［Original］

Relationship Between Noise Annoyance and Cognitive Performance in Automotive Workers Exposed to Chronic Noise

Iraj ALIMOHAMMADI[1], Fakhradin Ahmadi KANRASH[1*], Jamileh ABOLGHASEMI[2,3], Shahram VOSOUGHI[1], kazem RAHMANI[3] and Mohammad Hossein CHALAK[1]

[1] *Department of Occupational Health Engineering, School of Public Health, Iran University of Medical Sciences. Shahid Hemmat Highway, Tehran, 1449614535, Iran*
[2] *Department of Biostatistics, School of Public Health, Iran University of Medical Sciences. Shahid Hemmat Highway, Tehran, 1449614535, Iran*
[3] *Department of Epidemiology, School of Public Health, Iran University of Medical Sciences. Shahid Hemmat Highway, Tehran,1449614535, Iran*

Abstract **:** Among the most important complaints of people exposed to noise are the feelings of resentment and annoyance, and the changes in mental conditions, which are among the main psychological consequences affecting the concentration and accuracy of workers. This study was designed to investigate the relationship between annoyance and cognitive performance of workers exposed to chronic noise. This is a descriptive-analytical study conducted on workers in an automotive company. Three hundred workers exposed to noise were entered into the study in two groups: administrative (150 people) and industrial (150 people). The Tower of London and the Stroop computerized psychological tests were used to determine the cognitive status of the workers, and a questionnaire with numbered questions (numbered 1 to 11) was used in order to determine their level of annoyance. There was a significant correlation between the workers' cognitive performance and annoyance levels (P value <0.001). Linear regression results showed that cognitive performance had a significant relationship with the received sound intensity, while the workers' annoyance had a significant relationship with cognitive performance only in the number of wrong answers, the number of unanswered questions, and the number of correct answers in the Stroop test (P value <0.001). The researchers concluded that exposure to chronic noise in work environments could bring about occupational annoyance, and consequently, cognitive disorders, which could increase the risk of errors. More studies are needed to further explore this relationship.

Keywords **:** psychological tests, cognition, noise, ergonomics, Stroop test.

（Received May 21, 2019, accepted October 29, 2019）

Introduction

Noise, an unwanted and unpleasant phenomenon, causes physical and mental harm to humans. The most important adverse effects of noise on humans include hearing loss, visual impairment, disturbance of body balance, neuropsychiatric disorders, cognitive dysfunction, vocal disturbance, and sleep disorders [1−4]. Noise exposure is considered to be an important occupational safety and health problem in many industrial

*Corresponding Author: Fakhradin Ahmadi KANRASH, MSc Student, Department of Occupational Health Engineering, School of Public Health, Iran University of Medical Sciences. Shahid Hemmat Highway, Tehran, 1449614535, Iran. Tel:+989361043475, Fax: +982186704746, E-mail: F_ahmadi1367@yahoo.com

complexes in the world [5]. In this regard, the World Health Organization (WHO) considers accidents to be one of the indicators of noise-induced dysfunction, and has introduced environmental noise as a direct cause of mental disorders [6, 7]. Sensitivity to noise may differ from person to person, and fear of sound, which is associated with annoyance can reduce the quality of life in terms of physical health [8].

One of the most important complaints of people exposed to noise is a feeling of resentment and annoyance, which is the main psychological consequence of chronic exposure to noise. The resentment and annoyance describe all the unpleasant and negative emotions experienced by individuals in response to negative perceptions of the environment [9]. When noise is perceived as an obstacle to the continuation of an activity, some reactions arise that indicate the people's reluctance to be in such conditions. This unpleasant feeling that may be associated with other feelings such as fear, anger, and reduced accuracy and concentration depends on multiple acoustic and non-acoustic factors. Sound intensity, sound source, and the time of exposure to sound are acoustic factors, and the degree of noise interference with activity, the ability to cope with sound, expectations, the degree of sound sensitivity, and the fear of the source of sound as well as cognitive factors are classified as non-acoustic factors [9]. According to the WHO's findings, noise-induced annoyance has harmful and unpleasant effects on health-related quality of life [10, 11]. In addition, the rate of annoyance and cognitive disorders caused by exposure to noise is higher in older people than in younger one [12, 13]. Noise-induced annoyance also has a reciprocal effect on mental distress and sleep disorders [14].

