The effects of traffic noise on memory and auditory-verbal learning in Persian language children

Original Article

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Abstract:

Background: Acoustic noise is one of the universal pollutants of modern society. Although the high level of noise adverse effects on human hearing has been known for many years, non-auditory effects of noise such as effects on cognition, learning, memory and reading, especially on children, have been less considered. Factors which have negative impact on these features can also have a negative effect on learning and education development. In the present study, the effects of traffic noise were studied as pollutant on memory and auditory verbal learning of elementary school children.

Methods: The present cross-sectional study was conducted on 166 normal children aged 9-11 years. Eighty children were selected from noisy areas (Leq> 50 dBA) and compared with 86 children from low noise areas (Leq <50 dBA). Using Persian version of the Rey Auditory-Verbal Learning Test, various aspects of memory were studied in low noise and noisy environments.

Results: A significant difference was observed between two groups in all steps of the Rey test (p=0.00). There was a significant difference between two genders in various steps of Rey test (p=0.00). The average score of recognition was higher in the low noise group than the noisy one (p=0.00).

Conclusions: Traffic noise had an adverse effect on the auditory verbal learning and memory of the studied students. Its effect is more on boys than girls. Since learning is very important in the development of students' education and social skills, therefore, it is necessary to reduce the noise exposure of students in schools.

Keywords: Noise, memory, children, auditory-verbal learning.

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Introduction:

Sound is referred to as any pressure change in air molecules, which stimulates the sense of hearing. Each sound is produced from a source and reaches a receiver by passing through an interface. Produced sound can be pleasant and also unwanted and unpleasant. Unwanted sound which interferes with activities such as sleep and/or other physiological processes and leads to function decline is called noise [1]. In fact, noise which interferes with verbal communication, music etc. has an unpleasant effect on health and can cause pain and damage to hearing at high intensities. In addition to the direct effect of noise on hearing, its non-auditory effects such as effect on nerves, endocrines, cardiovascular system, learning, memory, cognition and reading are also taken into consideration [2].

In the present study, the effect of one of the most familiar sources of noise, namely, traffic noise, was investigated on memory and auditory-verbal learning. Memory and learning, especially auditory-verbal learning are effective tools on the formation and development of cognitive skills in children. "Learning" is a process through which knowledge is acquired. In other words, learning is referred to as the process of acquiring new information through the nervous system and is manifested by behavior change. "Memory" is referred to as durability or consistency of learning in a way that is callable after some time. In other words, memory is a process through which knowledge is encoded, stored and retrieved [3-5].

Verbal memory is the ability to remember verbal materials such as names, words and information verbally provided [6]. Auditory memory is the ability to receive verbal stimulation, process and save them and finally remember them. Schoolchildren for educational activities such as reading comprehension, reading, numeracy and understanding of vocabulary, transcription of the boards and orientation require an active memory. Various studies have explained that people who have learning disabilities have suffered from a kind of academic and social failure. For this reason, its evaluation is of utmost importance. The central role of memory in the development of skills such as learning and remembering words, comprehension and grammar application, expressive language and writing language, and the necessity of its clinical evaluation have resulted in conducting many researches and the emergence of several tests in this field [7]. Memory and auditory-verbal learning play an important role in the development of education and social skills. For this reason, its evaluation is very important. Although the use of auditory-verbal learning models for evaluation dates back to 1919 by Klapard, conducting auditory-verbal learning test by Andre Rey was considered again [8, 9]. The Rey Auditory-Verbal Learning Test is one of the most common tests used to evaluate memory and learning in neuropsychology. One of the most important benefits of this test is that it provides appropriate clinical information on various functional aspects of subjects [10].

Different studies have shown that noise affects the children's memory and causes disorders in remembering and recalling things [11]. It was observed that exposure to road traffic and aircraft noise can affect certain aspects of a child's memory; chronic exposure to noise affects memory function especially quick and delayed recall and causes damage to recognition memory [12, 13]. According to previous studies, attention, memory and read all cognitive processes are involved in early ages (5-11 years) and noise can have a negative impact on their formation and development [7, 14]. It has been found that children's attention is problematic in schools with high levels of traffic and aircraft noise [7]. Also, exposure to noise impacts on the activities including central processing and understanding language such as problem solving, reading, attention, memory, etc. [14]. At school ages, the importance of evaluating the effects of noise on memory and auditory- verbal learning will be double because of the importance of memory and auditory-verbal learning in education and social development, and the presence of numerous sources of noise in urban environments such as urban traffic.

