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RESEARCH ARTICLE

The effect of hearing aid use on dichotic listening performance of the hearing-impaired elderly

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Abstract

Background and Aim: One of the chronic health problems of the elderly is presbycusis, and one of the most important age-related changes in central auditory processing is dichotic listening deficit. The purpose of this study was to investigate the effects of using hearing aids on dichotic listening performance of the elderly with hearing loss by dichotic tests.

Methods: In this cross-sectional study, randomized dichotic digit test (RDDT) and dichotic auditory verbal memory test (DAVMT) were performed on 20 seniors with hearing loss (8 male, 12 female) aged 65−80 years. They were divided into two groups of test (with hearing aid, n = 10) and control (without hearing aid, n = 10). They were tested before and two months after the use of hearing aid and the results were analyzed using t-test for two independent variables.

Results: There was a significant difference in the total DAVMT score in control group before and after the intervention ($p < 0.001$) and not in test group, but in terms of right and left ear DAVMT and RDDT scores, showed no significant difference in any groups. Moreover, there was no significant difference in the mean DAVMT score of the right ear and the mean RDDT score between groups, but in terms of the total DAVMT score, a significant difference between two groups was reported ($p = 0.003$).

Conclusion: It can be said that the DAVMT has the ability to show adverse effects of hearing loss on recognition function and memory of the elderly.

Keywords: Randomized dichotic digit test; dichotic auditory verbal memory test; hearing aid; presbycusis

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Introduction

One of the chronic health problems of the elderly is age-related hearing loss. Hearing loss is the second most common health problem for the elderly and one of the leading causes of speech impairment, especially in noisy environments [1,2]. Age-related hearing loss results from the damage to peripheral and central auditory processing (CAP) which include progressive decrease in hearing sensitivity or presbycusis, auditory temporal processing deficit, and damage to dichotic auditory processing [3]. One of the most important age-related changes in CAP is dichotic listening impairment, which alters the linguistic

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information processing in the brain and reduces the performance of the elderly in competitive environments. Evidences suggest that the most damage to the central nervous system occurs in the corpus callosum and the superior temporal gyrus; and with the increase of age their thickness decreases. Therefore, by reduced density of gray matter in the temporal gyrus and reduced integrity of corpus callosum, there is an increased asymmetric performance in the two ears in the elderly [4,5].

Dichotic listening tests were first introduced in 1954 by Broadbent [6], but it was Kimura [7] who for the first time introduced the latest version of dichotic listening tests for clinical purposes. In one study, she examined patients with temporal lobe lesions using single-syllable numbers that were presented simultaneously to both ears, and found that patients with left temporal lobe lesions performed worse than those with right temporal lobe lesions. Based on the results, she emphasized the importance of considering the left hemisphere for language comprehension, which she had reported in her previous findings.

Difficulty in understanding fast speech perception and temporal gaps detection in the elderly indicate slower processing of the hearing system due to aging. However, as Huang and Tang [8] reported, it should be noted that changes in speech comprehension in the elderly, in addition to hearing loss, are affected by high-level cognitive functions such as attention and memory that are impaired in old age whose effect on speech comprehension of the elderly has been already reported. Dichotic auditory verbal memory test (DAVMT) is one of the speech tests that is used to evaluate memory function. The test was first introduced by Christianson et al. in 1987 [9]. In the study by Shahidipour et al. [10], on elderly people an increase in the pure tone average (PTA) resulted in a decrease in the mean score of DAVMT in both genders and all subjects. In fact, age-related hearing loss has had a significant effect on auditory verbal memory. The effects of age on memory and auditory-verbal learning have also been studied by Jafari et al. [11]. They also found that aging reduced the test scores. In a study by Hällgren et al., the scores of dichotic speech tests in the elderly group were also lower than in young people, and in syllables tests, the elderly group had poorer results when focusing on the left ear than on the right ear while the youth group showed the same situation for the right and left ears. In fact, the effects of age on dichotic speech test scores vary in the elderly [12].

Perhaps one of the most interesting discoveries made by biologists over the past 40 years in the field of sensory neuroscience is the stimulus differentiation of neurons and the ability to change and adapt cortical structures; i.e. plasticity. The use of mismatch negativity (MMN) following the use of hearing aids and examining the process of improving the individuals' auditory abilities after receiving hearing education and training, special place among the researches in the field of auditory plasticity [13]. The auditory system plasticity is a change in the development of nerve cells due to environmental influences. Hearing loss in people causes the brain to have less input from the cochlea over time and become so-called "lazy".

