Research Article

The Effect of Traffic Noise on Divided Attention and Perception Concerning Individual Role Differences: An Experimental Study

Ahmad Mehri[1], Mohammad Amin Rashidi[2], Amir Hossein Rashidi[3], Milad Abbasi[4], Farough Mohammadian[5*], Kamaladdin Abedi[5], Ebrahim Darvishi[5]

[1.] *School of Public Health, Hamadan University of Medical Sciences, Hamadan, Iran*
[2.] *Student Research Committee, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran*
[3.] *Department of Audiology, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran*
[4.] *Social Determinates of Health Research Center, Saveh University of Medical Sciences, Saveh, Iran*
[5.] *Environmental Health Research Center, Research Institute for Health Development, Kurdistan University of Medical Sciences, Sanandaj, Iran*

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Highlights

- Introverted individuals had a better performance in traffic noise
- Stable individuals had a better performance in traffic noise
- Capacity and speed perception do not change in unstable individuals in traffic noise

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*** Corresponding Author:**
Environmental Health Research Center, Research Institute for Health Development, Kurdistan University of Medical Sciences, Sanandaj, Iran.
F.mohammadian1986@gmail.com

ABSTRACT

Background and Aim: Noise pollution is one of the urban problems that can affect the exposed individuals' cognitive function. This study set to investigate the impact of traffic noise on drivers' cognitive variables including perceptual capacity, speed of perception, and divided attention concerning the role of individual orientation and neuroticism.

Methods: This study recruited 35 male student participants. The Eysenck personality questionnaire was used to evaluate the participants' personalities (neuroticism and extroversion). Participants were then exposed to traffic noise, and the Adaptive Tachistoscopic Traffic Perception Test (ATTPT) was performed to assess their capacity and speed of perception. The Peripheral Perception Test (PPT) was also conducted to evaluate the divided attention using the Vienna test system software.

Results: Introverted and stable individuals had better performance in perceptual capacity and speed of perception tasks after exposure to traffic noise. However, these effects were not observed in extrovert and unstable individuals. This study also showed no significant alterations in variables in extroverted (introverted/extroverted) subjects with neuroticism (unstable/stable) concerning divided attention tasks after traffic noise exposure.

Conclusion: This study showed that divided attention in extrovert individuals with neuroticism was not influenced by traffic noise exposure. But perceptual capacity and perception speed was influenced by traffic noise in introverts and unstable subjects.

Keywords: Traffic noise; divided attention; perception; individual differences

Introduction

Nowadays, noise pollution is one of the urban problems, and traffic noise is recognized as an important cause of pervasive noise pollution [1]. Traffic noise is one of the environmental stressors that affect human health based on parameters including exposure time, traffic volume, etc. The most important effects of traffic noise are classified into four categories: physical, physiological, psychological, and cognitive functions [2]. According to the World Health Organization report, about 65% of European Union citizens are constantly exposed to traffic noise [3]. Results of a systematic study performed in Serbia showed that over a 30-year period, the ambient noise levels during the days and nights increased by 11 to 16 dB A and 10 to 14 dB A, respectively [4]. A study in 2007 to determine the traffic noise pollution levels in Tehran was done, this study focuses on Emam Khomeini Square, one of the most crowded squares, as well as its seven connecting streets, which see heavy traffic during the day. To adequately reflect the many acoustically commercial situations, 115 measurement places were chosen along the city center's roadways, pavements, and shopping districts. The street measuring points were chosen at a distance of two meters from the vicinity driving lane, where the occupants were waiting for the cab, and the pavement, barrier, and shop measuring points were chosen at an average distance of seven, ten, and twenty meters from the nearest driving lane, respectively. The measurements were taken over the course of a week, beginning on Saturday morning and ending on Friday evening. They found that using sex to nine random day sampling, they could get 96 to 99 percent noise level accuracy at 75 dB A to within 2 dB A range [5]. In another study in 2016, to measure exposure to traffic noise, traffic noise was recorded from 5 points in District 6 of Tehran for two hours by a Sony voice recorder model ICD MX20. Simultaneously with the voice recording, the analyzer sound level meter model CEL-450 was installed on a base 120 cm above the ground and at a distance of two meters from the street edge. An equivalent sound level was measured in the slow time network and frequency network A, where the average sound level measured was approximately 73 dB A, which was higher than the WHO-recommended sound level (55 dB A) [6]. There are ambiguous complex and multidimensional relations between noise exposure and cognitive function, which are not completely understood [7]. Tao showed that noise causes impaired cognitive function [8], while other studies have shown that it improves cognitive function [9]. In a review study by Gawron including 58 studies on noise and cognitive function relations, the findings were as follows: in 29 studies noise had negative effects on cognitive function, in seven studies, noise improved cognitive function, and there was no change in 22 studies [10].

