Original Article

Evaluating the effects of traffic noise on reaction time and rate of error in drivers' movement time estimation

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ABSTRACT

Aims: The present study aimed to investigate the relationship between traffic noise and drivers' reaction time (RT) and their error in estimates of movement time.

Materials and Methods: In over all, 80 university students with at least 3 years postlicense experience of driving were divided into two groups including traffic noise exposure and control group. S5 test of Vienna test system package was used for assessment of RT. In addition, time-movement anticipation was employed for measuring the rate of error in estimation of movement time before exposing to the traffic noise. After a 1-month interval, participants in the experimental group were exposed to traffic noise about 2 h and the tests were performed again for both groups.

Results: Accordingly, RT was statistically higher after traffic noise exposure for male and female. However, there was no significant difference between time of movement before and after exposure to traffic noise both for male and female ($P > 0.05$). In addition, no difference was shown between movement time, number of accurate estimates, and number of estimates with gross errors before and after of traffic noise exposure in experimental and control group.

Conclusion: The results suggest that traffic noise may be associated with poorer mental processing, which can result in longer RT during driving. Therefore, traffic noise would expose drivers to consequent accidents and incidents.

Key words: Driving, error, movement time, reaction time, traffic noise

INTRODUCTION

Development of the cities and technology accompanied by increase in the economical level of the people had led to rise in number of motor vehicles and consequently the noise pollution. Noise has been long introduced as a critical health problem.[1] Vehicle traffic can be considered as the most important cause of noise pollution in urban areas.[2] It is showed that in 2000, more than 44% of European populations were continuously exposed to road traffic noise of 55 dB and above, which has the potential for making damages to human health. In addition, social costs due to road traffic noise in Europe are estimated to be at least €38 annually.[3]

It is well-known that noisy environments can lead to inaccuracy of brain activities, inconsistency in intellectual tasks, and also impairment of conversation. In addition, noise

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can reduce the power of learning and increase errors related to mental activities.[4]

Traffic noise has various physical and mental effects, and can cause interferences in sleep and daily activities, and also may impact job performance negatively. Therefore, it can greatly decrease concentration and consequently increase traffic accidents. In addition, exposure to high level of traffic noise can cause deterioration of cognitive function (information processing, perception, and learning) among adults. Human error is the most important contributory factor in 57% of all traffic accidents. In this sense, several aspects of human-related factors can be investigated of which reaction time (RT) is one the most important factors.[5]

Reaction time varies for different tasks, and it can also change for even one task under different situations. Indeed, RT is a complicated behavior which is influenced by several factors.[6] Components of RT included time of processing and motor time. It is noted that the total time of processing is 500-800 ms. Motor time is the designated time for executing the selected response in which the responder should have muscular movement.[7]

Reaction time is considerably important during driving due to its role in determining the differences between safe and accident-causing driving.[6]

According to some driving accidents,[8] which are due to vehicle collision with the front car or object, the reason is slow reaction of driver to the visual stimulus. In a study, Chraif investigated the relationship between RT and rate of driving accidents and reported a significant correlation between these two variables.[8]

Regarding the above-mentioned issues and since the road traffic noise is one of the inevitable environmental pollutions, this study aimed to investigate the relationship between traffic noise and drivers' RT and also their error in estimates of movement time.

MATERIALS AND METHODS

The participants were 80 university students from Tehran University of Medical Sciences, aged between 19 and 28 years old (mean = 23.5; standard deviation = 3.5), including 40 males and 40 females. Volunteers, with at least 3 years postlicense experience of driving, were divided into two groups: Experimental group (traffic noise exposure) and control group. Traffic noise was measured at 90 points in zone number 6 in Tehran, using sound level meter Model 2238 (Made in Denmark). Each point was measured 4 high traffic times (2 times at 8-10 am and 2 times at 6-8 pm), each time for 5 min. The measurements were done according to the calculation of road traffic noise. The following instruments were employed for measuring RT and determining the rate of error.

Vienna test system

This package consisted of several performance tests including RT.[9] The package includes 10 test forms (S1-S10), each of them has its specific combinations of visual and audible stimuli, which evaluate concentration and alertness. In the present study, the test S5 was employed for assessing RT (including RT and motor time) in millisecond.

The test is formed by two stimuli, including red/yellow light and an audible signal (noise with frequency of 1000 Hz), which 6 moods can be made by their combination. In this regard, the participant is asked to react when he/she perceives either red or yellow lights together or a yellow light and a 1000 Hz sound together. Each participant faces with 48 situations, which should react only to 16. Total duration of the test is 9 min and the time of appearing each stimulus is 1.5 s. The reliability (Cronbach's alpha) of this test for RT is reported to be between 0.83 and 0.98 and for motor time between 0.84 and 0.94.

In the present research, the RT is assumed as the time interval between appearing the signal and the start of mechanical response. It was expected that each participant shows reaction only when either red or yellow lights together or a yellow light and a sound together appear. During the tests, participants were asked to put their finger on a golden button (rest button) and when they see the stimuli put it on the black button (mounted on the panel control) and then put it on the golden button again. Using the rest button and the reaction button can determine the difference between movement and RT.