Hearing aids try to restore the behavior of cochlea and the brain, when a person first uses a hearing aid, the brain receives new signals and after a while, her/his brain adapts to it [14]. Considering the psychological, physical and social consequences of hearing loss and some of its accompanying disorders, especially tinnitus and dizziness, affecting the communication ability and quality of life, and due to the high prevalence of hearing loss compared to other disorders in the elderly, a coherent and sustainable scientific and executive investment is needed to identify and treat hearing loss and rehabilitate its associated disorders in this community. According to several studies that consider the incidence of plasticity in the elderly after processing interventions, it is expected that the elderly show better performance in central auditory skills after using hearing aids. Therefore, the purpose of this study was to investigate whether the use of hearing aids can develop top-down and bottom-up processing skills using dichotic hearing tests?

Methods

This is a cross-sectional study. Participants were

20 older adults (8 male and 12 female) aged 65−80 years with hearing loss in both ears referred to Audiology Clinic in 2017 who were selected by a convenience sampling method and based on the inclusion criteria. The sample size was calculated based on previous studies [15] using following formula, by considering 10 people for each group:

$$n = \frac{\left(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta}\right)^2 (\delta_1^2 + \delta_2^2)}{(\mu_1 - \mu_2)^2}$$

α: 0.05 β: 0.1

The inclusion criteria were: being right-handedness (based on Edinburgh handedness inventory score) [16], being monolingual (Persian), without any problems in the outer ear (no cerumen in the outer ear canal) and middle ear (normal tympanic membrane and type An tympanogram with pressure range from +50 daPa to −100 daPa), no history of Alzheimer disease, dementia and physical disabilities according to the mini-mental state examination (MMSE) score [17], no history of any neurological or psychological problems, head trauma or addiction, sensory-neural hearing loss symmetrically in both ears as 25−45 dB (± 20 dB) at a frequency of 500−4000 Hz with flat or moderately sloping audiograms due to old age (mild hearing loss in control group and mild to moderate hearing loss in test group), speech comprehension score above 80%, and using hearing aids binaurally and for the first time. On the other hand, fatigue and unwillingness to participate in the study, and the use of opioids and ototoxic drugs before study which can affect their hearing were the exclusion criteria. They were divided into two groups of test (with hearing aids, n = 10, mean age = 71.90 ± 5.27) and control (without hearing aids, n = 10, mean age = 70.90 ± 5.68).

The test was not invasive at all and was performed after obtaining written informed consent from the subjects (Ethics Code No. IR.SBMU.REC.1396.40) and fully explaining the study process, the test method, its phases and duration to them. After recording their demographic information, all underwent otoscopy (HEINE alpha, Germany) and low-frequency (226 Hz) tympanometry with a tympanometer (AT235, Intracoustic Co., Denmark). After measuring their speech recognition threshold (SRT) and word recognition score (WRS) using the AC40 audiometer (Intracoustic Co., Denmark), randomized dichotic digit test (RDDT) and DAVMT were conducted. Then, based on the results and counseling, prescription of an appropriate hearing aid and molding were done for the test group members.

The RDDT was performed using AC40 audiometer and Sony laptop model VGN-NR37G. The average of the three frequencies 500, 1000 and 2000 Hz per person was first calculated and the output of the audiometer was set to 35 dB SL and then, the stimuli were presented to both ears by laptop and headphones (TDH39). In fact, the test was performed as divided attention task. In this way, the subjects were asked to repeat all the numbers regardless of the order [18,19]. For the DAVMT, since the words were recorded in a dichotic mode, only laptop and headphones were used. The test consists of eighteen 10-word lists consisting of 2-, 3-, and 4-syllabe words, of which 6 lists were sufficient for each subject (three lists for the right ear and the reverse for the left ear, three lists for the left ear and the reverse for the right ear) [20]. The test was performed at the most comfortable level (MCL). After the presentation, the subject was asked to repeat all the target words he heard and the calculated score was normalized as a percentage. After two months, all the above tests were repeated with new lists and the results were recorded. Since the data collection method was observational, the test results before and after two months of using hearing aids were compared. It should be noted that all hearing aids were digital, completely in the canal (CIC) and from Signia company, the prescription formula was NAL-NL2, and the same conditions were set in terms of the number of visits to adjust the hearing aid and the adaptation process. Moreover, during two months, the average use of hearing aids per day for each subject in the test group was five hours, which was controlled by data logging of software.

Data analysis was conducted using SPSS version 18.0 (IBM Corporation, New York, USA).