Personality traits in individuals are a relatively stable pattern of thoughts, feelings, and behaviors that reflect the response tendency under certain circumstances through a particular method [11]. Personality traits generate serious changes in neuroanatomical and physiological systems. Two important characteristics related to individuals' personality traits are extroversion/introversion and neuroticism (instability/stability). Extroversion is closely related to the level of chronic cortical activity and refers to a variety of external orientations that cause a person to pay significant attention to what is going on around him; therefore, his energy concentrates on surrounding individuals, objects, and phenomena. Introversion is also a person's orientation toward him/herself and makes him/her sensitive to his/her own feelings (emotions) and experiences [12]. Eysenck stated that introverts have more potential for arousal and their concentration is more affected than extroverts [11]. Dobbs et al. believe that introverts experience a greater reduction in cognitive function than extroverts in exposure to noise [13]. But the results of a study conducted by Burtăverde and Mihaila showed no significant difference in cognitive function between introverts and extroverts [14]. Neuroticism is considered a dimension of human temperament. Individuals with neuroticism are more impulsive in confrontation with stressors and have poorer self-control capability in such circumstances. They express negative emotions such as anxiety, fear, irritability, anger, and sadness in the face of stressors which lead to a belief in the inability to cope with challenging events, and subsequently, they cannot present a proper response to such stressors [11].

Cognitive activities including judgment and decision-making, visual search behavior, awareness and attention process, and recall strategy can be affected by environmental stressors. Attention, the ability to concentrate on a particular task, is one of the important stages of cognitive functionality; in other words, attention is responsible for data selection and transfer between the memory system and data processing in working memory. Attention is categorized into the following classes in the most accurate classification systems: maintained attention, divided attention, alternative attention, and selective attention [15]. In many daily activities, especially driving, individuals must pay attention to more than one stimulus simultaneously. Therefore, divided attention plays a very important role in our daily activities [16].

Considering the importance of traffic noise and the lack of a comprehensive study on the effect of traffic noise on divided attention, perceptual capacity, and speed of perception, the present study was performed to determine the effect of traffic noise on cognitive functions including divided attention, perceptual capacity, and speed of perception concerning the role of differences in personality traits (extroversion/introversion, neuroticism).

Methods

Study design and research community

This experimental study was performed in the Trauma Research Center of Tehran University of Medical Sciences with the ethics code number of IR.MUK.REC.1400.004. Thirty-five male students with a mean age and standard deviation of 26.12(2.1) years participated in the study.

The following were the study's inclusion criteria: having a personal car and a valid driver's license (due to the nature of the cognitive tests), no history of smoking or taking medication, eight hours of uninterrupted sleep the night before the test, refraining from drinking tea, coffee, or caffeinated beverages, and using chocolate within two hours of the start of the test, and giving informed consent.

The study was performed in the following steps: first, the participants completed the Eysenck personality questionnaire to identify their personality types, and then they remained in a quiet laboratory environment for one hour before administering the cognitive function tests. Two weeks after the first test, the cognitive performance tests were repeated. The difference is that in the second stage, the participants were exposed to the recorded traffic noise for 1hours before the PPT and ATTPT tests.

