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RESEARCH ARTICLE

Auditory attention and memory in normal hearing individuals with and without tinnitus

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Abstract

Background and Aim: Research shows that 13-18 percent of the people suffer from tinnitus, almost 5 percent of which, have chronic or bothersome tinnitus. Chronic tinnitus may be accompanied by anxiety, depression, insomnia, and impairment in cognitive functions such as memory and attention. The purpose of this study was to compare the verbal auditory memory and divided attention between individuals with normal hearing in two groups of with and without tinnitus aged from 18 to 55 years old.

Methods: This study were performed on 16 tinnitus patients (6 men and 10 women) aged from 23 to 53 years old and 20 healthy volunteers (3 men and 17 women) aged from 21 to 49 years old with normal hearing thresholds. Puretone audiometry (PTA), Tinnitus evaluation, dichotic auditory verbal memory test (DAVMT), Randomized dichotic digits test (RDDT), and tinnitus handicap inventory (THI) were employed for all participants.

Results: Comparing the outputs of the RDDT and DAVMT tests between control and patients groups revealed no significant difference (p=0.65, p=0.21).

Conclusion: Based on the results of behavioral tests, divided auditory attention, and verbal auditory memory, which demonstrated no remarkable difference between control and patients groups, it is suggested that mild chronic tinnitus in individuals with normal hearing does not interfere in the divided auditory attention, verbal auditory memory.

Keywords: Tinnitus, memory, attention

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Introduction

Tinnitus is a prevalent phenomenon which refers to the perception of sound in the ears or the head, like ringing, buzzing, roaring, clicking, hush, and so on, in the absence of an external stimulation. Research shows that 13-18% of the people suffer from tinnitus [1,2]. Tinnitus may occur in individuals with normal audiometry or with hearing loss [3]. 30-40% of individuals with hearing loss experience tinnitus. Whilst, 90% of individuals with tinnitus report some form of hearing loss [4]. In both cases, the existence of defects in the attention of individuals with tinnitus is probable [3]. Almost 5% of individuals with tinnitus suffer from chronic or bothersome tinnitus which affects their lives' quality [5]. Chronic tinnitus may be accompanied by anxiety, depression, insomnia, and impairment in

cognitive functions such as memory and attention [1,6,7].

Cognitive functions can be observed in various levels from the most fundamental attention to memory processing levels. It seems that the capacity of the active memory is the basis for cognitive processing, specifically for speech comprehension. If this capacity declines, the individual becomes incapable of perceiving the speech characteristics. Some research have reported the impact of tinnitus on cognitive functions (selective attention, divided attention, and long-term working memory) [2,8-14]. Neuro-imaging research, relevant to the tinnitus perception, focuses on the role of cortex areas and the areas of brain which have more effects on the attention processing, short-term memory, and other extra-ordinary functions [15-17]. Tinnitus may be perceived in dorsolateral prefrontal cortex, limbic system, and secondary auditory cortex [18]. In electrophysiological techniques, as used by Walpurger et al., it has been revealed that there is a diminished evoked-related potentials (ERPs) response to auditory stimuli among tinnitus patients [19]. Similarly, it was stated that there might be an electrophysiological difference in initial selective auditory attention among the individuals with tinnitus [13].