Table 1. Mean and standard deviation of pure tone average (500, 1000, and 2000 Hz) in test and control groups

	Mean (SD) of PTA (dB HL)	
	Control group	**Test group**
Right ear	26.00 (10.20)	42.50 (4.24)
Left ear	26.00 (10.20)	39.50 (4.37)

PTA; pure tone average

Shapiro-Wilk test was used to investigate the normality of data distribution. In case of abnormal data distribution, Mann-Whitney test and if normal, t-test was considered to compare the mean scores of RDDT and DAVMT in two groups. The significance level was set as 0.05. Due to the significant difference in the DAVMT score of the right ear as well as the total DAVMT score after intervention, the ANCOVA method was used to compare the two groups in these variables. Also due to the significant difference in the RDDT score of the right ear after intervention in both groups that there was before intervention, the ANCOVA method was used for comparing two groups with respect to this variable whose results showed no significant difference in the two groups ($p > 0.05$).

Results

The mean and standard deviation of PTA (dB HL) in the participant's categorized based on groups are shown in Table 1. In the control group, the mean PTA in both ears was symmetrical but totally the mean PTAs in two groups are almost different.

The DAVMT score for each ear was calculated by averaging the scores of the three lists presented to each ear, and the total score was determined by averaging the score of the two ears. The scores of the right and left ears are different in the two groups (in total, the average test score in the two groups in the right ear was higher than in the left ear), which indicates the asymmetry in the response of the two ears. Moreover, in the control group, the mean DAVMT score of the right and left ears as well as its total score after two months was lower than that before, while this trend was quite opposite for the test group. In overall, the mean scores in the test group were lower than those in the control group (Table 2).

In the control group, the mean RDDT score of the right and left ears worsened after two months compared to the pretest scores, while it was improved in the test group (Table 2).

There was a significant difference in the total and right DAVMT scores of the control group before and after two months with no intervention ($p < 0.001$), but in terms of DAVMT score of the left ears, no significant difference was found in any groups. Results showed that in the both groups with and without hearing aids, there was no significant difference in the mean DAVMT score of the right ear ($p > 0.05$), but in terms of total DAVMT score, a significant difference was reported ($p = 0.003$). There was no significant difference between the two groups in any of the variables for RDDT.

Discussion

In this study with the aim of investigating the effect of hearing aids on dichotic listening of hearing-impaired elderly people, RDDT and DAVMT were conducted on 20 subjects who were divided into test and control groups. There were no significant differences in the RDDT scores. In the study by Rauna et al. [21], the effect of using hearing aids on the results of a dichotic test in the hearing-impaired people at high frequencies was examined. The dichotic consonant-vowel test was performed on participants before using a hearing aid in one ear and the tests were repeated after one and six months of hearing aid use. The results proved the right ear superiority as shown before the test. In fact, no change in test scores for any ears was observed after using hearing aid in one ear, which is consistent with the results of the present study and could be due to time constraints and using the hearing aid only in one ear. Danselmo et al. [22] investigated the role of memory and attention control on the hemispheres symmetrically using dichotic speech tests with consonant-vowel syllables. While the focus of attention and the time interval between stimulus and response

Table 2. Mean, standard deviation, minimum and maximum score of dichotic auditory verbal memory and randomized dichotic digit test in control and test groups before and after intervention for right and left ears

Variable (%)	Mean (SD, Min-Max) score in control group			Mean (SD, Min-Max) score in test group		
	Before intervention	After intervention	p	Before intervention	After intervention	p
Score of DAVMT in right ear	5.37 (1.03, 4-7)	4.34 (0.75, 3.30-5.60)	0.005	3.66 (0.94, 2.30-5.30)	3.73 (0.88, 2.60-5.60)	0.816
Score of DAVMT in left ear	4.01 (0.99, 2.30-5.30)	3.41 (1.19, 2-5.60)	0.167	3.30 (0.78, 2-4.60)	3.50 (0.69, 2.5-5)	0.394
Score of DAVMT total right and left ears	9.38 (1.42, 7.60-11.60)	7.75 (1.45, 5.60-9.60)	0.001	6.96 (1.04, 5.30-8.60)	7.01 (1.22, 5.12-9)	0.829
Score of RDDT in right ear	93.51 (4.70, 85.18-99.07)	92.40 (3.23, 87.03-95.37)	0.509	86.84 (7.04, 74.07-99.07)	86.94 (5.69, 75.92-96.29)	0.952
Score of RDDT in left ear	67.58 (9.97, 55.55-82.40)	62.77 (10.73, 50.92-82.40)	0.116	63.69 (19.33, 23.14-89.81)	66.94 (19.15, 25-90.74)	0.145