Studies on noise-induced annoyance have shown a relationship between the feeling of annoyance and sound level; however, the role of other sound features, such as frequency of cognitive disorders, is also of importance [15]. It has been reported that sound level has a dose-response relationship with the degree of annoyance [16]. Low-frequency sounds that have high penetration and are difficult to control cause more distress and annoyance than high-frequency ones. Personal differences also affect the response to noise [17]. People who are more sensitive to sound pay more attention to it, differentiate between sounds, and find them more uncontrollable and annoying. Hence, they show more severe reactions to sound compared to less sensitive people. They also become less accurate and spend more time on their activities than the standard amount of time. This can have an adverse impact of their productivity [18, 19]. The feeling of annoyance and cognitive disorders are among the most common outcomes of chronic exposure to noise, and problems with verbal communications, reduced ability, reduced concentration, and loss of performance are some of the consequences of exposure to noisy environments which can directly contribute to the occurrence of errors and accidents [20]. Hence, the feeling of annoyance and cognitive disorders caused by sound should not be neglected, but they should be considered as warning signs of serious risks to human health. Accordingly, it can be concluded that the effects of noise on individuals' cognitive performance and causing them annoyance may have adverse impacts on the health of workers and an organization's productivity. The fear of sound and negative attitudes towards loud noises in the workplace can also affect individuals' cognitive performance so that they might not have the precision and concentration necessary to do their work, may not be able to perform their tasks in the allotted time, and errors in doing their job might even increase. We decided to carry out a study on the relationship between annoyance and cognitive performance of workers exposed to chronic noise in the automotive industry, since there are few such studies.

Materials and Methods

Participants and study design

This is a descriptive-analytical study that examined the relationship between annoyance and cognitive performance in automotive workers exposed to chronic noise. To determine cognitive status and annoyance, computerized psychological tests and a questionnaire containing questions numbered from 1 to 11 were used, respectively. Each number on the questionnaire was a determinant of the level of noise-induced annoyance [21]. Having measured the sound pressure level based on the ISO 9612: 2009 standard using the Testo device (model CEL-815, Testo SE & Co. KGaA, Lenzkirch, Germany) in the administrative and industrial sections,

and measuring the 8-hour sound pressure level using the National Institute for Occupational Safety and Health (NIOSH) standard, we randomly selected 350 people based on statistical calculations and a review of the inclusion criteria, including the lack of underlying diseases such as heart, pulmonary and kidney diseases, as well as metabolic and psychiatric disorders. Individuals who were using Personal Protective Equipment during the study were excluded as well.

The subjects were divided into two groups of administrative (150 people) and industrial (150) workers once their informed consent was given in written form. This study has a code of ethics (IR.IUMS.REC 1395.9411139003) from the Ethics Committee of Iran University of Medical Sciences and the Occupational Health Department, received on April 5, 2017.

In the administrative group, the individuals chronically exposed to a sound pressure level of 38 to 46 dB were considered as the control group (non-exposed group), and the 150 subjects chronically exposed to a sound pressure level of 82 to 88 dB were selected as the case group (exposure group). Thus, the number of the subjects was the same in the two groups. The two groups were examined in the administrative and work environments, with and without exposure to noise. Two computerized psychological tests, the Stroop test and the Tower of London (TOL) test were used [22, 23]. The reason for using these two tests was their proper validity and reliability in different studies, as well as their role in examining visual acuity and attention and mental flexibility.

Computerized Stroop test

The Stroop test is used to examine issues such as selective attention and cognitive flexibility, and it has been used in other studies to examine cognitive aspects [22]. The test was done in two stages, the first of which was color selection. The aim of this stage was to acquaint the subjects with the position of colors on a computer keyboard, and it did not affect the results. In the second stage, 96 words were used, 48 of which were congruent (the word and color were the same) and 48 were incongruent (the word and color were different). The words were displayed randomly and sequentially. The aim of this stage was to measure mental flexibility, interference and inhibition [24]. The validity of this test was 0.83 in previous studies [24] (Fig. 1).

Tower of London test

The Tower of London test was first designed by Shallice in 1982 to measure executive performance, particularly to identify malfunctioning in planning and disorders in the problem-solving ability of patients with frontal lobe injuries [25]. In the main form of the test, there are two boards, each with three bars of different lengths, and there are three beads on the bars. The subject should move the beads on the work space

