

The Effect of Low Frequency Noises Exposure on the Precision of Human at the Mathematical Tasks

Abstract

Background: Low-frequency noise is produced from different sources in the working environments such as pumps. Thus, the aim of this study was to investigate the effect of low-frequency noise on precision and focusing of the studied subjects. **Methods:** This cross-sectional-interventional study was performed on 13 students of Isfahan University of Medical Sciences. The precision of individual subjects was evaluated using the mental arithmetic test. The sound sources with frequencies of 125, 250, and 1000 Hz at 75, 85, and 95 dB sound pressure levels. Also, the rate of precision was measured before the exposure (time “zero”), and at 45 and 90 min. SPSS (Ver. 26) software was used to analyze the data. **Results:** Comparison of the precision scores of the individuals between the frequencies of 125 and 250 Hz at the sound pressure level of 75 dB and at 45 min ($P = 0.032$). And 90 min ($P = 0.006$). And also, the frequencies of 250 Hz and 1000 Hz at the time of 45 min. At the sound pressure levels of 85 dB ($P = 0.019$). And 95 dB ($P = 0.043$) and at the time of 90 min. At the sound pressure levels of 85 dB ($P = 0.027$). And 95 dB ($P = 0.009$) demonstrated a significant difference. **Conclusions:** We concluded that low frequency noises could reduce the person’s precision. While for 125 Hz noises, just increasing of the exposure time was effective on the precision reduction. But for 250 Hz noises, both parameters increasing including exposure time and sound pressure levels, was effective.

Keywords: *Low frequency noise exposure, precision, sound pressure level, time*

Introduction

Low-frequency noise is defined as a broadband noise and often has a frequency range of 10–250 Hz or 20–200 Hz.^[1] Although most of the people are unable to realize the low-frequency noises, these types of noises may have detrimental effects on people’s health.^[2] Low-frequency noise, on the other hand, is common in both urban and industrial settings as the foreground noise.^[3,4] Therefore, the World Health Organization (WHO) has devoted special attention to the low-frequency noise as an environmental problem.^[4] Generally, low-frequency noises have natural and human resources among which the natural resources include natural sources including wind, lightning, volcanic eruptions, earthquakes, and human resources include ventilation systems, cooling and heating systems, fans, boilers, diesel engines, machinery as well as air, land, and sea traffic.^[5] For the people exposed to them, low-frequency noise can be subject to

a range of physical and mental effects, including temporary and permanent threshold changes for the hearing loss, mental distress, impaired focus and balance, headaches and dizziness, sleep disorders, stress, anxiety, and impacts on the social relationships, some of which may be combined and lead to adverse reactions and effects.^[6] Extensive studies have been done about the effects of low-frequency noises on the mental performance of individuals, but no proper results have so far been observed.^[7-11] Just as hearing sensitivity varies from person to person, often the effects of low-frequency noises may also vary from person to person. For instance, one person who is exposed to low-frequency noise may feel stimulated but the other person will may not.^[10] Thus, a study has shown that low-frequency noise increases the precision and speed of performance compared to silence, and there is no significant relationship between the low-frequency noise and distress due to the low-frequency.^[7] On the other hand, however, the results of several studies show the negative effects of low-frequency noise

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on precision and performance of individuals, including one study, which demonstrates that low-frequency noise in the common levels of industry reduces mental performance of individuals.^[12] The study by Nasiri *et al.* has shown that the low-frequency noises at 75, 85, and 95 dB sound levels are most effective regarding the speed reduction and increasing the rate of errors.^[13] In many sensitive occupations, the individuals such as control room staff, pilots, surgeons, and vehicle drivers, require high precision processing of information and may face unforeseen situations. Proper mental performance is quite important in such occupations and low-frequency noises can have the greatest impact on a person's paying attention and precision.^[14] For instance, some studies have shown that the existing low-frequency noise in the industrial control rooms can have adverse effects on the visual performance, precision and paying continuous attention, causing disorders in the work.^[15] Many studies have been done in this field. But so far no study has been aim to survey the effects of different sound levels on precision of different sound pressure levels and at different times. Therefore, regarding the importance of this issue in this study, the impact of low-frequency noise with 75, 85, and 95 dB sound pressure levels on the precision of some people was carefully examined during fulfilling the mathematical calculations.