Eysenck personality inventory

The extroversion/introversion personality trait was assessed using a standardized version of the Eysenck personality inventory for Iran [17]. This questionnaire has 57 questions that were graded on a binary basis (yes and no). Extroversion is measured with 24 items, neuroticism is measured with 24 items, and honesty is measured with 9 items. Extroversion, neuroticism, and dishonesty measures were used to assign 0 or 1 point to each item. The respondents were classified as extrovert and neurotic (unstable) if their sums of scores were greater than 12 in extroversion and 10 in neuroticism. A summing score of greater than four on the lying scale shows that the responses were not accurate or honest. The internal consistency of scales based on test-retest procedures ranged from 0.80 to 0.90, according to the reliability test. In an Iranian investigation, the scales of the Eysenck personality questionnaire were found to be reliable in the range of 0.56 to 0.78 [17].

Peripheral perception test

Participants' cognitive function was assessed using a computerized version of the PPT developed by Schuhfried Co. in Australia. A field of vision and a divided attention paradigm are used in the PPT. A horizontal moving red ball (reference value) on the screen must be monitored with a moving cross in the middle of the visual field (actual value). Diode panels are positioned in the left and right peripheral vision regions, causing the sensation of moving lights. A vertical line of diodes appears in the periphery from time to time. Participants must use a control gadget to track the real value while simultaneously seeing a vertical line form in the peripheral vision and pushing a foot pedal. An infrared camera measures the distance to the screen (at least 60 cm). The absolute divergence between the actual and reference value is used to calculate the divided attention. The visual field is defined as the largest field angle at which vertical lines of diodes may be perceived in relation to the screen's distance. The reliability coefficients for visual field and divided attention are 0.96 and 0.98, respectively.

The main and secondary activity, or double activity approach is used to test peripheral visual perception: the respondent's attention is kept in the center of the visual field by forcing him to complete a tracking task. At the same time, the respondent is exposed to peripheral light stimuli and is asked to react selectively to them. As a result, the exam is divided into two parts: a center tracking task and a peripheral perception task. A peripheral display consisting of vertical and horizontal rows of light diodes, via which light stimuli move from the center of the visual field to the periphery, is included in the computerized testing apparatus. A foot pedal must be depressed when a vertically blinking column with a blink speed of 60 ms emerges and is visible for 1040 msec. On the monitor, it displays the tracking work that must be accomplished at the same time. An ultrasonic distance sensor detects the distance in centimeters between the monitor and the respondent's eyes each time the pedal is pressed.

Then, the participants' fields of view were measured according to the distance between their eyes and monitor as well as their reaction to the environmental stimuli. Note that in these measurements, the distance between the participants' heads and the monitor should be 30 to 60 cm; otherwise, the system would give the participants a related warning. The number of vertical blinking's in this test included 40 stimuli (20 left/20 right) [18].

Adaptive tachistoscopic traffic perception test

An object perception test was developed by the ATTPT Schuhfried Co in Australia. For a brief period (700–1300 ms), traffic-specific pictures of various intricacies are displayed. Participants must choose whether they contain 1) autos, 2) bicycles, 3) pedestrians, 4) road signs, or 5) traffic lights. The dependent measure for perceptual speed is the number of properly-identified items weighted by the complexity of the figure. The coefficient of dependability is 0.80. The ATTPT test evaluates visual observational ability and proficiency in gaining an overview, as well as the visual orienting ability and perceptive speed. The items are constructed utilizing a clear, theory-driven logic that is based on a thorough examination of the cognitive processes involved in taking the test. The Rasch model was used to create and assess 84 items. Stimuli are provided adaptively, which means that after an initial phase, the respondent is presented with items that are more customized to his skill level. In this test, the percentile rank is presented together with the score according to the person's parameters. Because the Rasch model is legitimate, it provides dependability in the sense of internal consistency. The measurement precision is set at 0.49 crucial standard error of measurement. A high score indicates a well-developed ability to assess situations quickly and accurately, while a low score indicates slower or less accurate visual observational ability and skill in gaining an overview.