Although most researches state the impact of chronic tinnitus on the cognitive functions, some researches reported no interference of tinnitus in the behavioral—cognitive functions (attention and memory) [3,18,20]. For instance, by investigating individuals with tinnitus through questionnaires, and sustained attention, reaction time, and verbal memory tests, Hallam et al. reported the poorer performance of these individuals in divided attention and long term memory tasks. They also revealed the effect of tinnitus on working memory, divided attention, and long-term memory after several years [1,11]. Rossiter et al., by studying working active memory and attention in individuals with mild tinnitus through cognitive tests (reaction time, dual tasks, and Vechsler tests) and controlling the anxiety level by Spielberger questionnaire, expressed the disorder in functional skills (attention and memory) [2]. Stevens and Walker by investigating the influence of sever tinnitus on divided and selective attention using reaction time and stroop colored word tests, revealed a noticeable decrease in the performance of tasks such as reading words in stroop test and dual tasks in comparison to the control group which is indicative of a decrease in the resources peculiar to attention in these individuals [14]. Jafari et al., through examining the effect of tinnitus resulted from noise on divided and selective attention using Bergen dichotic listening test, reported a decline in the level of performance in divided and selective attention [1]. However, Acrani and Periera, by studying the temporal resolution and divided attention in individuals with normal hearing but with chronic tinnitus by means of central tests (gap in noise, speech in noise, and DDT), showed that tinnitus, in these individuals, did not interfere in the auditory ability (attention and temporal resolution) [3]. Through investigating attention and short-term memory in memory tasks, Husain et al. observed no difference between individuals with tinnitus and control group. Although, they noticed a significant difference in divided and selective attentions tasks [18]. Husain et al., through studying three groups (bilateral hearing loss with mild tinnitus, hearing loss without tinnitus, and normal hearing) by means of behavioral tests, did not notice a significant difference in auditory attention and short-term memory. By contrast, using fMRI and comparing with parietal and temporal lobe cortex and anterior cingulate, they observed a disparity in neural bases of individuals with chronic tinnitus and hearing loss. They treated this as the reason for the difference in auditory attention function and short-term memory [20].

Based on the researches regarding the complicated relation between cognitive functions and tinnitus [2,14], and considering the existing contrasts about the effect of tinnitus on cognitive functions [3], it sounds highly essential to hold a deeper investigation of the impact of tinnitus on the auditory memory functions and attention control. The present

study was performed aiming at comparing the verbal auditory memory and divided attention among individuals with normal hearing in two groups of with and without tinnitus, aged from 18 to 55 years old, by means of dichotic auditory verbal memory test (DAVMT), randomized dichotic digits test (RDDT), and tinnitus handicap inventory (THI).

Methods

This study was conducted on 16 tinnitus patients (6 men and 10 women) aged from 23 to 53 years old (mean of 36.44 and standard deviation of 9.09) with normal hearing thresholds (mean of threshold less than 25 dB from 500-8000 Hz) attending the Otorhinolaryngology Clinic in Imam Khomeyni Hospital and Municipality Clinic of Area 6, Tehran, Iran, from January to May 2015 and 20 healthy volunteers (3 men and 17 women) aged from 21-49 years old (mean of 33.65 and standard deviation of 7.61) as the control group.

By means of a questionnaire including information (age, sex, address, education, and profession) individuals were matched in two groups of tinnitus patients and control groups. The main inclusion criteria for tinnitus patients included: suffering from tinnitus for at least 9 months without receiving any medication, Persian mother tongue (mono-lingualism), right handedness in writing (based on the Edinburgh handedness inventory test), minimum of 18 and maximum of 55 years old, having normal hearing (mean of threshold less than 25 dB from 500-8000 Hz and symmetry in both ears), and in the control group, lack of experiencing tinnitus since 6 months before the test. They were not supposed to have a history of ear diseases, head injury, accident, brain surgery, seizure, and any substance or ecstasies drug abuse. The patients were selected by looking into the clinics database of a medical history form. The information was based on the audiological evaluations such as hearing threshold, the duration of suffering from tinnitus, and demographical information. This study has been approved by the Ethics Committee of Iran University of Medical Sciences.