Methods

Study sample and inclusion criteria

This cross-sectional-interventional study was performed in the sound and vibration laboratory of the Faculty of Health, Isfahan University of Medical Sciences in 2019. One of the inclusion criteria for the study was hearing health (hearing loss less than 25 dB). In this study audiometric test was used to assess the participants' hearing health. Moreover, not being sensitive and irritation to low frequency noises was another inclusion criterion. Participation in the study was completely voluntary. Participants in the study read and signed the Conscious Consent. They could also drop out of study whenever they wanted. Standardized questionnaires were used to measure irritation and sensitivity. Eventually, 13 male and female students at Isfahan University of Medical Sciences who had low irritation and sensitivity to low frequency noises were included as the participants to the study. It should be mentioned that the participants of the study were randomly selected.

Sensitivity to the low-frequency noises was assessed by a questionnaire according to the ISO 15666.^[16] The questionnaire consisted of three questions and each question had five rating scales, ranging from "strongly agree" to "strongly disagree". Thus, individuals who had the sensitivity score greater than or equal to 9 were assigned to the high-sensitive group towards the low-frequency noises, and the rest were categorized in the low-sensitive group. The noise irritation was also assessed by the ISO 15666. The questionnaire consisted of one question with

10 rating scales, rating from "very low" to "very high". Irritation score less than or equal to 5 was decided into the non-irritation group to low frequency noises. This questionnaire has also been used in studies in Iran. And its validity and reliability have been proven.^[8]

Study design

Sinusoidal noises at three frequencies equal to the 125, 250, and 1000 Hz and three pressure levels of 75, 85, and 95 dB were used as the noise sources. Because of the three frequencies and the three sound pressure levels, each person was tested 9 times. Each test was done in the 9 different days. To measure the precision, mental arithmetic test was done at time = 0 (starting time, subjective had no exposure to noise) and 45 and 90 minutes after exposure. LabVIEW software with data acquisition (DAQ) card was made by USA National Instrument^[17] was used for the playing of the noises. To equalize the intervention factors, all the participants in the study had the same conditions during the test. Participants were welcomed between stages of the test to prevent low blood sugar. Also, for the evaluation of the fatigue level of the participants, this factor measured at time = 0 and every thirty minutes by a Likert scale (0 to 10).^[18]

Precision test

The test was contained 15 numerical fraction, the numerator of this numerical fraction was a 2-digit number and the denominator of this numerical fraction was a 1-digit number, doing this division to two decimals was considered as the mental arithmetic test. The numbers of correct answers in each test was considered as the precision of the participants. To eliminate the mental intervention factors, the test results of each person were compared with themselves before and after.

Statistical analysis

Data was analyzed with using of SPSS (Ver. 26) software. Mean and standard deviation (SD) for quantitative variables and number and percentage for qualitative variables were used for descriptive statistics. Mann-Whitney U-test was used to survey the relationship between independent variables and two dependent variables. $P < 0.05$ was considered as the significant level.

Results

Table 1 shows the demographic characteristics of the subjects. The average age of the subjects was 24.84 with a standard deviation of 3.28 years. Also, 100% of the subjects were single in terms of marital status. Comparison of the fatigue results between time intervals, showed no statistically significant difference.

The results of the present study showed that increasing the exposure time increases computational errors of individuals. Comparison of the precision scores of the subjects at

Table 1: Demographic characteristics of samples

Property	Range and type	Number	Percent
Gender	Female	7	53.8%
	Male	6	46.2%
Age	24>	7	53.84%
	24<	6	46.16%
Level of education	Bachelor	5	38.5%
	Masters	8	61.5%
Marital status	Single	13	100%
	Married	0	0%

45 and 90 minutes showed a statistically significant difference in the frequency of 250 Hz and sound pressure levels of 85 dB ($P = 0.029$) and 95 dB ($P = 0.042$). Also, a significant difference was shown between 45 and 90 minutes at 1000 Hz with 95 dB sound pressure level ($P = 0.018$). Furthermore, there was a significant difference between 0 and 45 minutes as well as 0 and 90 minutes in all noise exposure conditions except for the 0 and 45 minutes at 250 Hz and the sound pressure level of 85 dB ($P = 0.072$) [Table 2].

