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The effects of low frequency noise on mental performance and annoyance

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Abstract Low frequency noise (LFN) as background noise in urban and work environments is emitted from many artificial sources such as road vehicles, aircraft, and air movement machinery including wind turbines, compressors, and ventilation or air conditioning units. In addition to objective effects, LFN could also cause noise annoyance and influence mental performance; however, there are no homogenous findings regarding this issue. The purpose of this research was to study the effects of LFN on mental performance and annoyance, as well as to consider the role of extraversion and neuroticism on the issue. This study was conducted on 90 students of Iran University of Medical Sciences (54 males and 36 females). The mean age of the students was 23.46 years (SD=1.97). Personality traits and noise annoyance were measured by using Eysenck Personality Inventory and a 12-scale self-reported questionnaire, respectively. Stroop and Cognitrone computerized tests measured mental performance of participants each exposed to 50 and 70 dBA of LFN and silence. LFNs were produced by Cool Edit Pro 2.1 software. There was no significant difference between mental performance parameters under 50 and 70 dBA of LFN, whereas there were significant differences between most mental performance parameters in quiet and under LFN (50 and 70 dBA). This research showed that LFN, compared to silence, increased the accuracy and the test performance speed ($p<0.01$). There was no association between LFN and noise annoyance ($p>0.01$). Introverts conducted the tests faster than extraverts ($p<0.05$). This research showed that neuroticism does not influence mental performance. It seems that LFN has increased arousal level of participants, and extraversion has a considerable impact on mental performance.

Keywords Low frequency noise · Mental performance · Annoyance · Extraversion · Neuroticism

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Introduction

Noise is one of the most important environmental pollutants. The most important indoor noise sources are ventilation systems and office machineries (Berglund et al. 1996). World Health Organization has determined the health effects of community noise including communication interference, noise annoyance, sleep disturbances, effects on the cardiovascular system, productivity, work performance, social behaviors, and hearing impairment

(Berglund and Lindvall 1995). Severity and effects of noise depends on sound pressure level, frequency spectrum, and temporal characteristics.

A segment of noise produced in community and industrial areas is known as low frequency noise (LFN). LFN is a broadband noise with sound energy dominated between 10–200 and 20–250 Hz (Pawlaczyk-Luszczynska et al. 2003; Leventhall et al. 2003). General sources of LFN are ventilation systems, pumps, compressors, diesel engines, and transportation vehicles (Persson-Waye et al. 1997).

Low frequency noise has objective effects on humans. Jerger et al. (1966) exposed subjects to noise with 7–123 Hz frequency and 19–144 dB level and found that temporary threshold shift of 20–25 dB had occurred, but threshold shift recovery occurred after a few hours. In general, one could expect that long-term exposure to LFN, with high-pressure levels, lead to permanent and temporary hearing threshold shift (Nixson 1973).

Not only does LFN have objective effects, but it can also cause noise annoyance in addition to effecting behavior, sleep period, task performance, and social attitudes (Leventhall et al. 2003). Although noise annoyance is connected to different concepts such as disturbance, aggravation, dissatisfaction, concern, bother, displeasure, nuisance, and distress, when actual activities are affected (Guski et al. 1999), it could be defined as noise overall unwantedness (Yano 2002). Noise annoyance—affected by personal and attitudinal factors—is a delayed effect of noise, causing behavioral changes and social reactions against noise (Nelson 1987). It seems that noise annoyance of LFN is more intensive than noises without dominant low frequency components. On the other hand, noise annoyance of LFN may arise in lower sound pressure levels than other noises (Pawlaczyk-Luszczynska et al. 2003).

Meanwhile, several researches have shown that LFN affects performance (Saeki et al. 2004; Pawlaczyk-Luszczynska et al. 2005; Persson-Waye et al. 1997). Mental performance applies to different types of responses such as activities control, rapidity of response, learning, and intelligence (Belojevic et al. 2003). Many studies have found that exposure to noise lead to a performance decrement, although some such findings are controversial. Both the noise characteristics and the type of tasks probably influence a decrease in performance level. For instance, psychomotor task is less affected by noise in comparison with cognitive processes (Staal 2004). Some researchers have considered performance parameters as the number of correct responses, reaction time, and some noise exposure symptoms such as fatigue, headache, and diminished concentration (Persson-Waye et al. 1997; Saeki et al. 2004).

