

Comparison between effects of low and high frequency noise on mental performance



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ABSTRACT

Purpose: There are few and controversial findings about adverse effects between the low frequency noise (LFN) and high frequency noise (HFN) on human. Although noise is presumed as a distracting stimulus, regarding controversial findings between performance effects of LFN and HFN, and scarcely studies on dissimilar effects of them, the present study was conducted to answer the following questions: is there any difference between LFN and HFN impacts on mental performance at a moderate noise level? And, how do LFN and HFN affect mental performance?

Methods: This experimental study was carried out with 89 students (54 males and 35 females) of Tehran University of Medical Sciences. All participants performed the Stroop and Cognitrone tests in quiet condition, when exposing to LFN and HFN at both 50 and 70 dBA.

Results: It was found that both LFN and HFN augmented the performance through increasing sum hits and sum correct rejection and also decreasing working time of the Cognitrone test. The findings of the present study showed that not only LFN and HFN had no negative effects on the performance but also performance speed improved.

Conclusion: This experiment study showed no differences between LFN and HFN effects on the performance; moreover, both LFN and HFN improved the participants' performance. Of course, more researches are suggested in this issue.

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1. Introduction

Mental performance can be defined operationally as the outcome of a task, effort, or activity that engages the central nervous system (CNS). There are many factors influencing mental performance such as ambient conditions, food intake, practice effects, and chronotype. Ambient conditions including lighting, temperature, and noise [1,2]. Sound quality is one of the important factors affecting the performance of subjects who are exposed to noise [3–6]. The response to noise may depend on characteristics of the sound, including frequency, intensity, complexity of sound, duration, tonality and the meaning of the noise [7,8].

There are few and controversial findings about adverse effects between low frequency noise (LFN) and other types of noise with different dominant contents of frequency—such as high frequency noise (HFN)—on human. LFN is usually defined as a broad band noise with the dominant content of frequencies from 10 to 250 Hz [9]. Some of the main sources of LFN in residential build-

ings are pumps, ventilating systems, and fans which could cause pollution inside and outside of a building [10].

LFN not only generates objective effects such as hearing impairment and body vibration, but also causes noise annoyance, behavioral disturbances, effects on sleep periods, deterioration of task performance, fatigue, headache and irritation [8,11–13]. To achieve a certain level of noise annoyance, LFN requires higher sound pressure level than higher frequency noise [8]. It has been shown that noise that has low frequency characteristics is more annoying than noise having other frequencies with the same A-weighted levels [14]. An experimental study showed that high frequency noises were more annoying than low frequency noises regardless of sex [15]. In addition, it was reported that HFN (frequencies from 500 to 8000 Hz) results in more errors in comparison with LFN, although this difference was significant only at high sound pressure level (100 dB) [16]. A laboratory study of the influence of sound quality on the annoyance caused by road traffic noise showed that high frequency noise contributes to listening interference [4]. On the other hand, it was announced that LFN could considerably decrease task performance in comparison with other dominant contents of frequency. LFN was rated as more annoying

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and more disruptive to working capacity than the flat frequency spectrum noise [11].

Many researches were conducted on the differences of LFN and other dominant contents of frequency effects on noise annoyance [5] but few studies have investigated on performance. On the other hand, the World Health Organization (WHO) has reported that the similarity and differences of LFN and HFN's effects were not examined [11]. Although noise is presumed as a distracting stimulus, regarding the controversial findings between performance effects of LFN and HFN and scarcely studies on dissimilar effects of them, the present study was conducted to answer the following questions:

- Is there any difference between LFN and HFN effects on mental performance at moderate a noise level?
- How do LFN and HFN affect mental performance?

2. Materials and methods

The present experimental study was conducted with 89 students (54 males and 35 females) of Tehran University of Medical Sciences, Tehran, Iran. The volunteer students were required to appear at the test hall. As an ethical issue, the detailed explanation of the experiment's purpose was offered to the participants; possible risks due to the experiment were explained and all participants were required to sign a consent form. The selected participants performed the hearing test and, if average hearing threshold levels were less than 20 dB, they were allowed to accomplish the mental performance tests. The hearing test was performed in un-echoing room by an audiometer (MEVOX ASB15).

