

HEARING AND COGNITIVE PERFORMANCE IN LOW-FREQUENCY NOISE

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1. INTRODUCTION

A recent investigation of noise and whole-body vibration exposure in Canadian Forces armoured vehicles found that the noise during high-speed driving is low-frequency dominant [1]. The crewmembers also indicated in their questionnaire responses that they had difficulty communicating inside the vehicle because of the noise. Low-frequency noise (LFN) may present challenges that are different from those associated with broadband noise because 1) it is difficult to attenuate with conventional hearing protectors, 2) low-frequency sounds mask higher frequency sounds, which may impair the ability to understand speech or detect auditory alarms and 3) it has been shown to cause greater annoyance and disruption in concentration than broadband noise, which may affect cognitive performance [2]. It was thus of interest to study hearing and cognitive performance in low frequency noise. In this study, auditory detection, speech intelligibility and cognition (by means of a cognitive test battery) were investigated in the presence of different noise exposures (quiet, pink noise and recorded armoured vehicle noise). The effects of wearing hearing protection (passive and active noise reduction [ANR]) were also examined.

2. MATERIALS AND METHODS

This study was approved by the Human Research Ethics Committee of DRDC Toronto. In total, 36 subjects (18 males and 18 females), aged 18 to 55 years with hearing thresholds no greater than 25 dB HL at 0.5 kHz, 1 kHz, 2 kHz and 4 kHz were chosen for participation. The subjects were divided into three groups of 12, balanced between age and gender. The first group performed the battery of tests in quiet, the second group in pink noise at 80 dBA and the third group in recorded LAV III noise (light-armoured vehicle) at 80 dBA. The subjects were tested under three listening conditions: unoccluded, wearing a passive earmuff (David Clark H10-13XL, ANR off) and wearing an active earmuff (David Clark H10-13XL, ANR on). The spectra of the pink and vehicle noise are shown in Fig. 1.

Auditory detection was measured using a variation of Békésy tracking [3] at six third octave band frequencies from 0.5 kHz to 8 kHz. Speech understanding was evaluated using the Modified Rhyme Test (MRT) of consonant discrimination [4]. The level at which the target

words were presented was adjusted iteratively such that 60% of the words were correctly recognized.

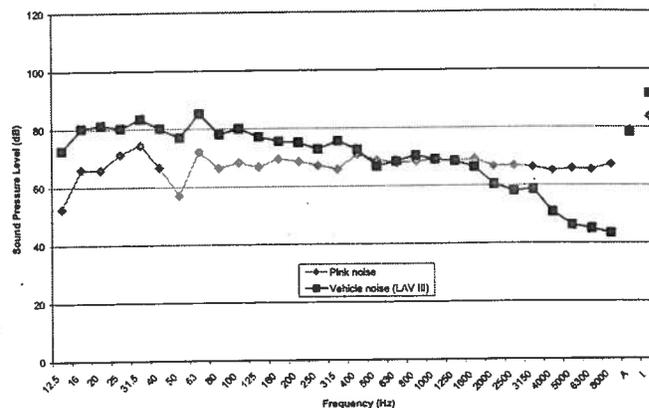


Fig. 1. Spectra of the pink and vehicle (LAV III) background noises.

The cognitive test battery consisted of a subset of tasks that have been used extensively in previous performance studies conducted at DRDC Toronto. The tasks included two subjective questionnaires (relating to mood, motivation and fatigue), a short term memory task, a serial reaction time task, mental addition, detection of repeated numbers and a logical reasoning task. For the questionnaires, subjects responded using a visual analogue scale (VAS) from 1 to 10. Descriptions of the tasks are given in [5].

3. RESULTS

3.1 Detection

The mean detection thresholds in the three backgrounds (quiet, pink noise and vehicle noise) are shown in Fig. 2 for the three ear conditions (unoccluded, ANR off and ANR on). In quiet, mean unoccluded thresholds were less than 20 dB from 0.25 to 2 kHz and 8 kHz. The threshold for 4 kHz was outside the range of the system for all subjects. When the muff was worn with ANR off, significant increases to 36 dB SPL were observed across the frequency region tested. With ANR on, significant increases to 52 dB at 0.25 kHz and 0.5 kHz, and 40 dB at 1 kHz were realized, compared to ANR off ($p < 0.001$). Detection thresholds in pink noise

were fairly consistent at 60 to 70 dB SPL regardless of ear condition or frequency. By comparison, detection thresholds in vehicle noise decreased from 79 dB SPL at 0.25 kHz to 45 dB SPL at 8 kHz. From 0.5-2 kHz, detection thresholds in the pink and vehicle noises, with or without earmuffs worn, were similar at 66 dB SPL.

performance on the cognitive tasks indicates that both pink and vehicle noise interfere with performance on vigilance tasks (serial reaction time, detection of repeated numbers).

4. DISCUSSION

The preliminary results of this study indicate that the use of the ear muff in pink or vehicle noise did not significantly affect signal detection at any frequency, for both the passive and active modes. This finding was consistent with the MRT results. A small, but significant (4 dB) increase in speech level was required for 60% correct understanding in pink noise compared to vehicle noise. This indicated that the vehicle noise had a weaker masking effect on speech. For the cognitive tests, it appears that the presence of noise affects vigilance, but does not affect performance on short-term memory or reasoning tasks.

5. ACKNOWLEDGEMENTS

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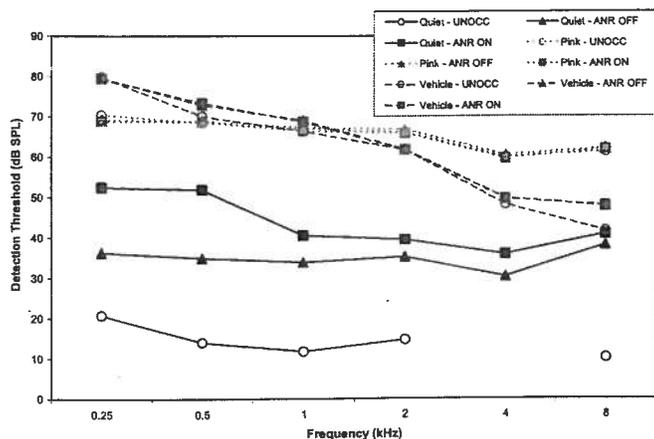


Fig. 2. Detection thresholds in quiet, pink noise and vehicle (LAV III) noise under three ear conditions: unoccluded (UNOCC), muff with ANR off and muff with ANR on.

3.2 Modified Rhyme Test

The mean speech levels required for 60% correct understanding are given in Table 1. An ANOVA applied to these data showed significant effects of group, ear condition and group by ear condition ($p < 0.001$). The required speech levels were significantly higher in both types of noise than in quiet, but there were no differences due to ear condition in the presence of noise (pink or vehicle). The increase in required speech level by 4 dB in pink noise compared to vehicle noise was significant.

Table 1. Speech levels (and standard deviations) required for 60% correct responses on the MRT.

Ear condition	Speech level required for 60% correct (dB SPL)		
	Background noise		
	Quiet	Pink	Vehicle
Unoccluded	41.4 (4.5)	88.8 (3.3)	84.5 (3.0)
ANR off	58.2 (4.7)	87.6 (3.4)	84.4 (2.8)
ANR on	63.6 (3.4)	87.6 (2.5)	84.0 (2.8)

3.3 Cognitive Test Battery

Analysis of the cognitive test battery results is in progress. The subjective questionnaire responses are particularly difficult to interpret because of the wide range of responses given. The preliminary analysis of