The respondent is shown photographs of traffic scenarios in the ATTPT test following a brief signal that serves as a cue. The respondent is told to pay close attention to the images and remember what they depict. The respondent next selects the appropriate fields to indicate what he has observed in the photographs. Five options are shown for each image: 1) pedestrians, 2) automobiles, 3) motorcycles, mopeds, and cyclists 4) signs of traffic 5) traffic lights. As for the first item, you will be given a medium-difficulty task. The first item's response is recorded and graded. If the answer was accurate, a more difficult item is picked; if the answer was erroneous, a less difficult item is chosen. The following item is always selected based on the respondent's current skill level estimation. The test is repeated until the standard measurement error falls below a pre-determined level or there is a strong statistical assurance (95 percent) that the latent dimension is greater than the predefined threshold value for traffic-psychological objectives. It is worth mentioning that not all the traffic situations are shown for the same length of time during the administration of the test: the picture presentation time varies between approx. 700 ms and 1300 ms. This variation is not arbitrary but serves to optimize the test's precision of measurement. As the construction rationale of the ATTPT makes clear, picture presentation time is one of the design elements that determine the difficulty of an ATTPT item. By deliberately changing the length of time for which a picture is shown, the difficulty of that item can be adapted in a controlled manner, within certain limits. This attribute is used by the ATTPT's adaptive algorithm to change the available items to the precise level of difficulty required to yield the most information about the respondent's ability. Finally, the person parameter of the variable acquiring an overview is a measure of the precision and speed with which visual observational ability and skill in gaining an overview, as well as visual orientation ability, are measured. As a result, this test parameter expresses perceptual capability and speed the most clearly [18].

Applied traffic noise

The analysis of the central frequencies for an octave band in A-weighting is presented in Figure 1. It is noteworthy that after recording the sound using a three-dimensional speaker, the traffic sound level was spread in the laboratory environment, and we placed the sound level meter device around the participants' ears and the speaker was adjusted so that 73 dB of noise was broadcasted. After this stage, a noise analysis frequency was performed, which was not significantly different from the real environment.

Data analysis

For data analysis, SPSS software version 17 was utilized. The Kolmogorov-Smirnov test validated the dependent variables' normal distribution. The quantitative variables were described using mean and standard deviations, whereas the qualitative variables were described using frequency and percentage. P-values of 0.05 or above were considered statistically significant. To assess cognitive performance measures before and after traffic noise exposure, the paired samples t-test was utilized.

Results

According to Eysenck questionnaire results, individuals were psychologically divided into introverted and extroverted groups (n=22 and n=13, respectively) and unstable and stable categories (n=15 and n=20, respectively). The results of this questionnaire are presented in Table 1.

The participants were divided into introverted and extroverted individuals based on the Eysenck questionnaire (Table 2), and the results were then analyzed using paired t-test approaches. The comparison of perceptual capacity and speed of perception variables differences in the ATTPT test in a quiet environment and in exposure to traffic noise in introverts shows a significant effect of traffic noise on this variable (p=0.018). It indicates that introverts focus more on perceiving traffic images task in traffic noise exposure as a stressor than in a quiet environment. However, in extroverts, the effect of traffic noise on perceptual capacity and speed of perception was not statistically significant (p=0.233).

According to the Eysenck questionnaire, the subjects were divided into two categories: stable and unstable (Table 3), and the data were then analyzed using a paired t-test approach. The comparison of the variable differences between the perceptual capacity and speed of perception in a quiet environment and after traffic noise exposure in unstable subjects shows that noise has no significant effect on the perception capacity and perception speed in these subjects (p=0.124). This variable caused improvement in the perception capacity and perception speed in stable subjects in the face of traffic noise (p=0.030). Regarding the differences in vision, tracking deviation, incorrect reaction, and omitted reaction variables in quiet environments and traffic noise exposure, no statistically significant changes were observed in the divided attention parameter for this group of participants (p>0.05) which indicates that traffic noise does not affect the divided attention in stable and unstable subjects.

