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The interactive effect of industrial noise type, level and frequency characteristics on occupational skills

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ABSTRACT

The effects of noise on human health and productivity represent major environmental and occupational issues. This study examined the combined effect of noise type (steady, intermittent and fluctuating), level (75 dB, 85 dB and 95 dB) and frequency (roar and hiss) on speed (time taken to complete the task) and accuracy (time taken correcting errors and error volume) using a Steadiness Test. Ten participants responded once to each of the 18 conditions, plus an additional condition with no noise present. Frequency characteristics significantly impacted performance more than other noise attribute, with hiss noise having the biggest impact in terms of decreasing speed and increasing error time and volume.

1. Introduction

One of the most important goals of industry is to optimise worker productivity and efficiency without compromising health. Worker productivity is a key indicator of overall job performance, with adverse environmental factors and hazards potentially hampering worker productivity (Kahya, 2007; Naravane, 2009). Industrial activities like mechanical processing, machining, and maintenance are high-complexity jobs, needing both a high level of skill and responsibility to successfully perform tasks (Kahya, 2007; Whitfield, 2000). Some industrial jobs are carried out in unpleasant physical conditions such as high heat, humidity or noise, which can have adverse effects on the health, productivity, performance and health of workers (Ismail, 2011). Out of all the environmental factors, the harmful effects of noise on human health, productivity and efficiency pose a growing problem (Broadbent, 1978; Kujala & Brattico, 2009; Naravane, 2009; Whitfield, 2000). Noise can impair alertness and decrease performance and concentration, and have a significant impact on the physical (increasing accident risk; Basrur, 2000) and psychosocial health of workers (Leather, Beale, & Sullivan, 2003; Oreizi, Nuri, & Shushtari, 2007). The effects of noise on task performance are complex (Suter, 1991), with the effect of occupational noise exposure upon performance depending on a number of factors, including the nature of the noise and the type of task involved (Belojevic, Slepcevic, & Jakovljevic, 2001; Broadbent, 1978; Leather et al., 2003).

While noise has little effect on simple tasks, noise levels over 100 dB have been found to be harmful for continuous performance tasks (Badayai, 2012; Suter, 1991). Ehlers' (1972) study evaluated the effect of noise on a circuit board inspection task, concluding that the performance of the inspector is more affected by 90 dB than other noise intensities. Fornwalt's (1965) study on the effect of steady, periodic and intermittent noise on industrial inspection tasks pointed out human errors were not affected by the presence of different noise intensities; higher error rates occurred when workers were exposed to steady and intermittent noise. It has also been shown that frequencies above 2000 Hz reduce performance efficiency to a greater degree than frequencies below 2000 Hz at the same sound pressure level (Bryan & Tolcher, 1976). The effects of noise on visual search in human inspection have been addressed by Taylor, Melloy, Dharwada, Gramopadhye, and Toler (2004), finding a decrease in performance for random and intermittent noise patterns relative to continuous noise sources. The results of Muzammil and Hasan (2004) found that noise intensity and the amount of work experience independently predicted performance during continuous noise.

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They also found that noise intensity, work experience as well as the interaction between noise and work experience were statistically significant for intermittent noise. According to Naravane (2009), there was no significant interaction between three different attributes of noise (noise intensity, noise type and noise source) and they did not affect the speed or response errors for a Steadiness Test. It was found that the speed and error response was mainly affected by the noise source. One conclusion that can be drawn from the research investigating the effects of occupational noise on performance is that sound level, noise type (temporal variability) and frequency are critical characteristics for noise to effect performance (Leather et al., 2003; Mital, Kilbom, & Kumar, 2000; Naravane, 2009).

It is therefore relevant to examine how environmental conditions can influence human performance in order to develop strategies that maintain or improve efficiency while preserving health. The present study aimed to delineate the interactive effect of industrial noise type, level (intensity) and frequency on speed and accuracy using the Steadiness Test. The study seeks to identify the factor, factors or combinations of factors that have the most effect on the speed and accuracy of occupational skills among participants.