The stimulus-based approach of stress does not pay enough attention to the personal characteristics that influence the effects of noise on performance. Commonly, the effects of noise on performance are related to extra/-introversion, neuroticism, and noise sensitivity, although some of these findings are controversial (Belojevic et al. 2003). Because of different motivation threshold levels, noise tolerance in extra- and introverts is different. It has been shown that optimum noise levels for extraverts are higher than those for introverts (Geen 1984). According to Eysenck's theory, based on activation thresholds in the sympathetic nervous system, neurotic people (unstable) with low activation threshold are unable to control emotional reactions and become easily nervous or upset. Emotionally stable people, who have good emotional control, experience negative affect only in the face of major stressors. Neuroticism or emotional instability is not only related to noise tolerance, but neurotics and introverts are also more susceptible to noise damage (Belojevic et al. 2003).

There are many factors affecting mental performance of exposed persons to noise, and therefore, the study results are not consistent or, at times, even controversial. The present study was based on the assumption that LFN affects mental performance by creating noise annoyance in exposed persons; personality traits including extra-/introversion and neuroticism may influence noise annoyance. The aim of this research was to study the effect of LFN on mental performance and annoyance considering extroversion and neuroticism.

Materials and methods

Materials

Ninety students of Iran University of Medical Sciences, Tehran, Iran (54 males and 36 females), mean age 23.46 (SD=1.97), participated in the study. The personality trait of extra-/introversion was measured by using Eysenck Personality Inventory (EPI) in a standardized version for Iran (Eysenck and Eysenck 1964). This questionnaire consisted of 57 items with binary scale (yes and no). There are 24 items for extroversion, 24 items for neuroticism, and 9 items for the subject's sincerity in answering. Each item was assigned 0 or 1 point in extroversion, neuroticism, and lying scales. If the sums of points were more than 12 in extroversion and 10 in neuroticism, the subjects were considered as extravert and neurotic (unstable), respectively. A summation score in the lying scale of more than four indicates lack of accuracy and honesty in answers. Accordingly, two students were excluded from the study.

Mental performance of participants was measured by using computerized tests of Cognitrone and Stroop Interference Test (Vienna Test System 2004/2005). Cognitrone test was used for evaluating attention and concentration via identical comparison of figures. In other words, Cognitrone test was applied to assess the attention and concentration through comparison of figures with regards to their congruence.This test is based on Reulecke's theory (1991) that concentration is considered constant and is defined by three variables: energy, performance, and accuracy (Wagner and Karner 2003).

Stroop Interference Test (Stroop 1935) is a sensorimotor speed test registering speed performance when reading words and naming colors and the speed performance under color–word interference conditions (Puhr and Wagner 2004). Stroop interference effect occurs when one must read the color of the word.

Methods

Participant recruitment procedure was as follows: at first, an announcement was made on the news boards of different university departments, and the volunteer students were required to appear at the test hall. In this manner, 92 volunteers were generated, of which two were excluded because of the high score in sincerity subscale of Eysenck Personality Inventory. The first detailed explanation of the experiment's purpose was offered to the participants; possible risks due to the experiment were explained, and participants were required to sign a consent form. Next, hearing performance was tested by audiometer (MEVOX ASB15) inside an acoustic room, and if the average of hearing threshold level in 0.5, 1, 2, 4, and 6 kHz was less than 20 dB (normal hearing or <25 dB HL), students could participate in the study. They were then required to fill up the Eysenck Personality Inventory.