This research contained two major steps: first, puretone audiometry and examining the psyco-acoustic characteristics of tinnitus, and second, conducting the cognitive tests (attention and memory). At first, the participants filled in the consent, hearing history, and tinnitus characteristics evaluation forms. For the first step, to prove acuteness of peripheral hearing and rejecting any transitional disorder or inner ear disorder, participants were checked up for otoscopy, immittance audiometry by Zodiac 901 (Madsen, Denmark), puretone audiometry (PTA) by Orbiter 922 (Madsen, Denmark) at frequencies 0.25, 0.5, 1, 2, 4, 6, and 8 kHz for air conduction (AC) and 0.5-4 kHz for bone conduction (BC). The normal hearing criteria were considered to be immittance audiometry that was carried out by tympanogram type A, and getting reflex in 75 to 90 dB SL at frequencies 0.5-4 kHz in acoustic reflex test and the average of pure tone thresholds less than 25 dB HL at frequencies 0.5-8 kHz. The purpose of examining the thresholds was to test the participants with normal hearing and homogenizing the two groups so that the possible effect of hearing loss on the test results was eliminated and the difference in thresholds between the two ears was not over 10 dB. Research has shown that the hearing loss accompanied by tinnitus would probably lead to a disorder in cognitive functions [21]. Due to this, the thresholds were initially examined. Then, the psychoacoustic characteristics of tinnitus were evaluated in all patients to determine the pitch, loudness, and annoyance. In pitch matching, two tones were presented for the patient and they were asked to choose the one more similar to their tinnitus. For qualitative loudness, the linear scale from 1 to 10 was used in such a way that the scores 1-2 showed slight, 4-5 moderate, 6-7 severe, and 8-10 extremely severe tinnitus [22]. To evaluate the annoyance level, a linear scale from 1-10 was also used so that the scores 1-2 showed non-annoying, 2-3 mild, 4-5 moderate, 6-7 high, and 8-10 very high [22].

In the second step, to evaluate the verbal auditory memory, the Persian version DAVMT,

normalized by Aghamollaei et al. [23] was employed. The test was carried out, using a Laptop by-phone at the most comfortable level (MCL) for the participant, by dichotic presenting of 10 consequent words into one ear and their reverse into the other ear. Among the words simultaneously coming to the ears, the individual was requested to pay attention only to the words coming to one ear and finally repeat as many as they remember at each time (without considering the order). In order to increase the credibility of this test, two different wordlists with time intervals of 20 seconds were presented to each ear so that the tested ear (the one receiving the words) would change frequently. In total, 4 ten-word dichotic lists (two wordlists for each ear) were implemented. Each individual's score was the mean of scores in both ears for the four wordlists.

Afterwards, to examine the divided auditory attention, the Persian version of RDDT, created by Mahdavi et al. [24], and evaluated in terms of equivalence and reliability by Aghazadeh et al. [25], as an important central auditory test was employed. This test possesses a high level of reliability for adults and elderlies and is robust to the effect of mild to moderate hearing loss [24,25]. The main material of this test is two lists, only one of which was used in this study. The list contains one-pair, two-pair, and three-pair items (18 items of each, randomly distributed). In each list, the raw score of 108 (100%) is considered for each ear. The test stimulus (digits) was presented in a dichotic manner and at the most comfortable level (MCL) of each individual while they were sitting behind a desk with the Laptop on top of it (minimum peripheral noise). The percentage of correctly repeated numbers in each ear was treated as the individual's score for that ear. In the end, the THI questionnaire was filled in. THI was used to evaluate the handicap due to the tinnitus for the patients group. This questionnaire includes the functional, emotional, and catastrophic aspects and is used to investigate the negative effects of tinnitus on daily life activities. The Persian version of THI, normalized by Shahmiri et al. [26], includes 25 items, which were 3-choice (Yes, Sometimes, and No). The score ranges from 0 to 100 and the final score for each individual determines the tinnitus level (0-16 for slight, 17-36 for mild, 37-56 for moderate, 57-76 for severe, and 77-100 for bothersome).

SPSS 22 was used for statistical evaluation. The data are reported as mean (standard deviation) and are considered significant at the level of p=0.05. The data distribution was studied by means of Kolmogorov-Smirnov test. The distribution of some data was normal and that of the others was abnormal. (The mean of scores for right ear and right ear advantage (REA) in RDDT were normally distributed and the mean of scores in DAVMT, and for the left ear in RDDT were abnormally distributed).

To compare the normally distributed mean scores of RDDT (right ear and REA) between the two groups, the Independent t-test was used and Mann-Whitney test was also carried out to compare the abnormally distributed mean scores of DAVMT and left ear in RDDT between the two groups.

