel operate in high noise environments that cause some degree of clinically-significant noise-induced hearing damage and/or tinnitus (Helfer et al., 2013). TCAPS and bone conduction devices will not solely be used by warfighters with normal hearing as some of these servicemen have already experienced hearing loss and tinnitus. Therefore, it is important to understand speech recognition performance over communication headsets as a function of hearing profile. Further, while speech intelligibility in noise is problematic for all listeners (Abel et al., 2011), it is usually a greater problem for those with hearing loss (Moore, 2003). Although the noise of tinnitus has an internal source, one form of tinnitus treatment is the use of sound masking devices that present white noise, pink noise, or other subtle ambient sounds designed to mask the tinnitus (Hoare et al., 2014). It may be that the external background noise used when testing speech intelligibility in noise actually serves to inhibit or mask the tinnitus. Therefore, a central question is whether there are differences in performance for those with tinnitus that are not observed for subjects with sensorineural hearing loss only.