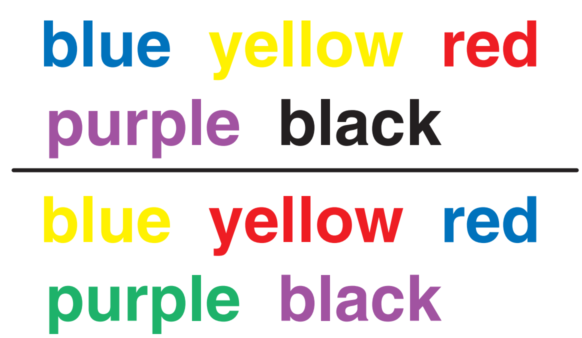

Fig. 1. Stroop test

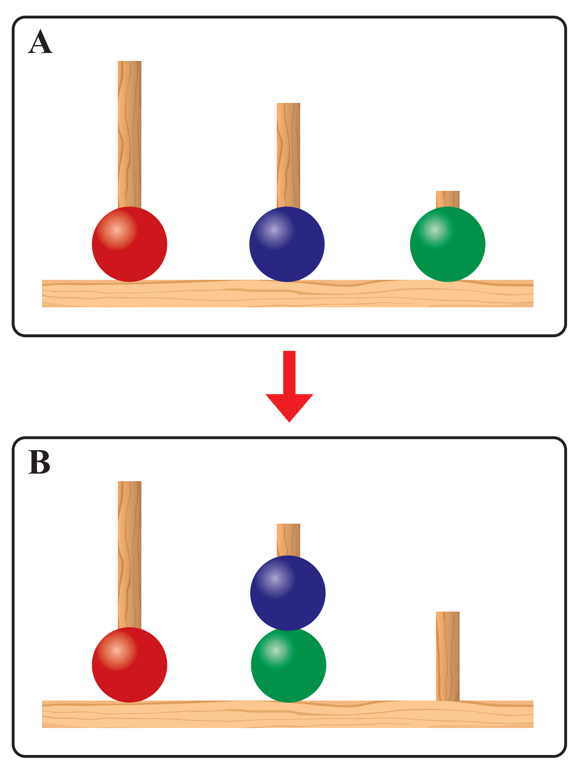

Fig. 2. Tower of London test

board (experiment) so that it becomes the same as a predefined pattern. This test consists of 12 problems, each being repeated 3 times in the case of non-response by a subject. According to Shallice, the ability to solve a problem is determined by the number of additional movements (errors) of the subject in comparison with the minimum number of movements necessary to do the model. In other words, the higher the number of additional movements by the subject, the lower his/her ability to solve the problem will be [23]. All the participants successfully did three experimental puzzles before doing the actual experimental test. The variables studied in this test included total time, response time, test time, test delay, error, and response interference. According to previous studies, its test reliability is 0.79% [26] (Fig. 2).

Data analysis

To analyze the data in this study, the variables were first examined using descriptive methods (frequency distribution tables as well as mean and standard deviation descriptive indicators). Using the Kolmogorov-Smirnov test, we verified and confirmed the normality of the data. The Pearson correlation coefficient, independent t-test, and multivariate linear regression model were also used, and the data were analyzed using Stata software (Version 12, Stata Corp LP, Texas). We used the multivariate linear regression model to investigate the relationship between annoyance and mental performance of the workers. In that model, the mental performance indicators in the Stroop and TOL tests were considered as independent variables, and the degree of annoyance and sound pressure level (in an individual model) were considered as dependent variables. Collinearity of the variables was also examined through the software, and the variables lacking collinearity were entered into the final model. All the tests were carried out with an error rate of 0.05.

Results

In the present study, the mean ages of the subjects in the exposed and non-exposed groups were 36.1 ± 3.64 and 36.19 ± 3.71 years, respectively. There was no significant difference between ages in the two groups (*P* value = 0.79). The mean work experience of the individuals in the exposure and non-exposure groups was 14.99 and 14.94 years, respectively. The little difference between the mean work experience of the two groups did not affect the results (*P* Value = 0.84). Regarding educational levels of the two groups, most of the subjects had a high school diploma (135 individuals (45%)), and there was a significant relationship between the two groups in terms of education levels. Most of the subjects in the two groups of exposure (140 people (93.3%)) and non-exposure (133 (88.7%)) were married, and no significant difference was found. Table 1 shows the demographic data of the subjects in terms of exposure and non-exposure to noise.

Table 2 shows the results of the Pearson correlation test used to examine the relationship between cognitive performance and annoyance. Although the mean score of annoyance was 5.41 ± 3.55, there was a significant relationship between annoyance and all cognitive performance indicators. There was also an inverse relationship between the total score on the TOL test and the number of correct responses in the congruent and incongruent Stroop test (Table 2).

The results of comparing the mean cognitive performance indicators in terms of exposure to noise are shown in Table 3. The mean of all the cognitive performance indicators in the exposure and non-exposure groups were significantly different (Table 3). The results of studying the simultaneous effects of sound and noise annoyance on the cognitive performance indicators using the linear regression model are shown in Table 4. All the cognitive indicators had a significant relationship with exposure to noise (adjusted for demographic variables), but in all the cognitive indicators (except for the number of errors in the congruent, and in the incongruent Stroop, non-responses in the incongruent Stroop, and the number of correct responses in the incongruent Stroop), annoyance did not have a significant relationship with cognitive performance (Table 4).

Discussion

This study, which aimed at investigating the relationship between annoyance and cognitive performance of automotive workers exposed to chronic noise, referred to the key role of noise on mental activities and the psychological damage and annoyance caused by noise.