Time-movement anticipation

One of the most important functions in many aspects of the modern life is the ability of individuals in imaging speed and estimating movements of an object in the space accurately.[10] For instance in traffic psychology, estimation of speed and movement of a vehicle during driving is of high importance. In this sense, for measuring the rate of error in estimation of movement time of an object in space, software time-movement anticipation (ZBA) from package of Vienna test system was used. This test asks the participant to estimate the velocity and time of reaching an object to a desired point. ZBA has four types (S1-S4), which in our study the type S4 was employed. Regarding its administration, a green ball appears on the screen which starts to move from right or left. At an unpredictable time, the ball suddenly disappears and simultaneously a vertical red line appears on the opposite side [Figure 1]. The participant asked to press the related button in the moment when she/he thinks that the ball will be reached the red line. Reliability of each component of this test is different. However, the minimum and maximum reliability for the average error rate for time of the linear path is 0.69 and 0.98, respectively. This type of test has the most similarity to the real movements in driving.

In the present research, participants in groups of experimental and control performed RT test and test of number of errors in estimation of movement time (ZBA), before exposing to the traffic noise. After a time interval of 1-month, participants in the experimental group were exposed to traffic noise in the acoustic room about 2 h and performed both tests again. It should be noted that, the sound pressure level of traffic noise in the acoustic room was 72.9 dB (network A). Since the frequency distribution of traffic noise that was broadcasted in the acoustic room differed from the real traffic noise, sound pressure level was measured several times for the frequency analyses purpose [Table 1]. All of the study procedures, except for broadcasting the traffic noise, were done for the participants in the control group.

RESULTS

In the present research, 80 university students (40 male and 40 female) with at least 3 years of experience in driving participated in two groups (traffic noise exposure and control).

According to results as presented in Tables 2 and 3, there is a significant difference between RT before and after traffic noise exposure for male and female ($P < 0.05$). However, no significant difference was observed between time of movement before and after exposure to traffic noise in both male and female ($P > 0.05$) [Tables 2 and 3].

Statistical test (*t*-test) was applied for comparing participants' movement time, number of accurate estimates and number of estimates with gross errors, before and after traffic noise exposure. As shown in Table 4, no statistical difference was shown between movement time, number of accurate estimates, and number of estimates with gross errors before and after of traffic noise exposure in experimental and control groups ($P > 0.05$).

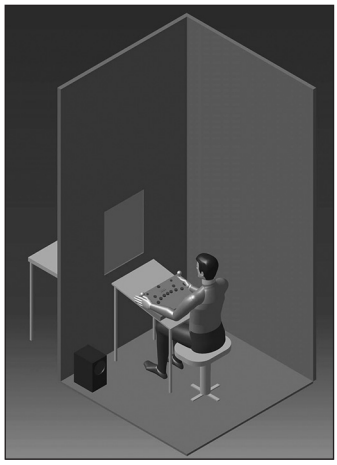

Figure 1: The three-dimensional stimulation of a participant in the acoustic room

DISCUSSION

The present research investigated the possible variation of RT due to road traffic noise exposure. RT is the mental processing speed of environmental stimuli, which can be influenced by factors including individuals working environments. Reduction in speed of mental processing can lead to increase in RT, which is of high importance in safety critical jobs such as driving.

Overall, results of this study confirmed 54.8 and 46.6 ms increase in RT after traffic noise exposure for female and male, respectively. According to literature, such increase in RT can consequently increase the braking time.[11] Driving is among job which requires a rapid response to

Table 1: Frequency analyses of traffic noise in the acoustic room

Frequency (Hertz)	31.5	63	125	250	500
Sound pressure level (dB)	67.6	50	73	67	66.5
Frequency (Hertz)	1000	2000	4000	8000	10,000
Sound pressure level (dB)	65	54	50	40	35

Table 2: Mean reaction and movement time (ms), before and after traffic noise exposure for female, paired samples *t*-test

Variables	Experimental group		Control group	
	Mean ± SD	*P*	Mean ± SD	*P*
Reaction time, before traffic noise exposure	561.2±88.2	0.000	585±139	0.281
Reaction time, after traffic noise exposure	616±88.5		587.5±141	
Movement time, before traffic noise exposure	206.5±39.25	0.872	200±56	0.106
Movement time, after traffic noise exposure	205.9±41.3		203.84±59.8	

SD: Standard deviation

Table 3: Mean reaction and movement time (ms), before and after traffic noise exposure for male, paired samples *t*-test

Variables	Experimental group		Control group	
	Mean ± SD	*P*	Mean ± SD	*P*
Reaction time, before traffic noise exposure	555.7±71.35	0.001	553.4±94.7	0.169
Reaction time, after traffic noise exposure	602.3±85.9		556.29±91.55	
Movement time, before traffic noise exposure	169.04±64	0.051	169.5±33.77	0.502
Movement time, after traffic noise exposure	161.72±67.6		170.29±35.94	

SD: Standard deviation

Table 4: Comparing mean estimates of movement time, number of accurate estimates, and number of estimates with gross errors, before and after traffic noise exposure, for female, paired samples *t*-test