After filling up the EPI questionnaire, subjects appeared at the acoustic room, equipped with a personal computer monitor and the universal panel of Vienna Test System. They then started to perform Stroop and Cognitrone tests under quiet condition (Leq=10 dBA). LFN in 50 and 70 dBA was produced inside the acoustic room by Cool Edit Pro. 2.1. Some of the main sources of LFN are computers, printers, and air conditioner systems, usually known as quiet devices. In many administrative offices, the Leq=50 dB noise can be considered as quiet conditions (Belojevic et al. 2003). Meanwhile, based on the authors experience, the noise level in the relatively crowded offices is around Leq=70 dB. Therefore, two levels of 50 and 70 dB were used in this experiment. The reason of using two levels of LFN was to make a change in the mental performance of subjects. After 30 min, subjects performed Stroop and Cognitrone tests again. During performing tests, there was LFN as well. In other words, the exposure duration to LFN was 30 min plus test performance time. For reducing recall bias, half of the subjects were exposed to 50 dBA at first, and the others were exposed to 70 dBA. At the beginning of each test, sound pressure level was measured near the head of the subject in octave band frequency by B&K (model 2238). Figure 1 shows the results of octave band frequency analysis.

The response panel was used as the input device of computerized Cognitrone and Stroop tests. In Cognitrone, an animated instruction phase and an error-sensitive practice phase lead to the task itself. In this research, S11 form (no time limit, short form) of Cognitrone was used. In the test forms, with no limited working time, the respondent's task was to compare an abstract figure with a model and to decide whether the two were identical. Once the answer registered, the next item was shown automatically. It was not possible to skip an item or go back to a preceding

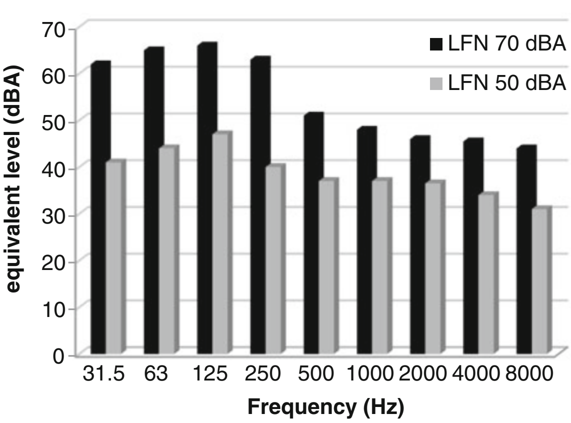

Fig. 1 Equivalent level of octave band frequency of LFN 50 and 70 dBA

one. Four figures were displayed on top, and one figure, displayed beneath. If one of the four figures was identical with the lower figure, subjects were to press the green bottom, and if the figures were not the same, they were to press the red bottom. Sum of hits, sum of correct rejections, and working time were considered as mental performance parameters in this test. Stroop test S8 form, which was used in this research, had two stages. In the first stage, participants must read the words without considering the color of the word and press the suitable button of the control panel. In the second stage, they must name the color of the word without paying attention to its meaning. Number of incorrect reactions in reading of incongruent words, number of incorrect reactions in naming of incongruent words, and working time were considered as performance parameters in Stroop test. Necessary instructions were given to the participants before performing the tests, and they were asked to act as fast and accurate as possible.

After participants were exposed to LFN, noise annoyance was directly measured after the test with a 12-scale self-report item (0 to 11). The higher point meant higher annoyance. Then, participants filled up a general questionnaire (demographic). All the trials were performed between 0800 and 1200 hours to unify the performance ability of subjects during the test.

Results

The number of extraverts, introverts, stable, and unstable participants were 70, 20, 48, and 42, respectively. The subjects were divided into three categories including less annoyed (25 students, 28.1 %), moderately annoyed (51 students, 56.3 %), and highly annoyed (14 students, 15.6 %).