Table 1. Comparison of demographic and background variables in terms of exposure to noise in selected workers

Variable		Noise		Total Mean ± SD	t	*P* value
		Exposure Mean ± SD	No exposure Mean ± SD			
Age (years)		36.1 ± 3.64	36.19 ± 3.71	36.14 ± 3.68	0.267	0.79
Experience (years)		14.99 ± 2.04	14.94 ± 2.06	14.96 ± 2.02	0.197	0.84
		Number (%)	Number (%)	Total Number (%)	X^2	*P* value
Education	High School Diploma	113 (75.3%)	22 (14.7%)	135 (45%)	123.11	<0.001*
	Associate degree	31 (20.7%)	60 (40%)	91 (30.33%)		
	Bachelor's degree or more	6 (4%)	68 (45.3%)	74 (24.67%)		
Marriage status	Single	10 (6.7%)	17(11.3%)	27 (9%)	1.99	0.11
	Married	140 (93.3%)	133(88.7%)	273 (91%)		

*: significant at the level <0.01

Table 2. Comparison of cognitive performance and annoyance indicators based on Pearson correlation coefficient

Cognitive test	Cognitive performance indicators	Mean ± SD	Pearson Correlation	*P* value
TOL	Test time (sec)	115.95 ± 87.86	0.540	< 0.001
	Test delay (sec)	49.27 ± 30.92	0.560	< 0.001
	Total time (sec)	165.22 ± 109.33	0.592	< 0.001
	Mean number of errors	4.96 ± 2.68	0.497	< 0.001
	Test score	29.59 ± 3.76	−0.639	< 0.001
Stroop Congruent	Test time (sec)	51.02 ± 10.17	0.581	< 0.001
	Mean number of errors	6.32 ± 2.47	0.266	< 0.001
	Mean non-response	0.96 ± 0.71	0.659	< 0.001
	Mean number of correct responses	40.72 ± 2.72	−0.413	< 0.001
	Response time (ms)	1055.96 ± 189.3	0.862	< 0.001
Stroop Incongruent	Test time (sec)	59.04 ± 9.18	0.735	< 0.001
	Mean number of errors	7.71 ± 3.06	0.448	< 0.001
	Median non-response	2 ± 0.71	0.684	< 0.001
	Mean number of correct responses	38.29 ± 3.44	−0.540	< 0.001
	Response time (ms)	1174.99 ± 253.5	0.889	< 0.001
	Mean interference score	3.19 ± 2.14	0.302	< 0.001
	Interference time (sec)	119.03 ± 95.49	0.651	< 0.001

ms: millisecond, TOL: Tower of London

Although brain activities and mental function in job environments are influenced by environmental factors such as light, sound and temperature, few studies have been done on the role and effect of noise annoyance on mental function and sustained attention in job environments [27, 28]. High sensitivity to sound as well as noise annoyance can cause psychological problems and neurological disorders. In fact, people who have low sensitivity to sound have a lower degree of discomfort and annoyance than those sensitive to sound, and they are more concentrated and accurate in doing their job [29]. Cognitive indicators such as the number of errors and the response time showed a positive relationship with annoyance score in the individuals with higher

Table 3. Comparison of cognitive indicators and noise based on independent t-test

Cognitive test	Cognitive performance indicators	Noise		*P* value	t
		Exposure Mean ± SD	No exposure Mean ± SD		
TOL	Test time (sec)	169.88 ± 97.06	62.01 ± 14.73	<0.001*	13.45
	Test delay (sec)	68.57 ± 31.64	29.96 ± 12.9	<0.001*	13.83
	Total time (sec)	238.45 ± 111.53	91.98 ± 27.35	<0.001*	15.62
	Mean number of errors	6	3	<0.001*	10.18
	Test score	29.59 ± 3.76	32.12 ± 2.02	<0.001*	15.68
Stroop Congruent	Test time (sec)	57.47 ± 7.52	44.56 ± 8.19	<0.001*	14.21
	Mean number of errors	7	5	<0.001*	6.30
	Mean non-response	1.46 ± 0.5	0.46 ± 0.5	<0.001*	17.31
	Mean number of correct responses	42	39	<0.001*	−9.82
	Response time (ms)	1236.04 ± 75.30	875.87 ± 30.59	<0.001*	54.27
Stroop Incongruent	Test time (sec)	66.46 ± 5.45	51.62 ± 5.34	<0.001*	23.78
	Mean number of errors	9	6	<0.001*	11.42
	Median non-response	2.5 ± 0.5	1.5 ± 0.5	<0.001*	17.26
	Mean number of correct responses	36	41	<0.001*	−14.25
	Response time (ms)	1422.127 ± 66.61	927.84 ± 39.82	<0.01*	77.99
	Mean interference score	3	2	<0.001*	6.55
	Interference time (sec)	186.08 ± 3.94	51.97 ± 14.74	<0.001*	17.08