Results

The tinnitus patients group included 16 patients, aging from 23 to 53 years old (mean of 36.44 and standard deviation of 9.09) and the control group included 20 healthy individuals, aging from 21 to 49 years old (mean of 33.65 and standard deviation of 7.61). There were no significant difference between the two groups in terms of sex, age, and education (p>0.05). As it is shown in Table 1, most of the patients had been suffering from tinnitus for 9 months to 3 years and had bilateral tinnitus as well. In addition, the mean of tinnitus handicap (27.12) was in level 2 (mild). Furthermore, most of the individuals were in the range of mild and moderate in terms of tinnitus qualitative loudness and annoyance. The tinnitus frequency was high for most of individuals.

Fig. 1, compares the RDDT results (the mean of total scores for right and left ears and REA) between the tinnitus patients and control groups. The corresponding mean (and standard deviation) of scores are 89.68 (4.92), 77.02

Table 1. Tinnitus characteristics in 16 normal hearing individuals with tinnitus

No	Age	Sex	Duration (month)	Localization	Loudness	Annoyance	Pitch (Hz)	Handicap (THI) (%)
1	**42**	**M**	18	B	4	3	8000	46
2	**32**	**F**	12	UL	4	4	1500	24
3	**48**	**M**	12	B	2	3	750	20
4	**35**	**M**	30	B	8	4	4000	18
5	**53**	**M**	9	B	4	4	4000	8
6	**26**	**F**	84	B	2	3	4000	8
7	**45**	**F**	108	B	2	4	4000	28
8	**52**	**F**	84	UR	8	6	2000	36
9	**34**	**M**	48	B	2	3	8000	54
10	**36**	**F**	12	UL	6	8	10000	54
11	**37**	**F**	9	UL	1	3	2500	16
12	**31**	**F**	9	B	6	6	2000	54
13	**30**	**F**	120	UL	1	3	2000	30
14	**29**	**F**	36	B	6	6	6000	32
15	**30**	**F**	108	B	2	3	6000	0
16	**23**	**M**	12	UL	4	1	10000	6

B: Bilateral, UL: Unilateral Left ear, and UR: Unilateral Right ear
M: Mail, F: Female

(12.09), and 12.65 (11.34), respectively, for the tinnitus patients group, and 89.82 (5.63), 78.60 (9.65), and 11.21 (7.71), respectively for the control group. These values show no meaningful difference between the two groups (p=0.93, p=0.83, and p=0.65, respectively).

Table 2, depicts the DAVMT results for the groups under investigation. No significant difference can be noticed between these two groups (p=0.21).

Discussion

In the present study, which was performed to compare the verbal auditory memory and divided attention among normal hearing individuals in two groups of with and without tinnitus, aging from 18 to 55 years old, the results of DAVMT and RDDT (the mean of scores for right and left ears and REA) tests revealed no noticeable difference between the tinnitus patients and control groups (p>0.05). Generally, the results do not confirm the hypothesis of the effect of chronic tinnitus on decreasing the cognitive functions and indicates that the mild chronic tinnitus does not interfere in the performance of verbal auditory memory and divided attention of individuals with normal hearing. This might be due to either the mildness of the tinnitus, the low level of tinnitus loudness and annoyance, or the cancellation of the effect of hearing loss. There is no similar study to investigate the effect of tinnitus on individuals with normal hearing by means of DAVMT and RDDT. Thus, the results of studies in the field of memory and attention function through other tests, are discussed. In