The mean and standard deviation of performance parameters under quiet, LFN 50 dBA, and LFN 70 dBA are shown in Table 1. According to the results of this research, no significant differences were found between performance parameters under 50 and 70 dBA of LFN (Table 2), whereas most parameters had significant differences between subjects under quiet and noise (50 and 70 dBA). It was found that tests performance time under noise decreased compared to the quiet condition ($p<0.01$), whereas there were no differences in tests performance time between LFN 50 dBA and LFN 70 dBA. The results showed that sum of hits and sum of correct rejections (Cognitrone test) under LFN 50 and 70 dBA increased compared to silence ($p<0.0001$). One-way ANOVA test showed no significant differences in mental performance parameters of participants under acoustic conditions and between different groups of noise annoyance (Table 3). Furthermore Kruskal–Wallis test showed no significant association between noise annoyance and performance parameters ($p>0.05$).

Between groups, analysis showed that none of mental performance parameters were influenced by neuroticism, whereas extra/introversion had some effects on mental performance (Tables 4 and 5). Sum of hits in LFN 50 dBA, Stroop test working time of LFN 70 dBA, Cognitrone test working time of LFN 70 dBA, and working time under quiet in extraverts were higher than those in introverts. In other words, introverts conducted the test faster than extraverts.

Table 6 shows the distribution of extroversion and neuroticism with regard to noise annoyance. All introverts subjects were highly annoyed ($p<0.000$). No significant differences were found between performance parameters among female and male students in the study. Due to the age range being very narrow (average=23.5, SD=1.97), it was not possible to study

Table 1 Means and standard deviations of performance parameters under quiet, LFN 50 dBA, and LFN 70 dBA

Type of test	Performance parameters	Silence Mean (SD)	LFN50 dBA Mean (SD)	LFN70 dBA Mean (SD)
Stroop test	Number of incorrect reactions of reading incongruent	2.04 (2.10)	2.21 (2.11)	1.97 (2.21)
	Number of incorrect reactions of naming incongruent	2.38 (2.50)	2.18 (2.12)	2.24 (2.68)
	Stroop working time (s)	276.06 (46.83)	259.36 (44.19)	255.73 (45.79)
Cognitrone test	Sum of hits	21.68 (1.85)	22.86 (1.25)	22.66 (1.75)
	Sum of correct rejections	33.83 (2.22)	35.13 (1.31)	35.02 (1.16)
	Cognitrone working time (s)	152.26 (40.14)	119.00 (25.62)	116.11 (28.19)

Table 2 Comparison of mental performance parameters in different levels of low frequency noises and silence

Type of test	Performance parameters	Silence, LFN 50 dBA[a] *p* value	Silence, LFN 70 dBA[a] *p* value	LFN 50 dBA–LFN 70 dBA[b] *p* value
Stroop test	Number of incorrect reactions of reading incongruent	0.516	0.791	0.253
	Number of incorrect reactions of naming incongruent	0.000[c]	0.000[c]	0.961
	Stroop working time (s)	0.777	0.738	0.145
Cognitrone test	Sum of hits	0.000[c]	0.000[c]	0.267
	Sum of correct rejections	0.000[c]	0.000[c]	0.587
	Cognitrone working time (s)	0.000[c]	0.000[c]	0.209

[a] Wilcoxon's test

[b] Mann–Whitney test

[c] Significant at the 0.01 level

the association between the effects of LFN exposure on individuals' performance among different age groups.

Discussion and conclusion

This investigation showed that LFN (50 and 70 dBA) affects performance more than silence that it decreases test performance duration and increases the accuracy of answers (Tables 1 and 2). This is not consistent with Kjellberg and Wide's (1988) findings that noise at 51 dBA and higher frequency disturbs the performance. On the other hand, our study showed no significant difference between performance parameters under 50 and 70 dBA of LFN. Determining the level of noise that could decrease performance is difficult. It seems that exposure to continuous noise at 75–80 dB decreases performance. It has been reported that noise has a negative effect on accuracy, but no influence on speed, which is inconsistence with our results (Staal 2004).