Comparison of the precision scores between the frequencies of 250 and 125 Hz at the sound pressure level of 75 dB and 45 min. ($P = 0.032$) and 90 min. ($P = 0.006$) showed a significant difference. Moreover, the statistically significant difference was observed between frequencies of 250 and 1000 Hz at 45 min. with the sound pressure levels of 85 dB ($P = 0.019$) and 95 dB ($P = 0.043$), and at 90 min. with the sound pressure levels of 85 dB ($P = 0.027$) and 95 dB ($P = 0.009$). Significant difference was also observed between 125 Hz and 1000 Hz at 90 min. with the 95 dB sound pressure level ($P = 0.015$) [Table 3].

Comparison of precision scores demonstrated a statistical significant difference at frequencies of 1000 Hz and 45 minutes between the sound pressure levels of 75 and 85 dB ($P = 0.043$) and between the sound pressure levels of 75 and 95 dB ($P = 0.035$). There was also a statistically significant difference between the sound pressure levels of 75 and 95 dB at 90 min. in the frequencies of 250 Hz ($P = 0.040$) and 1000 Hz ($P = 0.011$) [Table 4].

Discussion

The results of the present study indicated that exposure to low-frequency noise increased the computational error of individuals compared to non-exposure to these frequencies. Recently, many studies have been conducted to compare the effect of low-frequency with high frequency noises on the behavior of individuals. Some of them have shown that individuals with high frequencies are more likely to have impaired performance than low frequencies.^[19,20] However, contrary to these findings, a number of other studies about the effect of low-frequency noises have shown that low-frequency noises can also cause dysfunction.^[8,15] In these circumstances, it seems that the findings on the effects

of different frequencies are contradictory and low-frequency noises have so far received less precision than high frequency noises.

The effects of noise are significantly influenced by the nature of the noise in terms of the level of sound pressure level, frequency bandwidth as well as the type of study design, personality characteristics of the studied subjects, and sound pressure level to noise.^[21] Changes in any of the above can alter the observed effect.^[7,15,17]

In this study, the effect of changes in the parameters of sound pressure level, frequency, and duration of exposure on the precision of the subjects was analyzed. In terms of sound pressure level, since the low-frequency noise level is higher than the 50–40 dB range. And also because 75, 85, and 95 dB sound pressure levels are usually recognized as the common sound pressure levels in the industry.^[13] Also according to OSHA standard (PEL: 90-dBA for 8 hours exposure and Exchange rate: 5 dB).^[22] Sound pressure levels 75, 85, and 95 dB were consequently used in this study to investigate the effects of the low-frequency noise. In order to correctly understand the effects of low-frequency noise, the effects of low-frequency noise levels with 125 and 250 Hz were compared against exposure to the noise with 1000 Hz. In fact, in order to understand the effects of low frequencies, comparisons were made between 125 Hz and 250 Hz frequencies. Determine which of the two low frequencies has the most impact on people. In order to evaluate the effect of time, the rate of precision before the exposure (time “zero”), and 45 as well as 90 min after the exposure was also measured.

Studies have shown that the exposure time to noise can be considered as an important parameter for the impaired cognitive function and increasing of errors, such that chronic exposure to noise can affect cognitive function and cause deficits in continuous precision and visual attention.^[23] In such circumstances, it seems that low-frequency noise is effective in causing this type of disorder through different mechanisms. Studies have shown that exposure to low-frequency noises can increase the symptoms such as fatigue, tinnitus, feeling pressure in the head and eyelids.^[14,24] It has also been found that the increased exposure to low-frequency noise exacerbates these symptoms.^[24] In a study by Pathak, frequency analyzes of the ambient noise showed that the low-frequency noise due to the land traffic has caused headache, dizziness, and fatigue in the residents of such regions.^[25] Decreased ability to process information and precision is one of the documented consequences of fatigue in the real world.^[26] Welford demonstrated in his study that pilots with post-flight fatigue performed significantly higher errors in subsequent flights than did the properly rested pilots.^[27] On the other hand, tinnitus can cause stress, mental distress and sleep disturbances in individuals.^[28,29] It can also cause functional disorder and

Table 2: Comparison of precision scores in sound pressure level and constant frequency and different times