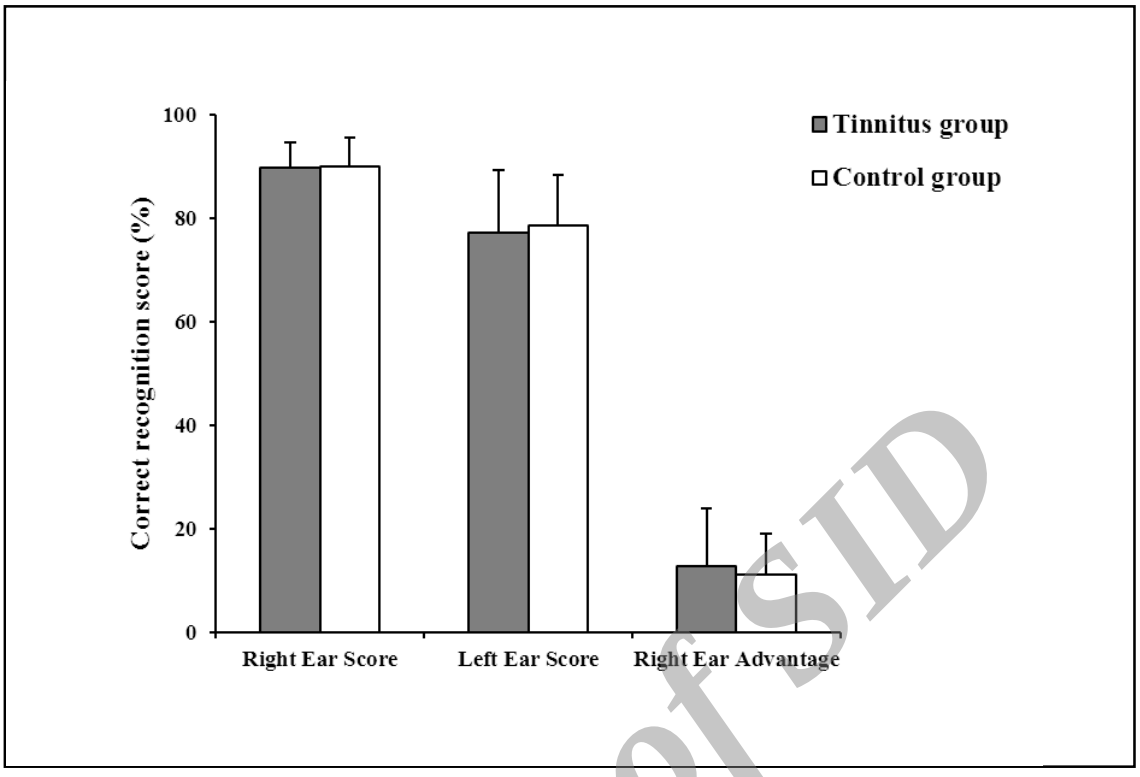

Fig. 1. Mean (standard deviation) correct recognition scores in randomized dichotic digits test of the right ear, left ear, and REA in control and tinnitus patients groups.

the present study, almost the same value of REA is observed for both groups of tinnitus patients and control and there was no significant difference between these two (p=0.65). The lack of interference of tinnitus in the results of the attentional function is in agreement with those of Acrani and Periera [3], and in contrast to those of Stevens and Walker [14], Rossiter et al. [2], Hallam et al. [11], and Anderson et al. [8]. In addition, memory test results in this study, as in the Husain et al. [18] and Husain et al. [20], revealed no difference in the behavioral responses of memory tasks between the two groups. Similarly, Mckenna stated that tinnitus did not interfere in the cognitive function in paced auditory serial addition test (PASAT). This finding was contrary to the hypothesis of interference of tinnitus in the cognitive processes and occupying the store resources of short-term memory [27]. The results of memory test in the present study was in contrast to the results of studies by Stevens and Walker [14], Rossiter et al. [2], Heeren [12], and Araneda et al. [10]. It is worth noting that, however, the chronic tinnitus was moderate and severe in Rossiter et al. [2] and Stevens and Walker [14], respectively. While, the tinnitus was mild in the present research, Acrani and Periera [3], Husain et al. [18, [20]. Considering the fact that a great percentage of the tinnitus patients under study are with mild tinnitus, it seems that mild tinnitus usually does not interfere in the daily life activities and or they are not hampered by this level of tinnitus. For individuals with severe tinnitus, however, it is very probable to see the tinnitus interference. The possibility of occurring cognitive damages in individuals with severe tinnitus is generally higher [2]. Moreover, according to the controlled processing hypothesis, in individuals suffering from tinnitus, attention is disrupted when the individual consciously and intentionally pays

Table 2. Mean (standard deviation), minimum, and maximum scores of dichotic auditory verbal memory test in control and patient groups