Discussion

The goal of this study was to learn more about the impact of traffic noise on cognitive performance and how extroversion-introversion and stability-instability qualities play a role. To process their required information in confrontation with environmental stresses such as noise, people need to respond by adaptive behaviors, including divided attention and perception speed, and capacity toward stimuli [19]. Noise exposure as a stressor has been reported to interfere with the performance of visual search activities as well as the speed and accuracy in response to a stimulus.

According to cognitive-evaluation theory, the effect of stress on individuals is related to individuals' attitudes toward the stress, so people with different personality types show different reactions to the same stressors [20]. Also, based on the person-in-context model, the personality type may influence the arousal selection in high-stress situations. Therefore, neuroticism is one of the personality type variables. Neuroticism is associated with the ability to cope with stress in trauma and is an important risk factor in stress-related disorders [21]. The differences between the field of vision, deviation tracking, incorrect reactions, and omitted reactions in stable and unstable people were not statistically significant in quiet environments and traffic noise conditions with regard to peripheral perception activity. The findings are consistent with the results of a study by Alimohammadi et al. [5], showing no correlation between neuroticism and performance. Macleod and Mathews [22] demonstrated that stress in unstable individuals disrupts the data processing activities which lead to the constriction of environmental attention. They suggested that anxiety causes deficiencies in cognitive functions with resultant deviations in ongoing activities through allocating mental resources to unrelated activities, which is inconsistent with the current results. Another study showed that neurotic persons were not irritated by the traffic noise and there was no change in their performance, which is directly correlated to the present results [23]. These explanations demonstrate that the current findings are in contradiction with the attentional control theory that says stress in anxious people is an effective factor in reducing their attention [24].

There was no significant difference in ATTPT activity with increasing activities and workload in unstable people in a quiet environment and traffic noise exposure, but in stable people, there was better performance in the face of traffic noise. These findings are significantly correlated with evaluations in several studies [25, 26], which indicated that unstable people had a worse performance and lower motivation in assigned tasks in the face of stress compared to stable individuals. Also, Osorio et al. showed that stress in unstable people causes a defect in cognitive function due to the allocation of mental resources to irrelevant activities, which results in deviation in ongoing activities [27]. One of the noticeable points was the violation of the chronic distance hypothesis. This hypothesis states that people with a high level of instability have a motivation suppressive tendency, and performance degradation is evident in them [28]. In gen-

Table 1. Number of participants in Eysenck questionnaire

Sections eysenck	Subsections eysenck	No.(%)
Personality	Introvert	13(37)
	Extrovert	22(63)
Neuroticism	Unstable	15(43)
	Stable	20(57)

eral, the results emphasize the triple vulnerability theory; in this theory, the role of neuroticism is highlighted as an underlying factor that causes abnormalities such as unpredictability and uncontrollability [29]. In a meta-analysis by Connor-Smith and Flachsbart, the negative impact of neuroticism (instability) on cognitive function is identified [30].

Based on PPT and ATTPT tests' results in stable and unstable individuals, there is a direct relationship between instability and noise sensitivity. Accordingly, the effect was not evident in simple PP activities, whereas it was identified in complex ATTPT tests. The perceptual capacity and speed of perception increased in stable subjects despite the noise, but no significant change was observed in unstable individuals [31]. Also, Thomas showed that based on Yerkes-Dodson law, background noise may over-arouse noise-sensitive individuals, degrade their performance, and provoke a sense of vulnerability in them [32]. Highly sensitive persons (unstable individuals) act like low-sensitive people in simple cognitive activities but perform clumsily in complex activities that require decision-making in a limited timeframe. The reason can be a decrease in energy for filtering out the noise/annoying factor or excessive stimulation and consequently loss of functional ability [33]. The discrepancy between the present results and other studies may be explained by Macleod and Mathew's study [22], which suggested that such divided processing with threat-based cues is performed under certain conditions and in individuals with outstanding anxiety characteristics.