It was indicated that the children living in noisy environments than peaceful ones made more errors in reading the test [11, 13]. Moreover, the chronic exposure to aircraft noise significantly was related to poor recall information and poor recall understanding [11].

Given the above points, in the present study, the effect of traffic noise on auditory-verbal memory of children aged 9- 11 years was studied using the Persian version of the Rey Auditory-Verbal Learning Test.

Methods:

This cross-sectional study was conducted on 166 normal children with normal intelligence quotient (IQ) (over 85 by the Wechsler children intelligence test). In order to control the interfering factors, all samples a) had normal peripheral hearing, b) were monolingual Persian language and right-handed, and c) had no history of neurological disorders and head trauma and they were randomly selected by school teachers. The average age of children was 10±1.4 years (aged 9-11 years) (44, 72 and 50 of children were in the third grade, fourth grade and fifth grade of primary school, respectively). Eighty subjects of noisy classes and 86 cases of low noise classes were investigated (84 males and 82 females), and finally these two groups were compared. Regarding the control of other factors, the results indicated a difference between these two groups in terms of traffic noise effect. First, the children who had the inclusion criteria were entered into the study by measuring the noise in schools of region 6 of Tehran. Noise levels in schools were determined by measuring noise using sound level meter (SLM) Nor140 of Norsonic Co. Measurement scheme included: 1- dBA network 2- fast time constant 3-randome incidence microphone 4- Leq 60sec with 90% cut off 5- multiple-area sampling (to ensure that the students were exposure to uniform noise) 6- microphone positioned at the ear level of students. According to previous studies, schools with Leq> 50 dBA were considered as noisy schools, and schools with Leq <50 dBA were considered as low noise ones [15]. First, all samples were otoscopied and evaluated (using MEVOX SA960 of Welton Co.) and those who had normal hearing were included based on the Goodman classification. Then, the Rey Auditory-Verbal Learning Test (Persian version) was performed individually in a quiet room of a school [16]. This test was performed in elementary schools in region 6 of Tehran during 4 months (fall and winter 2012).

The Rey test including 9 steps was performed after full explanation. Steps one to five of the test (I-V) or recall step was as following. First, list of A words was read to a subject by presenting a word in seconds with live sound and the subject was asked to express everything was recalled after reading. If a person asked a question whether the word had already been mentioned or not, the examiner would have to give the answer. Otherwise, the examiner might refer to repetitive response, which could distract one's senses and intervened in the performance. When the schoolchild said that he/she did not remember any word, the same list was read with the same conditions again and each time the answer was inserted in the form used for recording the results. In the guidelines, it is necessary to emphasize that the mentioned words in the first run were repeated. Otherwise, the person may remove these words from the test.

To investigate the effect of repeated stimulus and a subject learning ability, the first list was successively presented 5 times. Total mean score of recall was calculated by determining the average scores of the first five steps. Intervention list words (List B), which were very similar to list A words in terms of phonetic balance with different words, were also presented once by similar conditions of the first step, and the subject's answer was recorded.

Immediately, after presenting the intervention list and again with delay and after 20 min (steps VI and VII), the subject was asked to recall and repeat the words in list A. In the present study, subjects were asked to rest within 20 min and not to have verbal communication.

In the final step, a subject was asked to identify the words in list A among 50 words (30 words in list A and 20 new words in list B). In conducting the Rey Auditory-Verbal Learning Test Persian version, only meaningful monosyllabic words were used, words of each list were chosen in a way that had no phonetic or semantic similarity with each other [16].

The present study was confirmed by Research Assistants of Tehran University of Medical Sciences in terms of adhering to moral considerations. Data were analyzed using nonparametric tests. Friedman test was used to investigate the learning effect and compare the first 5 steps of the Rey test. Also, in order to investigate the effect of noise on Rey test results in different steps and the effect of gender on Rey test results, the Mann-Whitney test was used in noisy and low noise areas. The Wilcoxon test was used to investigate the relationship between immediate, delayed recall and recognition in noisy and low noise areas. Data were analyzed using statistical software SPSS 18 at significant level of 0.05.

Results:

the results indicated that in each group, a significant difference was observed between successive steps except steps 7 and 8 (p=0.00). In all steps of the Rey test, there was a significant difference when these results were compared to those of two noisy and low noise groups (p=0.00). Also, by performing the Mann-Whitney test in all steps of the Rey test, a significant difference was seen between the two genders of both groups (p=0.00). In all steps, the correct response rate was higher in girls than boys. The mean, standard deviation and changes of studied subjects in different steps in the Rey auditory- verbal learning test in noisy and low noise areas are shown in Table 1. Figure 1 illustrates the studied subjects' learning curve in noisy and low noise areas during the first step. As shown, the students in low noise areas remembered words more than students in noisy areas during the first step of the test.