Dichotic auditory verbal memory test	Control group	Tinnitus patients	p
Mean (SD)	4.98 (0.75)	6.11 (2.97)	0.21
Minimum	3.5	3.5	
Maximum	6.70	16.00	

attention to tinnitus. Most individuals with tinnitus unconsciously and automatically pays attention to their tinnitus which allocates a negligible portion of attentional resources to it. Whereas, conscious attention to tinnitus decreases the attention capacity of the individual and therefore, leads to less attention to other tasks [1,14]. Individuals with tinnitus are continuously aware of it and their attention to it, therefore, depleting available resources to maintain the tasks and more demanding actions. Nevertheless, in individuals with low level of tinnitus, the lack of conscious awareness of tinnitus results in less attention to it and less interference of tinnitus in cognitive resources [18]. Therefore, in the present study, Acrani and Periera [3], Husain et al. [18,20], which dealt with individuals with mild tinnitus, it is suggested that the reason for the lack of tinnitus interference in the cognitive function of behavioral tasks, could be the mildness of tinnitus and its lower annoyance and loudness levels compared to other studies. Similar to the current results, Husain et al. stated the lack of difference in the performance of individuals with mild tinnitus in the memory behavioral tests. By means of neuro-imaging tests, however, they expressed the difference in neural bases of these individuals as the reason of interference of mild tinnitus in the attention and cognition of them. They also stated that there could be a difference in responses in short-term memory network while comparing the studies on individuals with severe tinnitus with those with a mild one [20]. Some studies regarding neuro-imaging, point out the difference in short-term working memory and capacity and differing attention demands for different types of tinnitus (mild and severe). In the present study and similar ones, the loudness and annoyance was less than the former study by Hallam et al. [11]. Since the increase in the loudness of tinnitus makes it more important for the individual and leads to a higher level of interference in auditory perception [3], one can consider the low level of loudness and annoyance of tinnitus to be the probable reason for the lack of its interference. Another reason might be that the tasks did not have influential components [28]. Perhaps, different stimuli and more elaborate paradigms are needed to investigate the influence of tinnitus on the attentional and memory tasks in individuals with mild tinnitus. The probability of the impact of peripheral auditory damage on the capability of extracting the information of elaborate stimuli is also examined in some studies [21,29]. In Hallam et al. [11] and Rossiter et al. [2], precise evaluation of the thresholds audiometry of the participant was not performed and it was probable that the hearing loss affected the cognitive function. While, in this study and Acrani and Periera [3], individuals with tinnitus had normal hearing. One can state that when the individual with tinnitus possesses a normal auditory level, their tinnitus is masked in almost all hours during a day except during sleep. Therefore, the natural habituation happens more rapidly than that of a person with tinnitus and hearing loss. Due to this, they do not react to their tinnitus, since they automatically pay no attention to it and thus, their cognitive resources are occupied.

Although 23.5% of the participants with tinnitus

were with moderate and severe levels of it and the remaining 76.5% had slight or mild tinnitus, having the results corresponding to the individuals with mild tinnitus is very important, investigating individuals with mild tinnitus is a factor that we cannot extend the present results to all tinnitus patients. It was very tough to have access to the patients since first, a limited number of Persian individuals with chronic tinnitus and normal hearing referred to medical centers and second, these patients were dispersed in different cities. Eliminating some individuals, while having normal hearing and chronic tinnitus, due to dissatisfying the age criterion and or their bilingualism, and also spending long time to persuade attendants to participate in the study were of the major limiting factors in conducting this research. To overcome such problems, it might be better to examine the bilingual individuals with tinnitus in groups of hearing loss and normal hearing.

Conclusion

In the present study, individuals were with mild chronic tinnitus and normal hearing and possessed the capacity for changing their attention and verbal auditory memory. In addition, their tinnitus were considered a non-interfering parameter in cognitive processing. The development of awareness among the specialists in the field of cognitive functions for individuals suffering from chronic tinnitus and with normal hearing sounds crucial. The results of this study can increase the awareness about the effect of chronic tinnitus on cognitive functions and explain the necessity of conducting more research on tinnitus and relevant probable psychological factors by dissociating its severity. Probably, the behavioral tests, without including psychological investigations, do not properly show the interference of tinnitus in cognitive function for individuals with mild tinnitus. Therefore, employing other tests and neuro-imaging investigations for individuals with chronic tinnitus are suggested for future research.

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