Some of the results in this study can perhaps be explained by arousal theory. Arousability, which represents the activity level of the central nervous system,

Table 3 Relation between noise annoyance and mental performance under different noise levels

Type of test	Performance parameters	Noise annoyance	Silence Mean (SD)	*p* value	LFN 50 dBA Mean (SD)	*p* value	LFN 70 dBA Mean (SD)	*p* value
Stroop test	Number of incorrect reactions of reading incongruent	Low	2.67 (2.06)	0.504	1.57 (1.40)	0.695	1.11 (1.36)	0.539
		Moderately	1.82 (2.00)		2.22 (2.10)		2.28 (3.14)	
		Highly	2.75 (1.70)		2.40 (1.67)		2.00 (1.22)	
	Stroop working time (s)	Low	264.89 (37.83)	0.155	249.83 (42.46)	0.541	256.56 (34.74)	0.477
		Moderately	299.24 (55.114)		273.06 (54.03)		281.28 (60.30)	
		Highly	258.00 (48.39)		252.40 (50.87)		261.20 (49.48)	
Cognitrone test	Sum of hits	Low	21.78 (1.48)	0.874	23.14 (1.21)	0.355	22.78 (1.79)	0.603
		Moderately	22.06 (1.73)		22.88 (1.36)		22.94 (0.64)	
		Highly	22.20 (1.30)		23.80 (0.45)		23.40 (0.89)	
	Sum of correct rejections	Low	33.89 (1.69)	0.237	35.71 (0.49)	0.386	34.56 (1.67)	0.636
		Moderately	34.83 (1.34)		35.29 (0.99)		35.00 (1.08)	
		Highly	33.80 (2.17)		35.00 (1.00)		35.60 (0.89)	
	Cognitrone working time (s)	Low	161.56 (44.31)	0.879	119.57 (16.99)	0.498	121.72 (28.05)	0.919
		Moderately	162.72 (40.96)		117.24 (22.31)		123.03 (26.11)	
		Highly	172.20 (26.17)		104.80 (30.43)		127.60 (21.46)	

One-way ANOVA test

Table 4 Performance parameters under silence, LFN 50 dBA, and LFN 70 dBA, in stable and unstable subjects

Type of test	Performance parameters	Silence			LFN 50 dBA			LFN 70 dBA		
		Stable Mean (SD)	Mean (SD) Mean (SD)	*p* value	Stable Mean (SD)	Unstable Mean (SD)	*p* value	Stable Mean (SD)	Unstable Mean (SD)	*p* value
Stroop test	Number of incorrect reactions of reading incongruent	2.47 (2.40)	1.71 (1.79)	0.455	2.07 (1.91)	2.04 (2.39)	0.304	2.09 (1.99)	1.85 (2.39)	0.792
	Number of incorrect reactions of naming incongruent	2.41 (2.08)	2.53 (2.85)	0.988	2.17 (2.13)	2.10 (2.10)	0.949	2.19 (2.60)	2.28 (2.88)	0.731
	Stroop working time (s)	282.10 (49.75)	269.03 (42.79)	0.216	264.90 (44.78)	253.35 (44.51)	0.257	258.94 (48.99)	253.33 (43.04)	0.583
Cognitrone test	Sum of hits	21.70 (1.71)	21.60 (2.04)	0.664	22.77 (1.36)	22.84 (1.15)	0.921	22.36 (2.02)	22.83 (1.48)	0.522
	Sum of correct rejections	34.29 (1.39)	33.37 (2.77)	0.259	35.27 (0.98)	34.97 (1.58)	0.604	34.97 (1.01)	35.04 (1.32)	0.465
	Cognitrone working time (s)	157.49 (45.46)	145.32 (32.54)	0.169	258.15 (37.62)	259.36 (50.08)	0.689	253.94 (36.38)	256.29 (54.08)	0.865

Mann–Whitney test

Table 5 Performance parameters under silence, LFN 50 dBA, and LFN 70 dBA, in intro- and extraverts