Proactive interference rate (difference between average score of recalling words in list A in the first step with an average score of recalling intervention words of list B), retroactive interference rate (difference between average score of recalling words in list A, in the fifth and seventh steps) and forgetting step (difference between average score of recalling words in list A, in the seventh and eighth steps) in noisy and low noise areas are represented in Table 2.

Table 1: Mean, standard deviation and scores' changes in different steps of auditory-verbal learning test in noisy and low noise areas (n=166).

Groups \ Rey test steps		M		SD		Min		Max	
		Noisy	Low noise	Noisy	Low noise	Noisy	Low noise	Noisy	Low noise
List I-A		5.7	7.34	1.99	2.08	1	4	11	13
List II-A		8.65	10.62	2.35	2.12	3	6	14	15
List III-A		11.01	12.44	2.46	2.06	6	8	15	15
List IV-A		12.18	13.38	2.40	1.52	6	10	15	15
List V-A		12.68	13.93	1.99	1.24	8	11	15	15
Average repeated scores	List A	50.19	57.69	9.58	7.35	27	44	67	70
	List B	5.24	6.37	1.56	1.89	1	4	10	11
List VI-A (Immediate recall)		11.63	13.06	2.65	1.81	5	9	15	15
List VII-A (Delayed recall)		11.38	12.69	2.73	2	4	8	15	15
List R-A (Recognition)		14.05	14.66	1.17	0.56	10	13	15	15

Table 2: M and SD of Rey Auditory Verbal Learning Test different indices (n=166).

Rey test indices	M	SD	M	SD
Group	(n=80) Noisy	(n=80) Noisy	(n=86) Low noise	(n=86) Low noise
Proactive interference	0.46	0.43	0.97	0.19
Retroactive interference	1.05	0.66	0.87	0.57
Forgetting speed	0.25	0.08	0.37	0.19

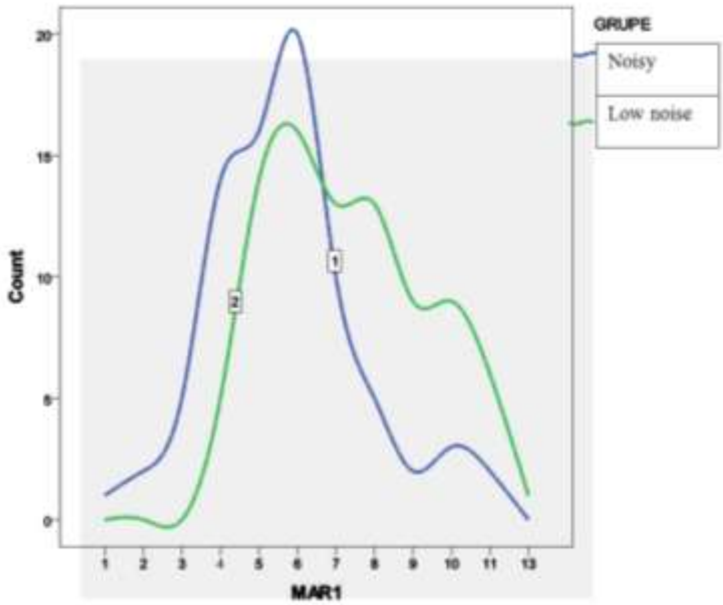

Figure 1: Learning curve of studied subjects in Rey Auditory Verbal Learning Test in noisy and low noise areas.

Discussion:

A significant difference was observed in evaluating the children of noisy and low noise groups in all the steps. This means that, noise causes the reduced function in all early, immediate and delayed recall and recognition steps. In the first step of the Rey test, the average response in low noise was 7.34 and in noisy group was 5.7 which is within the expected capacity for working memory (seven plus or minus two in adults) [17], meaning working memory capacity in low noise group is more than that in the noisy group. These findings are consistent with the findings of Kempen and Boman [7, 18] studied on the effect of noise on early, immediate and delayed recall and recognition steps. The first step of the Rey test is used in evaluating working memory and the number of words recalled in this step indicates working memory capacity. Words provided in the first step of this test are remembered through a phonological loop in working memory whose function is keeping verbal information in a phonological reserve by reviewing the provided words [19].