Frequency	SPL [‡] Time (min)	75 dB (A)		85 dB (A)		95 dB (A)	
		Mean rank	P	Mean rank	P	Mean rank	P
125 (Hz)	0	16.96	0.020	16.46	0.045	18.04	0.002
	45	10.04		10.54		8.96	
	0	17.65	0.005	18.77	0.001	19.08	0.001
	90	9.35		8.23		7.92	
	45	14.58	0.468	16.27	0.062	14.92	0.333
250 (Hz)	90	12.42		10.73		12.08	
	0	17.04	0.016	16.12	0.072	17.42	0.008
	45	9.96		10.88		9.58	
	0	17.96	0.002	18.19	0.002	19.62	0.001
	90	9.04		8.81		7.38	
1000 (Hz)	45	15.38	0.203	16.69	0.029	16.50	0.042
	90	11.62		10.31		10.50	
	0	16.42	0.048	19.12	0.001	19.04	0.001
	45	10.58		7.88		7.96	
	0	17.85	0.003	18.65	0.001	19.12	0.001
	90	9.15		8.35		7.88	
	45	15.65	0.138	15.81	0.119	17.00	0.018
	90	11.35		11.19		10.00	

[‡]Sound Pressure Level

Table 3: Comparison of precision scores in sound pressure level and constant time and different frequencies

SPL	Time Frequency (Hz)	0 (min)		45 (min)		90 (min)	
		Mean Rank	P	Mean Rank	P	Mean Rank	P
75 dB (A)	125	11.50	0.173	10.31	0.032	9.42	0.006
	250	15.50		16.69		17.58	
	125	13.12	0.796	11.50	0.174	11.88	0.274
	1000	13.88		15.50		15.12	
	250	14.96	0.310	15.04	0.299	15.62	0.149
85 dB (A)	1000	12.04		11.96		17.38	
	125	13.23	0.854	12.08	0.332	11.04	0.096
	250	13.70		14.92		15.96	
	125	12.15	0.356	15.50	0.179	14.54	0.484
	1000	14.85		11.50		12.46	
95 dB (A)	250	11.96	0.289	16.96	0.019	16.77	0.027
	1000	15.04		10.04		10.23	
	125	12.23	0.377	12.50	0.499	14.15	0.655
	250	14.77		14.50		12.85	
	125	12.46	0.464	15.62	0.153	17.12	0.015
	1000	14.54		11.38		9.88	
	250	13.69	0.893	16.50	0.043	17.35	0.009
	1000	13.31		10.50		9.65	

subsequently increase the functional errors.^[30] Moreover, studies have shown that the increased exposure time to noise can exacerbate some of the symptoms of noise such as fatigue and tinnitus.^[14,31,32] In such conditions, exposure to low-frequency noise seems to exacerbate the mental fatigue, tinnitus, and sleep disturbances and subsequently increase the functional errors.^[33,34]

Another effective parameter for the impact of low-frequency noises is the frequency effect of the exposure. The results of the present study showed that low-frequency noises can

increase the computational errors in individuals. Nasiri studies on the combined effect of noise type, noise level and frequency levels on speed, accuracy and precision of individuals showed that the frequency characteristic significantly affects the performance more than other noise properties and has the greatest impact in terms of speed reduction, increasing the time and the amount of the errors.^[13] Some researchers have shown in their studies that the children living near airports that are indeed exposed to the 10–250 Hz frequency range due to the air traffic

Table 4: Comparison of precision scores in time and constant frequency and different sound pressure levels

Time		0 (min)		45 (min)		90 (min)	
Frequency	SPL	Mean Rank	P	Mean Rank	P	Mean Rank	P
125 (Hz)	75	13.38	0.938	12.12	0.351	13.65	0.917
	85	13.62		14.88		13.35	
	75	12.54	0.508	11.73	0.231	11.58	0.194
	95	14.46		15.27		15.42	
	85	12.62	0.544	13.42	0.959	11.46	0.169
250 (Hz)	95	14.38		13.58		15.54	
	75	15.50	0.169	14.62	0.446	15.65	0.143
	85	11.50		12.38		11.35	
	75	13.73	0.874	14.54	0.485	16.50	0.040
	95	13.27		12.46		10.50	
1000 (Hz)	85	11.69	0.213	14.04	0.713	14.50	0.492
	95	15.31		12.96		12.50	
	75	12.35	0.430	16.50	0.043	16.15	0.072
	85	14.65		10.50		10.85	
	75	11.81	0.251	16.62	0.035	17.27	0.011
	95	15.19		10.38		9.73	
	85	13.58	0.958	13.35	0.917	15.08	0.282
	95	13.42		13.65		11.92	