The Un-echoing room was equipped with a PC monitor (12 inches diameter, resolution 786 * 1024, and frequency of 69 HZ) and universal panel of Vienna Test System (Fig. 1). After locating the participants in the un-echoing room at first necessary instructions about the Cognitrone and Stroop tests were presented to the participants. Then, all participants performed the two tests in quiet condition. Next, LFN and HFN were emitted by Cool edit pro 2.1 at the level of 50 and 70 dBA. Before performing the tests by the participants, total sound pressure level and sound pressure level at

octave band frequency were measured at participant head position by a sound level meter (B&K model 2238). After 30 min of noise exposure, the subjects started to perform the Cognitrone and Stroop tests. In order to reduce the recalling effect of the order of the figures presented in the Stroop and Cognitrone tests on results, 45 participants were exposed to LFN at first and then exposed to HFN, but 44 were exposed to HFN at first and then exposed to LFN. Furthermore, the half of the participants were firstly exposed to 50 dBA and the other were exposed to 70 dBA. In this study, the Cognitrone and Stroop interference tests were used for measuring mental performance. The Cognitrone test evaluates the concentration and attention through the identical comparison of figures [17]. In this research, S11 version (no time limit, short form) of the Cognitrone test was used. Four figures were displayed on top and one figure displayed under them. If one of four figures was identical with that down, the subjects must have pressed the green bottom and, if the figures were not the same, the red bottom must have been pressed. Sum hits, sum correct rejections and working time were considered as performance parameters of the Cognitrone test.

The Stroop interference test is a sensory-motor speed test registering speed performance when reading color words. S8 form of the Stroop test used in this research had two stages. In the first stage, participants must read the words without regarding the color of them and press the suitable button of a control panel. In the second stage, they must name the color of the words without regarding the meaning of them. The number of incorrect reactions (reading incongruent, number of incorrect reactions (naming incongruent)), and working time were considered as performance parameters of the Stroop test.

Before performing the tests, necessary instructions were presented to the participants and they were asked to act as fast and accurate as possible. To uniform the performance ability of the subjects during the tests all the trials were performed between 8.00 and 12.00 AM.

3. Results

In this study, the participants were 54 males and 35 females with an average age of 23.46 years ($S.D = 1.97$). The minimum and maximum ages were 19.80 and 30.20 years, respectively.

The frequency distributions of LFN and HFN emitted have been shown in Fig. 2. As can be seen from the figure, the pressure level of LFN noises in low frequencies was higher, whereas the reverse trend was seen for HFN.

The mean and standard deviations of performance parameters under different acoustical conditions in the Stroop interference test have been presented in Table 1. Paired T-test showed that there were no significant differences between performance parameters in the Stroop interference test (Table 2).

Table 3 shows the mean and standard deviations of performance parameters under different acoustical conditions in the Cognitrone test. As can be seen, a significant relationship was not observed among most performance parameters, especially between working time of tests in Cognitrone test (Table 4).

This experiment showed that the speed of test performing under HFN was less than that of LFN. In other words, participants under LFN performed the tests faster than participants under HFN. This has occurred for both 50 and 70 dBA noise pressure levels.

LFN and HFN at both levels of 50 and 70 dB increased numbers of sum hits and sum correct rejections in comparison with the quiet condition (Table 4). Moreover, duration of test performing of Cognitrone decreased in participants under noise (LFN and HFN) compared to the quiet condition. That is, both emitted noises (LFN and HFN) not only caused to escalation accuracy of respond-



Fig. 1. Schematic figure of un-echoing room equipped with universal panel of VTS.

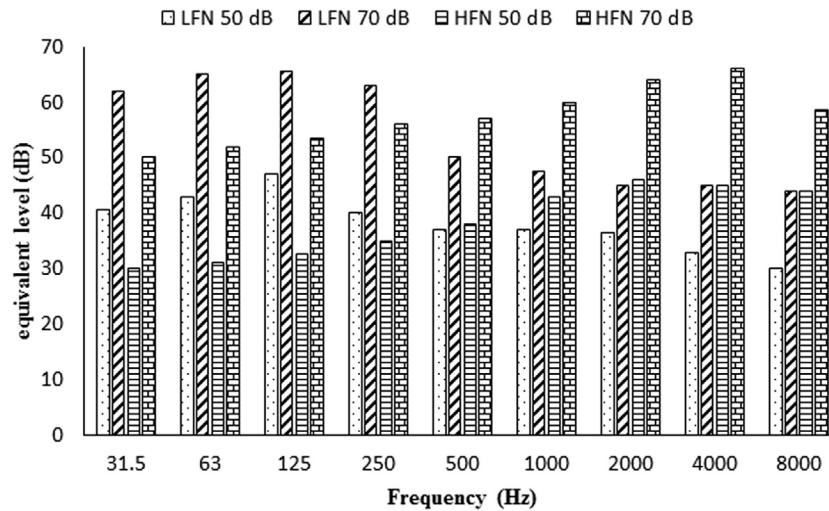


Fig. 2. Distribution of frequency of emitted noise.