DAVMT; dichotic auditory verbal memory test, RDDT; randomized dichotic digit test

were controlling by the examiner, attention was examined under three conditions: no focus, focused on the right ear and focused on the left ear. Memory response was different using 4 delays (0, 1, 3 and 4 seconds) between stimulus presentation and response. The results showed the superiority of the right ear under the two non-focused and focused on the right ear conditions. The superiority of the left ear under the focused on the left ear condition was also reported. These results were discussed in the context of the relationship between attentional processes and memory. The higher score of the right ear has been reported in various studies using dichotic listening tests. In dichotic presentation of the stimuli, the superiority of the right ear is a common finding in right-handed normal people [23] and the superiority of the left ear is due to the concentration which contradicts the results of this study. In another study by Ribas et al. [24] on 30 people aged 60−81 who had been candidates for wearing hearing aids in both ears for more than six months but had used only one of them, all of the subjects tested failed in the RDDT. In fact, in the elderly with hearing loss in both ears who used only one hearing aid, there was right-ear superiority and a correlation between the superior ear and the hearing aid used ear which can still be due to using the hearing aid only in one ear. Lessa [25] studied 17 elderly people aged 60−84 who had recently used hearing aids divided into two groups; the first group used hearing aids and the second group received hearing rehabilitation program. All participants were assessed with dichotic tests at two different times. The second group showed significant improvement in both hemispheres and the first group only for the left hemisphere, which shows the usefulness of using the rehabilitation program for the elderly.

In the present study, the auditory-verbal memory function of hearing-impaired seniors was assessed based on the DAVMT results which showed some improvement in their performance in the group used hearing aids. Shahidipour et al. [10] used the DAVMT on 47 elderly people aged 60−80 years who were divided into two groups; the first group (n = 24) were normal hearing subjects and the second group (n = 23) were those with mild-to-moderate bilateral sensory-neural hearing loss at high frequencies. A significant difference was observed between the two groups. According to the correlation test, increased PTA resulted in a decrease in the mean DAVMT score of both genders and all subjects. In fact, age-

related hearing loss had a significant effect on auditory-verbal memory. The effects of age on memory and auditory-verbal learning have also been studied by Jafari et al. [11]. They also found that aging reduced the test scores, which is in agreement with the results of the present study. Aghamolaei et al. [26] evaluated the effect of ear on the Persian version of the DAVMT in 110 young people aged 18−25 years (male and female). Their results showed the superiority of right ear in both genders under this test compared to the left ear. In the present study, under both dichotic tests in both groups, the superiority of right ear scores was also reported. There are, however, some studies with contradictory results. For example, Wester and Hugdahl [27], using the English version of DAVMT, examined 32 normal-hearing adults. There was no difference between right and left ear results. Structural differences in the right and left hemispheres are the reason for the difference in the processing of speech stimuli in the two hemispheres. For example, it has been shown that the planum temporal in the left hemisphere is larger than in the right hemisphere, and this can be the source of the difference in the specialization of the two hemispheres [23]. Lavie et al. [28] found that hearing aids in hearing-impaired seniors could improve speech comprehension and dichotic listening. They divided 47 hearing-impaired seniors into four groups using dichotic listening and speech recognition tests; 36 in three groups, before and after (4, 8 and 14 weeks) using hearing aids, and 11 in control group with no hearing aid. The results showed improvement in dichotic listening after 8 weeks and in the speech recognition in noise after 4 weeks of hearing aid use, but no improvement was observed in the control group. In fact, the use of hearing aids, even for a short time, causes changes in the processing of auditory inputs of the elderly in functions such as speech recognition in noise and dichotic listening. These changes suggest that the elderly people's central auditory system retains the behavioral potential of plasticity. Perhaps the type of hearing tests and the degree of further hearing loss in study by Lavie et al. is the reason for to the discrepancy. Overall, according to the findings of the present study and its comparison with other studies, it can be said that the DAVMT has the ability to show adverse effects of hearing loss on recognition function and memory of the elderly. With more studies in this field, it can turn this test into a useful and common clinical test for auditory verbal memory in this group.

Conclusion

The adverse effects of aging and hearing loss on listening function were identified using the DAVMT. Although the scores of this test are reduced in the elderly with hearing loss, but it can be slowed down by the timely use, proper prescription and adjustment of hearing aids. Moreover, this test is an appropriate method for demonstrating auditory memory problems along with other tests and assessment methods that can make it a suitable tool for assessing auditory-verbal memory in clinical works and various studies. The use of this test in the evaluation of elderly people with hearing loss can provide a clearer picture of the patients to the audiologists, and be helpful in better rehabilitation using hearing aids.

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Conflict of interest

The authors declared no conflicts of interest.

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