Type of tests	Performance parameters	Silence			LFN 50 dBA			LFN 70 dBA		
		Introvert Mean (SD)	Extravert Mean (SD)	*p* value	Introvert Mean (SD)	Extravert Mean (SD)	*p* value	Introvert Mean (SD)	Extravert Mean (SD)	*p* value
Stroop test	Number of incorrect reactions of reading incongruent	2.50 (2.28)	1.96 (2.09)	0.387	2.73 (2.88)	2.09 (1.87)	0.543	2.30 (2.05)	1.87 (2.24)	0.825
	Number of incorrect reactions of naming incongruent	2.87 (2.33)	2.37 (2.55)	0.646	2.78 (2.29)	1.93 (2.01)	0.554	2.90 (3.78)	2.03 (2.30)	0.974
	Stroop working time (s)	268.50 (40.68)	270.12 (39.44)	0.199	257.82 (35.50)	258.46 (50.66)	0.951	244.03 (37.00)	266.20 (51.06)	0.035[a]
Cognitrone test	Sum of hits	21.56 (2.12)	21.67 (1.83)	0.086	22.78 (1.03)	22.81 (1.33)	0.031[a]	22.85 (1.34)	22.52 (1.89)	0.924
	Sum of correct rejections	33.68 (1.62)	33.85 (2.40)	0.396	35.26 (0.80)	35.08 (1.44)	0.960	35.00 (1.37)	35.01 (1.11)	0.772
	Cognitrone working time (s)	140.23 (32.47)	161.41 (43.23)	0.014[a]	112.95 (27.23)	120.46 (25.42)	0.295	108.18 (32.89)	123.27 (23.94)	0.020[a]

Mann–Whitney test

[a] Significant at the 0.05 level

fluctuates between sleep and alertness (Razmjou 1996) and adjusts human response to stimulus (Stokes and Kite 2001). Although, nowadays, there is no comprehensive agreement with arousal theory, and even it is said that this theory is not suitable for describing the relationship between noise and mental performance (Christianson 1992), yet according to this theory, low and high arousal (or low and high level of stress) causes decrement of performance (Yerkes and Dodson 1908). Increment of performance parameters in subjects exposed to LFN (in comparison to quiet condition) may show an increase in arousal level. It has been reported that noise causes increment of arousability by decreasing the extension of attention (Staal 2004). Lack of differences in mental performance parameters between LFN 50 and 70 dBA is likely related to arousability level of two groups that was not significantly different. According to Hockey's theory—based on arousal theory—noise through the motivation of analyzing processes affects performance. Hockey's theory identifies noise as a stimulus, which increases arousal level and performance. This increment continues to the point that over-arousal occurs, and after that point, performance decreases (Staal 2004). In other words, if an extensive range of noise levels were used in this research, the performance level would have been significantly different.

Improvement of participants' task performance, when exposed to noise, represents an increase in arousal. This finding is in disagreement with Giesbrecht's finding showing that complex task performance, such as mathematical calculations, decreases with enhancement of arousal (Giesbrecht et al. 1993), although the tasks applied in the present study are not that complex. This controversy is probably due to the level of required effort for Stroop and Cognitrone tests. According to Yeo and Neal (2004), the level of task difficulty is dependent on the level of effort.

There were no significant differences in performance parameters under silence and noisy conditions, in low, medium, and highly annoyed subjects. It has been reported that noise annoyance increases arousal and decreases processing capacity (Eysenck 1982). In addition, annoyance may pressurize persons to work faster in order to get rid of the annoying situations. This may decrease working time and accuracy, although according to Stokes et al. (1990) noise increases the speed of Stroop test because of tunneling of attention. Lack of a relationship between noise annoyance and performance parameters in the present study is probably because subjects were exposed to LFN in a short period, so they were not strongly annoyed.