Despite changes in the mean differences for the field of vision, tracking deviation, incorrect reactions, and omitted reactions variables in quiet environments and after traffic noise exposure, there were no statistically

Table 2. The results of the adaptive tachistoscopic traffic perception test and peripheral perception test between introverted and extroverted individuals

Personality	Test	Variables	Mean(SD)		p*
			Silent	Noise	
Introvert	ATTPT	Perceptual capacity and speed of perception	–0.44(0.92)	0.32(0.94)	0.018
		Field of vision	168.31(19.84)	169.4(21.88)	0.572
	PPT	Tracking deviation	10.92(13.02)	7.92(2.53)	0.444
		Incorrect reactions	0.54(0.66)	0.92(0.95)	0.268
		Omitted reactions	9.62(8.25)	9.08(7.59)	0.790
Extravert	ATTPT	Perceptual capacity and speed of perception	–0.33(0.67)	–0.15(0.88)	0.233
		Field of vision	172.91(14.11)	172.82(13.60)	0.971
	PPT	Tracking deviation	6.41(1.33)	7.00(2.53)	0.258
		Incorrect reactions	1.64(1.81)	2.09(3.25)	0.582
		Omitted reactions	7.95(6.63)	7.18(6.92)	0.617

ATTPT; adaptive tachistoscopic traffic perception test, PPT; peripheral perception test

* Independent Paired sample t-test

Table 3. The result of the adaptive tachistoscopic traffic perception test and peripheral perception test between unstable and stable individuals

Neuroticism	Test	Variables	Mean(SD)		p*
			Silent	Noise	
Unstable	ATTPT	Perceptual capacity and speed of perception	–0.50(0.64)	–0.057(1.15)	0.124
		Field of vision	174.93(11.95)	177.87(7.75)	0.406
	PPT	Tracking deviation	6.47(1.30)	7.40(2.92)	0.195
		Incorrect reactions	1.53(2.03)	2.20(3.91)	0.568
		Omitted reactions	6.73(5.97)	6.00(5.90)	0.748
Stable	ATTPT	Perceptual capacity and speed of perception	–0.27(0.80)	0.08(0.72)	0.030
		Field of vision	168.40(18.80)	166.80(20.30)	0.285
	PPT	Tracking deviation	9.30(10.63)	7.30(2.28)	0.426
		Incorrect reactions	1.00(1.12)	1.25(1.07)	0.489
		Omitted reactions	9.95(7.86)	9.30(7.76)	0.620

ATTPT; adaptive tachistoscopic traffic perception test, PPT; peripheral perception test

* Independent Paired sample t-test

significant differences in these variables in introverts and extroverts ($p>0.05$), indicating that traffic noise does not affect divided attention in introverts and extroverts. One study showed that the extroverts' and introverts' attention was not significantly affected by noise exposure [34]. Also, a study by Kou et al. showed no significant impact of extroversion/introversion on the mental response of people in the face of traffic noise [35], which is consistent with our study. But Gallagher and Vella-Brodrick showed that extroversion can influence attention through its adverse effects [36]. Also, Dobbs et al. [13] demonstrated that individuals with high levels of arousal show better performance than introverts, which contradicts the current findings. Perhaps, the differences in the findings compared to some other studies can be attributed to factors such as the differences in the type and level of noise, the complexity of the activity, the type of activity (multitasking, cognitive), exposure time, and other reasons. According to resource theory, the individual has a general pool of mental resources from which they can draw to help complete task demands. From a theoretical standpoint, this pool of resources is thought to change in size depending on the individual's level of arousal. Kahneman [37] hypothesized a finite pool of mental resources that could be divided between different tasks. So, when managing or performing multiple tasks simultaneously, there will be a conflict in attention for performing multiple tasks. He stated that this conflict is due to the allocation of mental resources (from primary to secondary tasks). It is noteworthy that the study results