*: significant at the level <0.01, ms: millisecond

Table 4. Results of regression between annoyance and cognitive performance in exposure to noise (Adjusted for demographic variable)

Cognitive test	Cognitive performance indicators	Annoyance score		Noise (dB)	
		β (SD)	*P* value	β (SD)	*P* value
TOL	Test time (sec)	−3.01 (2.75)	0.274	−127.31 (19.48)	< 0.001**
	Test delay (sec)	−0.51 (0.96)	0.596	−41.89 (6.79)	< 0.001**
	Total time (sec)	−3.52 (3.21)	0.275	−169.21 (22.79)	< 0.001**
	Mean number of errors	0.07 (0.09)	0.431	−2.25 (0.65)	< 0.001**
	Test score	−1.60 (0.11)	0.149	4.02 (0.78)	< 0.001**
Stroop Congruent	Test time (sec)	0.02 (0.31)	0.938	−12.75 (2.21)	< 0.001**
	Mean number of errors	−0.18 (0.09)	0.04*	−2.9 (0.65)	< 0.001**
	Mean non-response	0.02 (0.02)	0.410	−0.89 (0.14)	< 0.001**
	Mean number of correct responses	0.17 (0.09)	0.067	3.79 (0.66)	< 0.001**
	Response time (ms)	−1.97 (2.27)	0.387	−372.92 (16.14)	< 0.001**
Stroop Incongruent	Test time (sec)	−0.05 (0.21)	0.831	−15.12 (1.52)	< 0.001**
	Mean number of errors	−0.28 (0.1)	0.006**	−5.18 (0.71)	< 0.001**
	Median non-response	0.05 (0.02)	0.02*	−0.7 (0.14)	< 0.001**
	Mean number of correct responses	0.22 (0.1)	0.026*	5.88 (0.74)	< 0.001**
	Response time (ms)	−0.37 (2.18)	0.866	−496.65 (15.44)	< 0.001**
	Mean interference score	−0.08 (0.08)	0.340	−2.01 (0.56)	< 0.001**
	Interference time (sec)	1.61 (2.69)	0.552	−123.73 (19.11)	< 0.001**

*: significant at the level <0.05, **: significant at the level <0.01, ms: millisecond

sound annoyance. Studying the personal qualities of the subjects with noise annoyance indicated that they had lower intellectual ability and social skills, and were more likely to protect their privacy compared to those less exposed to noise. Such people were also more sensitive to their surroundings and considered their environment as a stimulus that causes early fatigue, lower accuracy, and increased errors in doing work [30].

In the present study, people with noise annoyance were highly sensitive to the work environment and were also less accurate, which was in line with the results of other studies. Noise annoyance causes a series of psychological disorders in people so that those who have fear and high sensitivity to sound will suffer from sleep disorders, depression and reduced efficiency in doing their jobs. Ultimately, their accuracy in doing their tasks will decrease and they will be more influenced by environmental stimuli [31]. This is consistent with the results of the present study in terms of the increased response time and the large number of errors in the TOL test. Studies have shown that exposure to noise is associated with increasing speed and action of cognitive performance, like what was seen in the test results in this study, and there is a strong dose-response relationship between exposure to noise and cognitive indicators and noise annoyance. The effects of exposure to chronic noise in work environments is associated with increased speed and action of cognitive performance, reduced concentration, and increased errors in the work environment. It also leads to noise annoyance, as emphasized by various studies [32–35].

Physical factors in the work environment, such as exposure to noise, are potentially important in controlling brain activity and cognitive actions that are influenced by psychomotor functions and affect sound sensitivity and concentration [36–38]. As in the transactional model where threatening events and controlling external stressors are related to the mental stress experienced by the external environment, the workers' cognitive performance in this study was related to external stressful events (exposure to noise) [39]. The role of concentration in relation to the individual's response time could be mentioned as one of the most important factors in this study. That is to say, exposure to noise would interfere with concentration through physiological responses to mental actions in the body and lead to a significant increase in the response time and the correct response to the components tested in the Stroop test.

Regarding the congruent indicators of the Stroop test, due to the use of uniform patterns for the subjects, their concentration changed more in exposure to noise compared to the case of incongruent patterns, and this reveals the important effect of concentration on the response time in two different patterns. Few studies, however, have been conducted on the relationship between occupational annoyance and cognitive factors.

In this study, a relationship between the workers' annoyance in the workplace in the exposure and non-exposure groups with different cognitive performances was well documented [40–42]. Cognitive dysfunction (reaction time, attention, etc.) was more frequent in the high sound pressure level compared to the low one. In fact, sound is introduced as a stressor that plays a fundamental role in concentration, attention, accuracy, hypertension, etc., and has a variety of effects in frequency bandwidth so that the effects of exposure to high sound pressure levels can cause annoyance as well as disorders in the individual's cognitive performance and activities [15, 43].