Table 6 Distribution of neuroticism and extroversion with regard to noise annoyance

		Noise annoyance			*p* value
		Low (%)	Medium (%)	High (%)	
Neuroticism	Stable	8.9	24.4	66.7	0.678
	Unstable	12.5	17.5	70	
Extroversion	Introvert	0	0	100	0.001[a]
	Extravert	19.1	38.3	42.6	

χ^2 (chi-square) test

[a] Significant at the 0.01 level

There was a significant relationship between noise annoyance and extra-/introversion, so 100 % of extraverts were highly annoyed. In spite of some results (Ohrstrom et al. 1980), our study showed no significant relationship between neuroticism and noise annoyance (Table 6). The speed of tests was higher, and accuracy was less in introverts compared to extraverts. Extraverts' noise tolerance is more than in introverts, and extraverts prefer louder noise (Geen 1984). Therefore, it can be concluded that because of low threshold level of stimulation in introverts, the introverts' performance was more disturbed than the extraverts' performance. On the other hand, high arousal in introverts probably lead to reduced work time compared to extraverts (Dornic 1977), which means that introverts performed the tests faster to get rid of noise, and therefore, accuracy decreased.

In spite of our expectation, no significant relation was found between neuroticism and performance. Arousability level in stressful conditions is increased more than in normal situations in neurotic subjects and disturbed coping with noise. Furthermore, anxiety in neurotic people leads to diminished ability to deal with noise and other stressors. Some researchers have shown that the role of neuroticism in decrement of mental performance in complex tasks is more important than that of extra-/introversion (Belojevic et al. 2003). No significant differences were found between performance parameters in emotionally stables compared to neurotics, but extra-/introversion affected performance in the study subjects. This may be because of low task load and low complexity of

Cognitrone and Stroop tests. Noise disturbs deep mental processing but has no effect on or even improves shallow mental processing (Dornic 1975).

The findings of this study may be affected by the cognitive appraisal of the subjects. According to the transactional model (Stokes and Kite 2001), cognitive appraisal from threatening or ability to control a stressor was clearly related to the mental stress experience of individuals. Generally, cognitive appraisal of stress has an effect on performance, in a way that negative evaluation of the situation led to a negative output and positive evaluation led to increment of performance (Staal 2004). In this research, all participants were aware that the research was concerned with the effects of noise on mental performance. On the other hand, most of them were students of occupational health and environmental health courses and were aware of the hazardous effects of noise on individuals. Nevertheless, noise increased the performance showing that the students' awareness of harmful effects of noise did not influence the performance, which represents the evaluative cognitive of participants. They did not consider the noise as an impending harmful factor, which showed that the events did not cause stress itself, but evaluation of the event causes stress. Stress occurs when there is no ability to control the threatening factor (Lazarus 1990). Moreover, research shows that challenging events, and not threatening, make positive emotions and higher confidence (Skinner and Brewer 2002).

Authors believe that Stroop and Cognitrone tests are ideal for measuring and assessing disturbing factors on mental performance, because mental processing (analysis of stimulus and response) requires attention, a coincide interventional stimulus (for example, low frequency noise) which causes disturbance of task analysis and response to it, and therefore, it allow us to assess the effects of noise on mental performance. On the other hand, it seems that central information processing in participants was not disturbed by noise. The disturbing factors (such as noise) on central information processing, in high subjective load tasks, decrease the performance (Gamberale et al. 1990). It is reported that noise and other environmental factors decrease psychomotor task performance (higher-order cognitive task) (Stokes et al. 1990). Meanwhile, perceptual–motor task (lower-order cognitive task) is resistant to noise (Cohen and Weinstein 1981). As mentioned before, in the authors' opinion, the tests used in this research did not have a high level of complexity, and therefore, participants were not required to make much effort to handle them. Therefore, when exposed to noise, the arousal and performance status increased. Although noise increases arousability and performance at first, but if continued, adaptation occurs, and the level of arousal and performance decreases (Poulton 1979).

If we consider noise as a stressor that causes disturbance in normal tasks performance, although the stress concept in stimulus-based approach neglects personal characteristics, different situations and emotions influence effects of noise on performance (Stokes and Kite 2001). So, considering factors such as noise sensitivity, extra-/introversion, and neuroticism can lead to more accurate information.

This research showed that extra-/introversion influenced mental performance, resulting in an increase in accuracy and a decrease of performance time. There was no relationship between noise annoyance and mental performance. It seems that extroversion status has influenced mental performance in an independent way without being annoyed by noise. More research on this issue is recommended.

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