in exposure to the low-frequency noises have problems in listening comprehension, reading, mathematics, precision, and attention in comparison with the ones who are not exposed to such noise.^[35,36] Also, Pawlaczyk concluded by simulating the noise in industrial control rooms in his study that sounds in the range of 10–250 Hz can have adverse effects on visual performance, precision, and continuous attention continuous leading to impaired performance. In addition, people sensitive to the low-frequency noise may be at higher risk than non-sensitive people.^[15] Findings of this study showed that the number of computational errors in the frequency of 125 Hz was higher compared to the frequencies of 250 and 1000 Hz at the sound pressure level of 75 dB. This result is consistent with the results of other studies. The results of the study by Jafari *et al.* showed that the sounds in the frequency range of 10 to 250 Hz with 65 dB sound pressure reduces the response time in comparison to the sounds with high frequency and uniform sound pressure level, reducing the learning time. Frequencies are very low and very low. Also, the low-frequency noise reduces the mental performance in the tests requiring precision and paying necessary attention.^[14] Studies have shown that low-frequency noises have greater effects on increasing the level of annoyance and also on reducing the mental performance than the high frequency noises at similar sound pressure level, which are more evident in low-frequency subjects than non-sensitive subjects.^[8,37] Since annoyance is a mental performance that can impair mental functioning,^[3,38] it seems that creating annoyance by the low-frequency noise and also low-frequency noise sensitivity reduce the mental performance of individuals and consequently increase the number of computational errors.

The results of this study showed that increasing the sound pressure level at frequencies of 250 and 1000 Hz increased the number of computational errors. One of the causes of the increase in human error when exposed to noise is the change in speed of brain activity and consequently an increase in making errors. However, it can in general be said that the environments with high level of sound can disrupt conversations and comprehension, decrease brain activities, and disorganize physical tasks. Moreover, the capability to learn also reduces and the number of errors will be increased.^[39] Noise may exert its effects, directly or indirectly. In other words, exposure to noise has physical and psychological impacts, thus affecting the neuroendocrine homeostasis.^[40] High levels of noise can lead to adrenaline secretion and peripheral vasoconstriction, resulting in the increased blood pressure due to increased stress.^[41] It has been shown in a study that industrial noise at levels above 80 dB has a significant effect on increasing the secretion of cortisol.^[42] On the other hand, exposure to noise causes hypertension and cognitive changes, and increases noise annoyance and aggression in workers,^[43] such that aggression can lead to impaired cognitive functioning activities and increased human error.^[44] Another study showed that exposure to noise can lead to greater mental stress and discomfort in individuals.^[45] Studies have shown that all of these effects are strongly dependent on noise exposure, and as the sound pressure level increases, the effects usually increase. Thus, the increased amount of stress inflicted on a person due to the increase in the sound pressure levels has peculiar reasons. In such a situation, it seems that increasing the stress is associated with a decrease in the level of precision,^[3] and therefore, increasing the error

of individuals in such conditions cannot be out of mind. On the other hand, these effects are also observed for low-frequency noises. The results of a study demonstrated that the annoyance caused by exposure to low-frequency noise was higher than the medium frequency.^[38]

As a result, mental effects, hormonal secretion resulting from exposure to noise such as low-frequency noise, as well as exposure-induced stress and stress increase individuals' computational errors. Hence, it seems that mental effects, hormonal secretion due to the exposure to noise such as low-frequency noise, as well as annoyance and exposure-induced stress increase the computational errors of individuals. Since our study was conducted under laboratory conditions, the relevance of its results to actual work situations should be carefully evaluated. However, the findings presented herewith indicate that the negative effects which lead to the work disruption, especially in cases where greater attention and precision may be required, can be due to exposure to low-frequency noise. In addition, people who are known to be sensitive to low-frequency noise may be at higher risk.

Conclusion

We concluded that low frequency noises could reduce the person's precision. Precision scores were not the same for the 125 and 250 Hz noises. For the 125 Hz noises, increasing the sound pressure level was not caused the precision reduction while precision reduction was seen by the increasing of the exposure time. For the 250 Hz noises, increasing of both parameter including the exposure time and sound pressure level were caused the precision reduction.

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Conflicts of interest

There are no conflicts of interest.

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