Although the effects on cognitive performance and annoyance of exposure to noise with different sound pressure levels were not examined, in general, the results of this study are consistent with those of other studies on the relationship between noise exposure and cognitive performance and annoyance. According to the results, increased exposure to noise would increase the extent of annoyance. There was such a relationship between cognitive performance and exposure to noise, and the interactive effects of exposure to noise and annoyance would cause physiological responses such as stress in the individuals, which was associated with reduced concentration and increased systematic errors [11].

Annoyance, as a measurable mental response, is considered as one of the important and negative effects of noise on mental health and is associated with such issues as distress, resentment, grief, despair, and unpleasant feelings. It is considered as a psychological stress, too. According to the findings of the WHO, noise-induced annoyance has adverse effects on the quality of life of individuals, and also has reciprocal

effects on mental distress and sleep disorders of workers [6, 44, 45]. In some cases, annoyance is related to the individuals' mental performance, and according to the proposed model, it has a potential effect on the cognitive performance of workers exposed to noise. It has been shown that workers' annoyance is accompanied by increased errors at work, which is of great importance when concentration and accuracy come up [43]. A study by Alimohammadi *et al* also showed a relationship between cognitive performances at exposure to high- and low-frequency sounds, so that improving the functional speed of workers exposed to high-frequency sounds increased their total responce time and their reactions, and also changed their cognitive performance [43]. In our study, the individuals exposed to noise had a higher mean response time compared to the non-exposed ones, and they also had a high percentage of incorrect responses, indicating the effects of sound on the individuals' mental actions and cognitive performance.

Researchers have reported numerous, various and even contradictory factors that affect cognitive performance. The features of the sound exposed to and the work hardship are among the factors that affect cognitive and psychomotor performance, so that in exposure to sound, psychomotor activities are less affected than cognitive processes, and sound plays a key role in such situations [43]. It has been reported that sound and other environmental factors reduce psychomotor work functions that have the highest cognitive levels [46].

This study indicated that in some cognitive tests, such as TOL, cognitive activities were reduced, which is in line with most studies in this field. It in fact represents the effect of sound on reducing the workers' cognitive performance. But in other cognitive tests, cognitive activities of the workers exposed to noise had a significant increase compared to the non-exposed subjects, and this indicated that the central information processing of the participants in this study was not much affected by exposure to noise and the annoyance caused by it. Teichner *et al* showed that exposure to high-frequency sounds (higher than 100 dB) could increase occupational errors [47]. In our study, although this relationship was not measured at different frequencies, exposure to chronic noise in the work environment (which generally had a combination of high and low frequencies) increased the number of errors and mistakes that resulted from increased psychomotor activities, and such errors are enormously important in occupations like firefighting and driving. We conclude that exposure to chronic noise in work environments is associated with occupational annoyance and, consequently, cognitive actions that would increase the risk of errors.

Limitation

One limitation of this study was the lack of examining the relationship between annoyance and mental performance in female workers, which needs to be considered in future studies. The lack of follow up of the subjects to investigate their mental changes and the resulting noise annoyance at different times was another limitation of the present study.

Conclusion

Higher influenceability of the individuals' cognitive performance from exposure to noise compared to annoyance is one of the issues that can be considered as a key role of sound in changing the speed of workers' mental and brain actions towards annoyance. It was also well documented that chronic exposure to noise in work environments increases the speed of cognitive performance and mental processes in individuals. Further studies are needed to find out the confounding and interactive effects of annoyance on the cognitive performance of workers exposed to chronic noise.

Acknowledgement

The researchers are grateful to the Vice Chancellor for Research of Iran University of Medical Sciences and the car manufacturing factory of Tehran for their help to carry out this study.

Conflict of Interest

This research was financially supported by Iran University of Medical Sciences.

The authors have no potential conflict of interest pertaining to this journal submission.

