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The Effect of Exposure to High Noise Levels on the Performance and Rate of Error in Manual Activities

Farahnaz Khajenasiri[1], Alireza Zamanian[2], Zahra Zamanian[3]

[1] Ph.D. of Occupational Health, Assistant Professor, Department of Community Medicine, School of Medicine, Tehran University of Medical Sciences, Tehran, Iran
[2] Department of Ergonomics, School of Health, Shiraz University of Medical Sciences, Shiraz, Iran
[3] Ph.D. of Occupational Health, Associate Professor, Department of Ergonomics, School of Health, Shiraz University of Medical Sciences, Shiraz, Iran

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Abstract

Introduction: Sound is among the significant environmental factors for people's health, and it has an important role in both physical and psychological injuries, and it also affects individuals' performance and productivity. The aim of this study was to determine the effect of exposure to high noise levels on the performance and rate of error in manual activities.

Methods: This was an interventional study conducted on 50 students at Shiraz University of Medical Sciences (25 males and 25 females) in which each person was considered as its own control to assess the effect of noise on her or his performance at the sound levels of 70, 90, and 110 dB by using two factors of physical features and the creation of different conditions of sound source as well as applying the Two-Arm coordination Test. The data were analyzed using SPSS version 16. Repeated measurements were used to compare the length of performance as well as the errors measured in the test.

Results: Based on the results, we found a direct and significant association between the levels of sound and the length of performance. Moreover, the participant's performance was significantly different for different sound levels (at 110 dB as opposed to 70 and 90 dB, $p < 0.05$ and $p < 0.001$, respectively).

Conclusion: This study found that a sound level of 110 dB had an important effect on the individuals' performances, i.e., the performances were decreased.

Keywords: activities, coordination test, error, performance, manual, noise

1. Introduction

1.1. Background and study logic

Noise is probably the most common occupational danger, and it also is an environmental danger (1). From the physical perspective, there is no difference between noise and sound. In fact, sound is a sensory perception, and noise is the mental perception of the sound. In other words, noise can be defined as an unwanted sound (2). Noise exists in all human activities, and, considering the effect of noise on human health, it can be classified into two categories, i.e., occupational noise and environmental noise, which include traffic noise, music, and other sources (3). One reason for the large number of complaints about noise in the work environment is that noise is a physical phenomenon that can easily be felt in the work environment (4). Unwanted sound, as one of the most important physical factors in the majority of production units, imposes a great number of problems on industrial workers (5-8). Different studies have shown that 30 million individuals among the American workforce are exposed continually to high levels of noise (9). Being exposed to noise is one of the most common environmental dangers in industrial communities; however, it can have various effects depending on the type of occupation and the work environment (10).

Corresponding author:
Associate Professor Dr. Zahra Zamanian, Department of Ergonomics, School of Health, Shiraz University of Medical Sciences, Shiraz, Iran. Tel: +98.37251009, Fax: +98.37260225, E-mail: zamanianz@sums.ac.ir
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During the day, individuals perform various activities in different places and are exposed to a wide range of environmental noises. In fact, exposure to noise is not restricted to the work environment and may occur during free time activities, transportation, and shopping (11). To date, a great number of studies have confirmed the effect of noise on the auditory system. Regarding numerous studies, reduction in hearing ability and noise also affects the workers' cardiovascular system and leads to hypertension, headache, fatigue, nervousness, and anger (5, 6). Moreover, due to the higher noise levels in the workshops, the increase in human errors results in the increase in work-related accidents and finally leads to a decrease in productivity (5, 8). Overall, the effect of noise on mental health as well as efficiency has been proven and supported by industrial epidemiological evidence (12). Of course, there also is strong evidence regarding auditory irritation, which is defined as the feeling of indignation, dissatisfaction, and unhappiness that occurs as the result of disorders in one's thoughts, feelings, and daily activities (13-15). Although people get used to noise and can adapt to high noise environments, noise causes fatigue and decreases the individuals' working capacity in intellectual as well as physical occupations (16).Various studies have shown the serious effect of noise pollution on the staff's performance and productivity (17). Furthermore, daily developments in industries and technologies lead to an increase in the problems related to noise pollution, and noise, as one of the major environmental stressors, can have significant effects on people and the environment. In general, one of the major goals of all occupations is to achieve the maximum profit and to increase the staff's efficiency and productivity; however, environmental conditions can disturb productivity to a great extent (17, 20). To date, many laboratory and field studies have investigated the effect of noise on performance and have shown that, when hearing signals are necessary in performing a task, the intensity of the noise that prevents understanding the signals highly affects performance. An unfamiliar, intense noise can lead to agitation and interference in doing tasks, as well (18, 20). In general, some accidents can be considered as an indicator of the effect of noise on performance. Several studies have shown that high noise levels can result in more errors and, consequently, increase the possibility of accidents. This is quite important, particularly in mental activities, which require the working memory, including paying attention to several phenomena in complex systems (19-21). Based on what was mentioned above, noise is one of the environmental factors that highly affects individuals' performances, and its effect can be assessed in individuals who are exposed to noise in their work environment. Moreover, performance is one of the most sensitive parameters related to the effect of noise, and it causes physical as well as psychological damage to the individuals and affects their productivity. Therefore, since no similar studies have been conducted on this issue in Iran, the aim of this study was to assess the effect of noise on performance. The findings of this study can provide the basis for improving the conditions in workshops, factories, and educational environments and, as a result, prevent the occurrence of dissatisfaction and the problems mentioned above.