2. Materials and methods

2.1. Experimental design

The experiment followed a 3 × 3 × 2 factorial design (as shown in Table 1). The independent variables were three sound levels (75 dB, 85 dB and 95 dB), three noise types (steady, intermittent and fluctuating) and two frequency characteristics ("roar" <2000 Hz and "hiss" >2000 Hz). The treatment combinations were assigned randomly.

The dependent variables were the speed and the errors made by participants, and accuracy. Speed was defined as the length of time in seconds spent doing the test. Error time is the number of times errors occurred as measured by the Hole Type Steadiness Tester. Accuracy was calculated by Eq. (1):

$$\text{Accuracy} = \frac{\text{Total administration} - \text{Error time}}{\text{Total test administration time}} \times 100 \qquad (1)$$

The test site was the Physical-Agents Laboratory in the School of Public Health, Tehran University of Medical Sciences. The experimental test equipment was placed on a table and the participant sat on a chair in front of the equipment. The treatment condition noise characteristics were produced by a computer outside of the test site and transmitted by two speakers that were placed one-metre to the left and right of the participant. Participants performed the Steadiness test while exposed to the noise. In total, 18 tests were completed by participant under each combination of the noise attributes, with an additional test performed when noise generator was off. There was rest period of three minutes between tests.

2.2. Equipment

2.2.1. Sound recorder

Industrial noise sources with the desired sound characteristics were determined using library resources and a manufacturing plant was chosen for the sound recording. The sound was recorded by a B&K PULSE Multi-Analyzer System Type 3560 B/C/D/E version 12. The sound recorder was located at approximately ear height and at the typical distance from the source of workers.

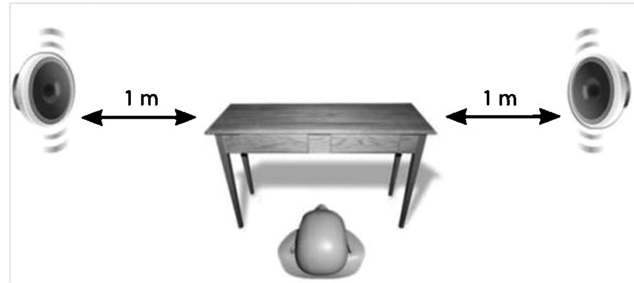

Fig. 1. A schematic of the experimental layout.

2.2.2. Sound level metre

The noise level and frequency analysis of the noise generated for the experiment was assessed by a B&K Sound Level Meter Type 2236.

2.2.3. Noise Production Software

The steady, intermittent and fluctuating noise was produce with the help of Goldwave software version 4.26. Goldwave software enabled the generation and editing of noise to achieve the lengths of steady, intermittent and fluctuating noise at 75 dB, 85 dB and 95 dB.

2.2.4. Stopwatch

Speed was measured using a stopwatch to determine the time spent doing the tests. A signal indicating the start of the task was sent to the stopwatch at the same time as it was sent to the participant, and stopped when the experimental task was completed.

2.2.5. Steadiness tester

Steadiness Test is one of the Occupational Skill Assessment Test Battery. The Steadiness Test is useful for assessing assembly tasks and determining capacity to return to work for injured workers performing steadiness tasks. The Hole Type Steadiness Tester (see Fig. 1) require participants to move a metal-tipped stylus in holes with diminishing diameters, adjusted for varying difficulty, without touching the sides. The holes were progressively reduced in size (Lafayette Instruments, 2009; Naravan, 2009). Participants were measured on the number of errors made, the total time spent on the condition and error time.

2.3. Participants

Ten male students from the Tehran University of Medical Sciences (age 24.51 ± 3.02 years) with normal vision and hearing reporting good general health volunteered to participate. Participants filled out consent forms before completing a questionnaire asking about their personal background and demographic information, smoking, auditory and visual health and confirmation of at least eight hours sleep before the test. Participants received theoretical and practical training in completing the Steadiness Test to review and become familiar with the equipment and test requirements.

3. Results

Figs. 2, 4 and 6 present results using the experimental condition codes described in Table 1.

3.1. Speed response

Fig. 2 presents the mean speed response for the Steadiness Test across the experimental conditions. Speed was highest for the

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