References

1. Freitas E, Mendonça C, Santos JA, Murteira C & Ferreira JP (2012): Traffic noise abatement: How different pavements, vehicle speeds and traffic densities affect annoyance levels. Transp Res D Transp Environ 17: 321−326
2. Gorai AK & Pal AK (2006): Noise and its effect on human being − A review. J Environ Sci Eng 48: 253−260
3. Hammer MS, Swinburn TK & Neitzel RL (2014): Environmental noise pollution in the United States: Developing an effective public health response. Environ Health Perspect 122: 115−119
4. Concha-Barrientos M, Campbell-Lendrum D & Steenland K (2004): Occupational noise: Assessing the burden of disease from work-related hearing impairment at national and local levels. Environmental Burden of Disease No.9. World Health Organization, Geneva 32 pp
5. Jahangiri M, Golmohammadi R & Aliabadi M (2014): Determination of main noise sources in a thermal power plant. JHSW 4(3): 13−22(in Persian)
6. Alimohammadi I, Ahmadi Kanrash F, Abolghasemi J, Afrazandeh H & Rahmani K (2018): Effect of chronic noise exposure on aggressive behavior of automotive industry workers. Int J Occup Environ Med 9: 170−175
7. Lee EY, Jerrett M, Ross Z, Coogan PF & Seto EY (2014): Assessment of traffic-related noise in three cities in the United States. Environ Res 132: 182−189
8. Shepherd D, Welch D, Dirks KN & Mathews R (2010): Exploring the relationship between noise sensitivity, annoyance and health-related quality of life in a sample of adults exposed to environmental noise. Int J Environ Res Public Health 7: 3579−3594
9. Passchier-Vermeer W & Passchier WF (2000): Noise exposure and public health. Environ Health Perspect 108 (Suppl 1): 123−131
10. Stansfeld SA & Matheson MP (2003): Noise pollution: Non-auditory effects on health. Br Med Bull 68: 243−257
11. Waye KP & Öhrström E (2002): Psycho-acoustic characters of relevance for annoyance of wind turbine noise. J Sound Vib 250: 65−73
12. Berglund B, Lindvall T & Schwela DH (2000): New WHO guidelines for community noise. Noise Vib Worldw 31(4): 24−29
13. Mendl M (1999): Performing under pressure: Stress and cognitive function. Appl Anim Behav Sci 65: 221−244
14. Bakker RH, Pedersen E, van den Berg GP, Stewart RE, Lok W & Bouma J (2012): Impact of wind turbine sound on annoyance, self-reported sleep disturbance and psychological distress. Sci Total Environ 425: 42−51
15. Babisch W, Houthuijs D, Pershagen G *et al* (2009): Annoyance due to aircraft noise has increased over the years-results of the HYENA study. Environ Int 35: 1169−1176
16. Kaczmarska A & Łuczak A (2007): A study of annoyance caused by low-frequency noise during mental work. Int J Occup Saf Ergon 13: 117−125
17. Saremi M & Rezapour T (2013): Non-auditory effects caused by environmental noise pollution. J Kerman Univ Med Sci 20: 312−325 (in Persian)
18. Öhrström E, Björkman M & Rylander R (1988): Noise annoyance with regard to neurophysiological sensitivity, subjective noise sensitivity and personality variables. Psychol Med 18: 605−613
19. Zimmer K & Ellermeier W (1999): Psychometric properties of four measures of noise sensitivity: A comparison. J Environ Psychol 19: 295−302
20. Sočan G & BucikV (1998): Relationship between speed of information-processing and two major personality dimensions − extraversion and neuroticism. Pers Individ Dif 25: 35−48
21. Alimohammadi I , Nassiri P, Azkhosh M & Hoseini M (2010): Factors affecting road traffic noise annoyance among white-collar employees working in Tehran. J Environ Health Sci Eng 7: 25−34
22. Stroop JR (1935): Studies of interference in serial verbal reactions. J Exp Psychol 18: 643−662
23. Injoque-Ricle I, Barreyro JP, Calero A & Burin DI (2014): Tower of London: Planning development in children from 6 to 13 years of age. Span J Psychol 17: E77
24. Wecker NS, Kramer JH, Wisniewski A, Delis DC & Kaplan E (2000): Age effects on executive ability. Neuropsychology 14: 409−414
25. Injoque-Ricle I & Burin DI (2008): Validity and reliability of the Tower of London's pretest: A preliminary study. Rev Argentina Neuropsicol 11: 21−31 (in Spanish)
26. Zarghi A, Zali A, Tehranidost M, Zarindast MR, Ashrafi F, Doroodgar S & Khodadadi SM (2011): Demographic variables and selective, sustained attention and planning through cognitive tasks among healthy adults. Basic Clin Neurosci 2(3): 58−67
27. Ernst M, Matochik JA, Heishman SJ, Van Horn JD, Jons PH, Henningfield JE & London ED (2001): Effect of nicotine on brain activation during performance of