1.2. Objectives

The general objective of this study was to determine the effect of exposure to noise on healthy students at the sound levels of 70, 90, and 110 dB. The specific objectives were: 1) to determine the effect of sound levels on individual performance, 2) to determine the performance mean time based on the capability of manual tools at three sound levels, i.e., 70, 90 and 110 dB.

2. Material and Methods

2.1. Research design and sampling

This aim of interventional study was to determine the effect of exposure to noise on 50 students (25 males and 25 females) at Shiraz University of Medical Sciences, as a sample of a healthy Iranian community in 2014. Due to the reduction in different personal or the physiological characteristics caused through selecting independent samples as the study population (intervention and control group), each case was considered as its own control group. All participants were subjected to sound levels of 70, 90, and 110 dB using one and multiple speakers. The sample size was calculated as 50 with an alpha value of 0.05 and a power of 80%. Since this an exploratory study (20) and considering similar studies as well as the statistical criteria, the selected sample size was confirmed by the study's statistical adviser (21, 22).

2.2. Measurement tools

An interview-administered questionnaire (GHQ-28 Goldberg) was used to collect information on the participants' general health. The questioner addressed four areas, i.e., physical complications, anxiety and insomnia, unusual social performance, and stress. A hand tool dexterity test was used to assess the individuals' capabilities in using tools. The lengths of time spent using the tools also were measured using a timer.

2.3. Data collection

Quantitative data were obtained from this study, and performance was assessed by measuring the length of time required to do the Two-Arm coordination test (22). In doing so, three loud speakers (multiple sources) were placed at both sides and behind the subjects at distances of 1.5 m (23). In each condition, a noise intensity of a fixed level was created through the Gold Wave software (21), and, after being exposed to the noise for 5 minutes, the individual's performance was assessed through the test (20). Image 1 shows the Two-Arm coordination test and a study subject. In this laboratory study, different noise intensities and numbers of speakers were used through the factorial design based on the 3×2 matrix (6 cells) and the individuals' doing the test in each cell. Due to the within-subject design of the present study, in which the subjects have to take part in all the conditions of the matrix, the neutralization process was used in order to eliminate the transition and sequence effects. In doing so, different conditions were presented to the study participants in various sequences, and each of the 6 conditions were selected randomly through satiation. After data collection, the normal distribution of the variables was determined, and the data were entered into the SPSS Software. Then, repeated measurement test was used to compare the length of performance as well as the errors measured in the test.

2.4. Inclusion criteria and ethics

We interviewed all participants who were healthy, particularly regarding their auditory and visual systems. An informed consent was obtained from all participants before the interviews were started. Ethical approval was given by the Research Ethical Comity of Shiraz University of Medical Sciences.

2.5. Statistical analysis

The data were analyzed using SPSS version 16 (SPSS, Inc., Chicago, Illinois, USA). The main study variables included both quantitative (age, work history, rate of performance) and qualitative (marriage statues, job, education) measures. Repeated measures strategy and ANOVA were used to compare both the length of performance and the rate of errors of the participants.