Table 1

Mean and standard deviations of performance parameters under different acoustical conditions in Stroop interference test.

	Silence		LFN, 50 dB (A)		LFN, 70 dB (A)		HFN, 50 dB (A)		HFN, 70 dB (A)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Incorrect reactions (Reading incongruent)	2.04	2.10	1.84	1.56	1.69	1.62	1.71	1.63	1.78	2.05
Incorrect reactions (Naming incongruent)	2.38	2.50	2.04	1.97	1.92	2.03	2.03	1.67	2.04	2.02
Working time (seconds)	276.06	46.83	259.36	44.19	255.73	45.79	261.10	44.80	260.94	44.22

Table 2

Comparison between participants' performance parameters difference under different acoustical conditions in Stroop interference test.

	LFN50dBA-silence	LFN70dBA-silence	HFN50dBA-silence	HFN70dBA-silence	LFN-HFN 50 dBA	LFN-HFN 70 dBA
Incorrect reactions (Reading incongruent)	0.516	0.791	0.955	0.896	0.247	0.696
Incorrect reactions (Naming incongruent)	0.356	0.342	0.361	0.742	0.527	0.498
Working time (seconds)	0.777	0.738	0.784	0.796	0.629	0.103

Table 3

Mean and standard deviations of performance parameters under different acoustical conditions in Cognitrone test.

	Silence		LFN, 50 dB (A)		LFN, 70 dB (A)		HFN, 50 dB (A)		HFN, 70 dB (A)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Sum hits	21.68	1.85	22.85	1.25	22.82	1.31	22.98	1.08	22.71	1.70
Sum correct rejections	33.83	2.22	35.31	1.18	35.10	1.08	35.22	0.85	35.35	0.74
Working time (seconds)	152.26	40.14	117.11	22.82	114.99	26.29	124.76	28.50	124.76	28.50

Table 4

Comparison between participants' performance parameters difference under different acoustical conditions in cognitive test (* Significant level at <0.10, ** Significant level at <0.05, *** Significant level at <0.01).

	LFN50dBA-silence	LFN70dBA-silence	HFN50dBA-silence	HFN70dBA-silence	LFN-HFN 50 dBA	LFN-HFN 70 dBA
Sum hits	<0.001**	<0.001**	<0.001**	<0.001**	0.572	0.549
Sum correct rejections	<0.001**	<0.001**	<0.001**	<0.001**	0.082*	0.052*
Working time (seconds)	<0.001*	<0.001**	<0.001**	<0.001**	0.074*	0.020**

ing but also decreased duration of test performing. In balance, it could be concluded, disregarding energy distribution of frequencies, noise improved participant's task performance. The results illustrated that subjects under LFN performed the Cognitrone test faster than subjects under HFN (Table 4).

4. Discussion

The findings showed that both types of the emitted noises affected subjects' performance. It was found that both LFN and HFN augmented the performance through increment of sum hits and sum correct rejection and also decrement of working time of the Cognitrone test. The results of the present study showed not only LFN and HFN had no negative effects on the performance

but also the performance speed was improved, which is inconsistent with some experiments [18–20].

Hockey reviewed conducted researches and some conclusions are as follows: 1 - Noise could affect negatively and positively the performance, 2 - Negative effects of noise on the performance is more probable in complex tasks, 3 - Noise could increase the performance in boring tasks and less-complex tasks (noise enhances alertness of the subjects who exposed to noise), and 4 - Compared to intermittent noise, continuous noise cause to less detrimental effects on the performance. Hockey suggested two theories to negative and positive effects of noise on performance including distracting theory and stimulating processing. According to distracting theory, human information processing center is singular with limited capacity and noise during performing tasks disrupts simply the performance. According to second theory-based on arousal theory, noise facilitates functioning by stimulating processing [21,22].

Therefore, the intensification of participants' performance under LFN and HFN could be explained by the arousal theory. According to this theory, arousability (a hypothetical construct that represents the level of the activity of the central nervous system alongside a behavioral continuum ranging from sleep to alertness) could mobilize energy and adjusts human response to stressors. As noise causes increment of arousability level, simple, monotonous and boring tasks will be performed better under noise than quiet condition, because the arousability level of subjects remains closer to the optimum level [10].