Repeating the first list in steps one to five in both groups suggested the improved scores as "learning effect" like previous studies [20-22]. As seen in this study, the mean score of studied subjects in noisy group increased from 5.7 in step 1 to 12.68 in step 5 and low noise group increased from 7.34 in step 1 to 13.93 in step 5. It demonstrates learning effect. Improved scores are due to the entry and storage of permanent information in long-term memory. During learning, a component of working memory as episodic buffer establishes the relationship between working memory and long-term memory and phonological loop allows the possibility of more permanent information entry and storage in long-term memory [23, 24].

In this study, although the average learning effect was 6.98 and 6.59 in the noisy group and low noise group, respectively, absolute learning had quite a higher score in the low noise group.

The average increase of children's learning (aged 9-10 years) was 3.8 in the study of Oliveira et al [10]. This value is almost half in the present study. It seems that the reason for this difference is as a result of the use of complete version of the Rey Auditory- Verbal Learning Test in this study, while in the study of Oliveria et al. [10], the short test was used.

In the current study, a proactive interference rate in the noisy group was 0.46 and in the low noise group was 0.97, meaning that the average words' recall score of list A in the first step was higher in the noisy group (5.7) than words' recall score of intervention list B (5.24), and in low noise group (7.34), it was higher than words' recall score of intervention list B (6.37), reflecting proactive interference, which means that learning the previous list interferes with learning the next list [25, 26]. The proactive interference level in the low noise group is more than the noisy group (p=0.00). Also, after providing the intervention list B, the average score of list A was reduced in noisy and low noise group from the fifth step to the immediate recall step, reflecting retroactive interference, indicating that learning new materials interferes with recalling earlier learned materials [26]. In the present study, the amount of this type of interference obtained in noisy group was 1.05 and in low noise group was 0.87. The retroactive interference level in the noisy group was more than that in the low noise group (p=0.00).

Information forgetting speed after a delay of 20 min was determined by comparing immediate and delayed recall scores. Forgetting speed in the current project was 0.25 and 0.37 in the noisy group and low noise group, respectively, meaning that a 20-min delay in the two groups did not lead to a reduction in the function of subjects. In some previous studies on adults, 20-30 min delay did not have an effect on the ability to remember words. Although a delay of 20 or 30 min is proper for clinical evaluation of forgetting process, more time is needed to show the effect of forgetting on normal subjects (more than 24 h). It seems that further investigation on children is needed to understand information on forgetting speed [27]. Delayed recall like learning requires the function of two components of working memory: episodic buffer (to combine phonological loops and visual-spatial information with long-term memory information) and phonological loop (to store and keep auditory information active) [23, 24].

In steps of immediate and delayed recall, a significant difference was seen between the low noise and noisy groups which means that noise affects words' recall either immediately or delayed. In Matsui et al.'s (2004) study conducted on 236 children in elementary schools, it was found that exposure to air traffic noise affected immediate and delayed recall of children memory which is consistent with the findings of the present study [12].

The average recognition score of the subjects in this study in the noisy group was 14.05 and in the low noise group was 14.66. Also, recognition like delayed recall requires co-function of episodic buffer and phonological loop. The average recognition score in the low noise group is more than that in the noisy group (p=0.00). This means that noise has an adverse effect on word recognition, which is similar to the findings of Matsui and Boman [12, 18].

It seems that noise due to impaired concentration and conversion of simple attention practice to complex multi attention causes focusing a significant portion of a child’s energy on the issues which are not in his learning path, and for this reason, the scores of children in noisy environment are lower compared to children in low noise areas [4].

In this study, the rate of correct answers was higher in girls than boys. This finding shows that girls have better function than boys at recalling words (p=0.00). This result is consistent with that of Van Den Burg and Boman [4] who studied on the effect of gender on the results of the Rey test [18, 28,29]. It seems that women because of their shorter nerve pathways have higher neural synchrony and better focused attention than men.

Regarding the limitations in providing sample size with different levels of education, the results of the present study cannot be generalized to subjects with higher education level. In many noisy schools, traffic noise is not the only source of noise. Noise may increasingly hurt the students who are not successful. So it is not correct to generalize the findings to all students.

In the current study, in all Rey test steps between two noisy and low noise groups, a significant difference was found. Among the delayed recall and recognition steps, a significant difference was found. In this study, in all Rey test steps, a significant difference was observed between the two genders. According to the results, education authorities can be informed and municipal authorities should pay serious attention to noise pollution of schools and prevent education, cognitive, and social problems. Reducing the noise level in training centers, especially in the studied age is required. The findings of current study can guide future studies due to the limited research on Persian version of Rey test. The results indicated that this test could be used as a good test to evaluate the memory in Persian speaking children and memory in children with learning disorder and other developmental defects in different environments.

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