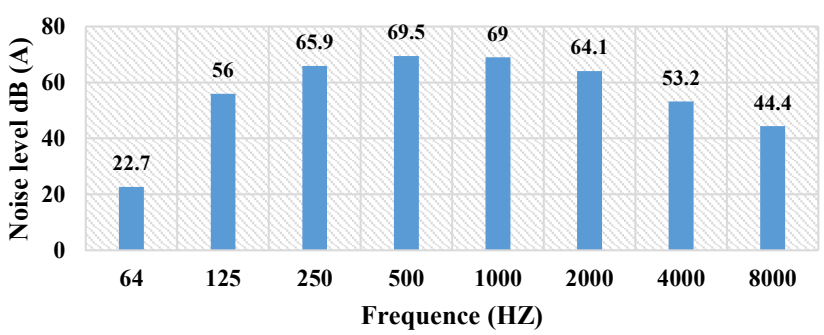

Figure 1. Analysis of the octave's central frequency in A-weighting

regarding introverts and extroverts can be expressed as a factor such as simple PP activity. Further studies are recommended regarding the effect of noise on divided attention with respect to the discrepancies among different studies.

In the ATTPT activity, the variables' differences were statistically significant for introverts in quiet environments and traffic noise, approving the positive influence of traffic noise on introverts with increasing the workload, but it was not effective on extroverts. This may be attributed to Eysenck's theory that states introvert unexposed to the stimulus levels or exposed to a medium level of stimulus (traffic noise) have more cognitive ability. However, these introverts experience significant cognitive ability degradation in the face of high levels of stimulation [38]. The Eysenck findings were confirmed in an experimental study by Dobbs et al. [13]. It should be borne in mind that according to researchers' findings, different types of noise produce different effects on introverts and extroverts [34]. The findings may have been influenced by the transactional stress model [39]. The transfer stress model is based on individuals' cognitive assessments and is an essential component in data processing and human performance. In this model, the negative assessment of cognitive load is traumatic to cognitive function, while a positive assessment of the cognitive load improves cognitive function.

It should be noted that one of the study's flaws is the lack of female participants in the current study, which is suggested for future research into the effect of traffic noise on women's performance. Another limitation of this study is the time of participants' exposure to sound. This change in exposure time may have different results, so it is recommended to do more studies in this regard in the future.

Conclusion

In the present study, there was no change in the divided attention of introverts including peripheral attention, central attention, incorrect reactions, and omitted reactions to visual signals after exposure to traffic noise. However, the perception speed and perception capacity of introverts improved after exposure to traffic noise. More interestingly, none of the divided attention variables indicated a change in perception speed and perception capacity. Also, compelling results were obtained for unstable and stable subjects after exposure to traffic noise; in stable subjects, perception speed and perception capacity improved despite the stability in divided attention, incorrect reactions, and omission of reaction to visual signals. However, there was no change in divided attention, perception speed, and perception capacity in unstable individuals after exposure to traffic noise.

Ethical Considerations

Compliance with ethical guidelines

This research was approved by the Ethics Committee of Kurdistan University of Medical Sciences, Iran (Code: IR.MUK.REC.1400.004).

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Authors' contributions

AM: Study design, interpretation of the results, revise; MAR: Study design, acquisition of data, interpretation of the results, and drafting the manuscript; AHR: acquisition of data, interpretation of the results, and drafting the manuscript; MA: Interpretation of the results and drafting the manuscript; FM: Study design, acquisition of data, interpretation of the results, and drafting the manuscript; KA: acquisition of data, and drafting the manuscript; ED: Statistical analysis.

Conflict of interest

The authors declare that they have no conflict of interest.

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