There are several factors affecting the performance of exposure to the noise and for this reason researches' findings may be different and even controversial. Noise characteristics and task difficulty may probably impact performance level. For example, under the noise condition, psychomotor task performances are less affected than cognitive processes [22]. Task difficulty is dependent on effort needed for the completion of the task. It seems that central information processing of the participants in this study has not been affected by noises (LFN and HFN) because not only performance has decreased but also performance parameters have increased. According to Gamberale and colleagues (1990), interfering stimuli decreases task performance with high mental load through influencing central information processing. It has been reported that noise and other environmental factors diminish psycho-motor tasks' performance having a higher order cognitive level [3]. Furthermore, it has been cited that perceptual-motor or lower-order cognitive tasks are resistant to performance decrement. Thus, it may be claimed that Cognitrone and Stroop tests do not have enough complexity and the participants do not need to high effort to perform those. The simplicity of tasks depends on well-learned persons. If the arousal level rises in non-well learned persons, performance decreases. The participants of this study stated that the Stroop and Cognitrone tests are difficult and simple, respectively. Perhaps this is why the Stroop test did not show any deviation in under noises performance parameters of participants in comparison with the quiet condition (Table 3).

Broadbent examined the effects of low and high frequency noise on the performance of the five-choice serial reaction tasks [23]. The high frequency noise increases errors although this difference was only significant in condition with the highest intensity (100 dB). Relative to the effect of noise frequency on performance, some literature reviews indicated that noise, which has high frequency, has a detrimental effect on task performance compared to low frequency noise [15]. It should be noted that no direct relationship between learning to perform a complex task while exposed to low and high frequency noise and annoyance has not been reported. Also, Broner concluded that the effects of low frequency noise are similar to those of higher frequency noise [24]. It has been claimed that noise has a negative effect on accuracy, but no

influence on speed, which is inconsistency with our results [22]. In the study conducted by Trimmel et al., it was found that background noise led to prolong reaction time of the visual-spatial attention task in 10 participants [18]. A significant difference between performance parameters of the subjects who were under noises (LFN and HFN) with under quiet condition is likely related to arousability level of the two groups that were not significantly different. According to Hockey's theory, which is based on arousal theory, noise through the motivation of analyzing processes affects the performance. Hockey's theory identifies noise as a stimulus, which increases the arousal level and performance. This increment continues to the point that over-arousal occurs and, in turn, the performance decreases [22].

One of the plausible reasons for increment of subjects' performance in the present study was subjects' perceived control over noise and in general it is a positive cognitive appraisal of the subjects [25]. According to the transactional model, cognitive appraisal from threatening or ability to control a stressor was clearly related to mental stress experience of the individuals. Generally, the positive cognitive appraisal of stress led to increment of performance and negative appraisal led to negative outputs [22]. The stress or negative appraisal occurs when there is not the ability to control the threatening factor. Moreover, researches show that challenging events, and not threatening, make positive emotions and higher confidence [26].

Many field researches have shown that noise decreases performance but objective measure of performance shows usually different results, which is probably because of the nature of noise [25]. In this experiment, the participants were exposed to continuous noises. Intermittent noise compared to continuous one led to higher fluctuation in performance, although this effect limited to short period of following the onset and offset of the noise [25,27].

The effects of noise on choice reaction time tasks were studied [28] and it was found that reaction time in noise was faster compared to silence-which conform our result-but it has been influenced by attitudinal set of subjects to noise. The results suggest that pessimistic expectancies about the effects of noise may play an important role in determining the effects of noise on performance. Many studies have suggested that the effects of noise on performance can easily be modified by other factors [29]. It has been argued that noise changes the individual's perception of what is competent performance; and, the effect of noise reflects the interaction between subject's beliefs about detrimental effects of the noise, the level of performance the subject considers appropriate and demand characteristics of the experiment [25].

5. Conclusion

In this study, the effects of LFN and HFN noises on mental performance were compared. The findings showed that both noises affected subjects' performance. The study declares that there were no differences between LFN and HFN effects on performance and both them improved the participants' performance. This study demonstrated that LFN and HFN not only had no negative effects on performance but also improved performance speed. More researches are suggested in this issue.

Conflicts of interest

The authors declare that there is no conflict of interest regarding the publication of this article

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