Variables	Experimental		Control	
	Mean ± SD	*P*	Mean ± SD	*P*
Estimates of movement time, before traffic noise exposure	0.626±0.22	0.642	0.578±0.268	0.369
Estimates of movement time, after traffic noise exposure	0.650±0.3		0.586±0.247	
Number of accurate estimates, before traffic noise exposure	2.25±1.95	0.701	2.3±1.09	0.86
Number of accurate estimates, after traffic noise exposure	2.4±1.72		2.33±0.85	
Number of estimates with gross errors, before traffic noise exposure	2.15±2.21	0.298	2.4±1.61	0.743
Number of estimates with gross errors, after traffic noise exposure	1.74±2.41		2.45±1.6	

SD: Standard deviation

visual signals such as pedestrian, front vehicle, etc.[12] It is stated that 40% of road accidents are due to front-to-rear end collisions.[11]

If the brake light of the front vehicle be considered as a visual stimulus, the driver must break after viewing and processing this stimulus. Therefore, what is important in this procedure is the speed of mental processing, which can be influenced by environmental factors. Overall, the findings of this study showed a considerable increase in RT after exposing to traffic noise, which is in accordance with the results of several preceding studies.

Strick investigated the effects of different level of music on the drivers' RT and observed 0.12s discrepancies between RT with music for noise at 0 dB and noise at 95 dB.[11] Han *et al*. studied impacts of noise of 90 dB(A) on thinking performance and observed prolonged RT after 2 h of noise.[13] In a driving simulation task by Richard *et al*., higher RT was observed for a search task while it was simultaneously occurred with an auditory task.[14] In another study, Trimmel and Poelzl have highlighted that background noises raise RT compared to that without noise (752 ms vs. 696 ms).[15] Marks and Griefahn investigated performance through a switch test after exposure to nocturnal traffic noise. They found that there was a strong trend toward longer RTs after noisy nights.[16]

However, there are controversial related studies as well. Using the Cognitrone test from Vienna test system, Alimohammadi *et al*. (2013) surveyed the effects of road traffic noise on mental performance and reported no significant difference between the mean of working time under quiet (56.30 ± 25.00) and that under traffic noise (61.90 ± 21.60). Bellinger *et al*. investigated the effects of music on RT and observed no increase in the RT.[17] In the study by Bellinger *et al*., the music was broadcasted during the test while in our study after 2 h exposure, the noise was stopped and then the test was performed.[17] According to literature, performance impairments occur when an individual exposes to intermittent noise for a long period. In this study, the increase in RT can be attributed to the continuous exposure (2 h) to traffic noise which is considered as an intermittent noise.

Regarding movement time, no significant difference was shown between movement time before and after exposure to traffic noise, which seems to be due to lack of effects of noise on neurotransmission from spinal cord to the target muscles.

Additionally, as presented in Table 4, there was no significant relationship between estimation of movement time before and after traffic noise exposure (for experimental group: $P = 0.642$, for control group: $P = 0.369$). In ZBA test, the participants should calculate the time that a stimulus reaches a particular point. It is worthwhile to note that this calculation can be considered as a problem-solving process. Conrad in study investigated the effects of intermittent noise on problem solving and showed that people who are exposed to intermittent noise have lower problem solving ability comparing those who are exposed to continuous noise and also the performance of problem solving ability had remained at a good level during continuous noise which is not consistent with the results of the present research.[18]

It seems that this is may be due to this fact that we did not consider the types of individual's personality characteristics. Previous studies have shown that the quality and quantity of information processed in extraversion and introversion people are different, which can be explained on the basis of arousal theory.[19]

Belojevic *et al*. examined the mental arithmetic power of 123 students under quiet (42 dB(A) Leq) and noisy conditions (88 dB(A) Leq), considering their personality traits. Accordingly, it was found that noise can improve the speed of arithmetic power of extroverted people (447 ± 137 (s) in noise and 482 ± 161 (s) in quit).[20]

In the ZBA test, two variables of accurate estimates and estimates with gross errors were measured. As mentioned in Table 4, there was no significant difference between the average of accurate estimates before and after traffic noise exposure. Similarly, Marks and Griefahn reported error rate to be unaffected after nocturnal traffic noise exposure.[16]

Nevertheless, the mental arithmetic power of participants cannot be judged based on these two variables due to the effects of training and the six trials before performing the tests which would decrease the number of estimates with gross errors. In addition, accurate estimation of the time that the ball reaches the target point is very difficult. Therefore, the effects of traffic noise on the changes of these two variables cannot be observed.

CONCLUSION

The present research manifested that traffic noise exposure increases RT rather than quiet condition, which may be due to reduction in mental processing of the participants. However, no difference was observed between movement time, number of accurate estimates, and number of estimates with gross errors before and after traffic noise exposure. Overall, many factors (such as noise characteristics, personal sensitivity, nature of tasks, personality trait, etc.) may affect mental performance of exposed persons to noise which limit the generalizability of the obtained results. Therefore, more research on this issue is strongly recommended.

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