a working memory task. Proc Natl Acad Sci USA 98: 4728−4733

28. Kalmijn S, van Boxtel MP, Verschuren MW, Jolles J & Launer LJ (2002): Cigarette smoking and alcohol consumption in relation to cognitive performance in middle age. Am J Epidemiol 156: 936−944
29. Belojevic G, Jakovljevic B & Slepcevic V (2003): Noise and mental performance: Personality attributes and noise sensitivity. Noise Health 6 (21): 77−89
30. Weinstein ND (1978): Individual differences in reactions to noise: A longitudinal study in a college dormitory. J Appl Psychol 63: 458−466
31. Job RF (1999): Noise sensitivity as a factor influencing human reaction to noise. Noise Health 1 (3): 57−68
32. Reynolds J, McClelland A & Furnham A (2014): An investigation of cognitive test performance across conditions of silence, background noise and music as a function of neuroticism. Anxiety Stress Coping 27: 410−421
33. Saeki T, Fujii T, Yamaguchi S & Harima S (2004): Effects of acoustical noise on annoyance, performance and fatigue during mental memory task. Appl Acoust 65: 913−921
34. Schreckenberg D, Eikmann T, Faulbaum F *et al* (2011): NORAH − Study on Noise-Related Annoyance, Cognition and Health: A transportation noise effects monitoring program in Germany. In: 10th International Congress on Noise as a Public Health Problem (ICBEN). ICEBEN, London pp 390−398
35. Sandrock S, Schütte M & Griefahn B (2010): Mental strain and annoyance during cognitive performance in different traffic noise conditions. Ergonomics 53: 962−971
36. Turner ML, Fernandez JE & Nelson K (1996): The effect of music amplitude on the reaction to unexpected visual events. J Gen Psychol 123: 51−62
37. Alimohammadi I & Ebrahimi H (2017): Comparison between effects of low and high frequency noise on mental performance. Appl Acoust 126: 131−135
38. Staal MA (2004): Stress, Cognition, and Human Performance: A Literature Review and Conceptual Framework. NASA Technical Reports Server. CA 176 pp
39. Stokes AF & Kite K (2001): On grasping a nettle and becoming emotional. *In*: Stress, Workload, and Fatigue. (Hancock PA & Desmond PA, *ed*). Laurence Erlbaum Associates, New Jersey pp 107−132
40. Eom JS, Kim SH, Jung SS & Sohn JH (2014): Low frequency noise and it's psychological effects. J Ergon Soc Korea 33: 39−48
41. Key KF & Payne MC Jr (1981): Effects of noise frequency on performance and annoyance for women and men. Percept Mot Skills 52: 435−441
42. Pawlaczyk-Luszczyńiska M, Dudarewicz A, Waszkowska M, Szymczak W & Sliwińska-Kowalska M (2005): The impact of low-frequency noise on human mental performance. Int J Occup Med Environ Health 18: 185−198
43. Farhang Dehghan S, Monazzam MR, Nassiri P, Haghighi Kafash Z & Jahangiri M (2013): The assessment of noise exposure and noise annoyance at a petrochemical company. JHSW 3(3): 11−24 (in Persian)
44. Naravane S (2009): Effect of industrial noise on occupational skill performance capability. Binghamton University State University of New York, 2009, Master of Science Thesis
45. Stansfeld SA, Berglund B, Clark C *et al* (2005): Aircraft and road traffic noise and children's cognition and health: A cross-national study. Lancet 365: 1942−1949
46. Smith A (1990): Noise, performance efficiency and safety. Int Arch Occup Environ Health 62: 1−5
47. Teichner WH, Arees E & Reilly R (1963): Noise and human performance, a psychophysiological approach. Ergonomics 6: 83−97

自動車生産工場における慢性騒音にさらされた労働者の騒音の不快度と認知能力の関係

アリモハンマディ　イラジ[1]，カンラシュ　ファフラディン　アフマディ[1]，アボルガセミ　ジャミレ[2,3]，ヴォスギ　シャラム[1]，ラーマニ　カゼム[3]，チャラク　モハマド　ホセイン[1]

[1] イラン医科大学　公衆衛生学部　労働衛生学部
[2] イラン医科大学　公衆衛生学部　生物統計学科
[3] イラン医科大学　公衆衛生学部　疫学学科

要　　旨：騒音にさらされている人々の主な不満には, 鬱憤や不快感, 精神状態の変化があり, これらは労働者の集中と正確さに影響を与える心理的影響の一つである．この研究は, 慢性的な騒音にさらされた労働者の不快感と認知能力の関係を検討するために実施された．これは, 自動車会社の労働者を対象とした記述分析的研究である．この研究では, 騒音にさらされた300人の労働者を, 管理・事務（150人）と生産（150人）の2つのグループに分けた．コンピューターによるロンドン塔課題とストループの心理検査を使用して労働者の認知状態を評価し, 1から11の番号付けした質問からなる質問紙を使用して不快度の程度を評価した．労働者の認知能力と不快度には有意な相関があった（*P*値<0.001）．線形回帰の結果においては, 認知能力と音の強さとの間に有意な関連がみられた．一方労働者の不快度は, ストループ検査の誤回答数, 未回答数, および正解数のみと有意な関係があることが示された（*P*値<0.001）．我々は, 職場環境での慢性的な騒音への曝露は職業上の不快感をもたらし, その結果, 認知障害を引き起こし, エラーのリスクを高める可能性があると結論付けた．この関連をより具体的に調査するには, さらなる研究が必要である．

キーワード：心理テスト, 認知, 騒音, 人間工学, ストループテスト．

J UOEH（産業医大誌）41（4）：375 − 385（2019）