3. Results

This study was conducted on 50 students at Shiraz University of Medical Sciences, Shiraz, Iran. The demographic characteristics of the participants are shown in Table 1. Accordingly, the average of students was 22 ± 4.4 years of age being in healthy statuses. With respect to the questioner, all participants were in good mental health. Table 1 depicts the length as well as the error rate of the test. The findings of the study indicated that there was no significant difference between the two genders as well as different conditions of creating sound pressures regarding the length of performance ($p > 0.05$). Moreover, although the mean length of performance increased with the increase in the noise intensity at the sound levels of 70 and 90 dB, no significant difference was found between the lengths of performance at these two sound levels ($p > 0.05$). Nevertheless, a significant difference was observed between the sound level of 110 dB and sound levels of 70 and 90 dB regarding the length of performance ($p < 0.05$ and $p < 0.001$, respectively). The findings of this study also showed that, as the noise intensity increased, the rate of errors also increased. According to the results, a significant difference was observed between the error rate measured at the sound level of 110 dB and those measured at the sound levels of 70 and 90 dB. However, no significant difference was found between the error rates measured at the sound levels of 70 and 90 dB ($p > 0.05$). Moreover, male and female subjects were significantly different regarding the measured errors ($p < 0.05$). In addition, the measured times and errors in different cases of sound levels are shown in Table 2.

Table 1. Effect of noise on people and the amount of evidence available for each effect (3)

Health effect	Evidence	Permissible exposure limits (dB)
Efficiency	Limited	
Biochemical effects	Limited	
Immunological effects	Limited	
Birth weight	Limited	
Irritation	Sufficient	More than 55 in offices and more than 85 in industries
Hypertension	Sufficient	55-116
Hearing loss (adults)	Sufficient	75
Hearing loss (fetus)	Sufficient	More than 85

Table 2. Measured time and error in test coordination of both hands

Different case of Sound pressure		Gender	Time of test (second) [mean (SD)]	Test error [mean (SD)]
Test at 70 dB	One speaker	Female	53.66(26.42)	0.16 (0.47)
		Male	61.85 (26.00)	0.20 (0.81)
	Multiple speakers	Female	52.10 (21.91)	0.16 (0.47)
		Male	56.23 (22.27)	0.08 (0.27)
Test at 90 dB	One speaker	Female	57.26 (28.61)	0.40 (0.91)
		Male	58.07 (20.87)	0.20 (0.50)
	Multiple speakers	Female	53.05 (26.44)	0.68 (1.14)
		Male	61.25 (24.55)	0.16 (0.47)
Test at 110 dB	One speaker	Female	53.09 (24.52)	0.64 (1.35)
		Male	66.58 (23.37)	0.28 (0.61)
	Multiple speakers	Female	55.73 (27.20)	1.40 (1. 89)
		Male	69.48 (24.55)	0.72 (1.27)

4. Discussion

This was an interventional study that examined the relationship between a wide range of factors, including physical features (noise level, frequency, and time), non-physical features (information content, prediction, and control, the condition of noise source), and individual characteristics with the individuals' reactions to noise (24). In this study, physical features (sound levels of 70, 90, and 110 dB) and conditions of creating the sound pressure (one and multiple speakers) were taken into account, and, as the noise intensity increased, the length of performance also increased. Decreases were found in performing both mental and manual activities. Additionally, a direct and significant association between the error rate and the noise intensity was found. Accordingly, as the noise intensity increased, the performance decreased, and, at the same time, a considerable increase was observed in the individuals' rates of error. This was consistent with the results of the study conducted by Smith, which showed that, at first, noise can have a positive effect on performance; however, as time goes by, it weakens performance (25). In our study, by increasing the sound pressure to 90 dB, the performance decreased with a mild slope, which was different from Smith's study. This difference was due to the fact that the current research was conducted in the laboratory and included no interventions. The results also showed that, by increasing the sound level to 110 dB, the performance decreased with a sharp slope, and significant increases were observed in the individuals' rates of error. These increases occurred because the individuals attempted to do the test quickly so they could get relief from the pressure resulting from being exposed to high level noise. In this study, no significant relationship was observed between the conditions of creating the sound levels and doing manual activities, which was in line with the study conducted by Taylor (2004), which showed no difference between one and multiple sources of creating sound levels in doing easy or hard visual activities (26). Overall, in line with the study conducted by Muzammil in 2002, the findings of our study confirmed the effect of noise on performance (27). If the safety issues are not observed in industrial factories and workshops where the workers are exposed to noise generated by the equipment, performance and productivity will decrease significantly. Moreover, the individuals will be prone to committing errors in such environments, which can be highly dangerous for all the personnel working in that unit.

5. Conclusions

In this study, we found that a sound level of 110 dB was an important contributor to individuals' performances, i.e., the individuals' performances were decreased. However, sound levels of 70 and 90 dB had no significant association with the both error rate and the length of performance. Accordingly, it is recommended that such study should be conducted on different noise levels.

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Conflict of Interest:

There is no conflict of interest to be declared.

Authors' contributions:
All authors contributed to this project and article equally. All authors read and approved the final manuscript.

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