Future Directions for Research on the Combined Effects of Noise and Vibration on Cognition and Communication

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1. INTRODUCTION

Exposure to noise and vibration in military vehicles is still an unsolved problem. High noise levels have been known to cause hearing loss and difficulties in using intercommunication systems. Whole-body vibration (WBV) is a frequently reported source of annoyance that has been linked to incidences of back pain, but effects on performance are not well documented. For military personnel, clear communication and sharp situational awareness are essential for effective performance and, ultimately, survival. In order to gain a better understanding of how to optimize the performance of personnel operating military vehicles, it is important to consider the effects of realistic levels of noise and vibration. This paper presents an overview of previous studies of communication and cognitive performance in noise and vibration, and gives suggestions for future research on the combined effects of noise and vibration with regard to crew performance in military vehicles.

2. SPEECH INTELLIGIBILITY

The effect of noise on speech intelligibility has been studied extensively. Different types of hearing protectors have been considered. Kryter [7], for example, found that the use of earplugs does not negatively affect speech intelligibility for noise levels above 80 dB; in fact, it tended to increase the intelligibility. However, conventional hearing protectors decrease intelligibility for individuals who have hearing loss [1]. In military vehicles, operators use communication headsets that are sometimes modified with active noise reduction (ANR) technology or worn in combination with earplugs to improve ambient noise attenuation. Speech intelligibility tests using ANR headsets and headsets combined with communications earplugs (CEP) have shown that the noise reduction technology did not have a negative effect on intelligibility scores, for both normal hearing and hearing-loss individuals [10].

The issue of speech understanding in noise for individuals with hearing loss is important because 1) many military personnel suffer from noise-induced hearing loss and 2) it has been found that exposure to combined noise and vibration, causes temporary threshold shift (TTS). For example, Seidel *et al.* [11] found that the combination of noise and vibration can cause greater TTS than exposure to either noise or vibration alone. This included a significant amount of TTS at the 4 kHz octave band, which is known to be crucial to speech understanding [2].

3. COGNITIVE TASK PERFORMANCE

Previous studies of cognitive performance in noise and combined noise and vibration have utilized vigilance, short-term memory and counting tasks. The results of the studies are difficult to generalize because of the differences in the types of noise and vibration used (e.g. white noise vs. recorded noise, intermittent vs. continuous noise, sinusoidal vs. stochastic vibration). Two indicators of performance that have been used are reaction time and accuracy.

In an extensive study by Manninen [9], subjects were exposed to combinations of complex noise, WBV, temperatures and psychic load. One of several responses that were measured was reaction time. The effects of psychic load were observed by comparing the results of a competitive group, who had a monetary incentive to perform well, to those of a non-competitive group. Subject reaction times during a simple light cancellation task were observed. Reaction times increased when the non-competitive subjects were exposed to noise, but a combined effect of noise and vibration on reaction time was not found.

In a study that tested visual vigilance in the presence of intermittent noise, it was found that subjects who were exposed to noise tended to have a faster response time but poorer accuracy than subjects who were tested in quiet [4]. Exposure to WBV alone (without significant background noise) has been shown to cause slower reaction times and, in the case of 1.0 m/s^2 vibration only, increase response errors [12]. In another study of performance on a memory task, for different intensities of combined noise and vibration, significant changes in reaction time were not found across the three intensity levels [8]. However, since the effects of noise and vibration were not tested independently in the study, no conclusions could be drawn about the effects of vibration.

4. FUTURE RESEARCH DIRECTIONS

To date, most experiments of human response to combined noise and vibration have focused on subjective annoyance or discomfort, motor control and TTS. Fewer studies have looked at the effects on cognitive performance, and, to the best of the authors' knowledge, the effects on speech intelligibility have not been studied. Suggestions for consideration in the design of noise and vibration experiments are given below.

4.1 Noise and Vibration Signals

When performing noise exposure experiments using human test subjects, it is generally considered that the appropriate jurisdictional exposure guidelines for workplace noise should be followed (e.g. 85 dBA for 8 hours by Canadian standards [3]). There are currently no widely accepted exposure limits for WBV exposure in Canada. International standard ISO 13090-1 [6] gives guidelines for vibration experiments in terms of the magnitude of vibration that would require the attendance of a physician or medical doctor. These values are listed in Table 1.

Table 1. Exposure to vibration and repeated shock requiring the attendance of a physician or medical doctor [6].

Duration of exposure in any one 24hr period	16 min	1 h	4 h	8 h
Acceleration magnitude, m/s^2 (frequency-weighted rms acceleration)	2.2	1.6	1.1	0.9

Spectra of the noise and vibration signals must also be considered. The noise signals can be broadband, or recordings of actual vehicle/aircraft noise. In previous vibration experiments, sinusoidal vibration and stochastic vibration (typically between 2 and 16 Hz) have been used. These signals do not represent realistic vibration spectra, which often have dominant spectral components. In addition, previous experiments have used only vertical (z-axis) vibration. While vibration is dominantly in the vertical direction for many vehicle seats, vibration in the horizontal axes (left-right and back-front) and the seat back may also be significant.

4.2 Speech Intelligibility

Helmet-mounted communication systems used in military vehicles are required to provide adequate hearing protection while enhancing speech intelligibility in high levels of background noise. The finding from previous experiments that exposure to combined noise and vibration tends to exacerbate noise-induced TTS suggests that vibration should be considered when testing the speech intelligibility of communication systems. Normal hearing and hearing impaired individuals loss should be used as test subjects, and different types of hearing protection (ANR headsets, headsets combined with earplugs, etc.) should be considered.

4.3 Cognitive Tasks

Reaction time and accuracy have been used to evaluate the effect of noise and vibration on cognitive performance. Since previous studies have shown that exposure to noise tends to decrease both reaction time and response accuracy, while vibration tends to increase reaction time and decrease accuracy (for a particular vibration magnitude), it is of interest to investigate their combined effects. This would involve observing the performance of test subjects who are exposed to each stressor alone, and in combination to study the interactive effects of noise and vibration. For application to military vehicles, performance on vigilance tasks should be tested to investigate the possibility of attention lapses and mental fatigue.

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