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RESEARCH ARTICLE

Free and focused attention in young and aged listeners using randomized dichotic digits test

Fatemeh Heiran[1], Mohammad Ebrahim Mahdavi[1*], Fatemeh Heidari[1], Alireza Akbarzadeh Baghban[2], Mohammad Mehdi Heiran[3]

[1]- Department of Audiology, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran

[2]- Department of Basic Sciences, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran

[3]- Department of Emergency Medicine, Kerman University of Medical Sciences, Kerman, Iran

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Abstract

Background and Aim: Aging is associated with reduced cognitive abilities including attention and memory. There is some evidence that shows randomized dichotic digits test (RDDT) has enough difficulty to show the ear asymmetry in dichotic listening. This study aimed to compare the effect of free and focused attention on dichotic listening ability of young and elderly listeners.

Methods: The cross-sectional comparative study was performed on fifty right-handed young (18-25 years old) and fifty right-handed aged (60-80 years old) individuals with equal gender ratio. Recognition performance of right and left ears were compared in free and focused attention conditions.

Results: In the free attention condition, mean percent correct of right and left ears of aged group (83.1 and 61.5 respectively) was significantly lower than the scores of the young group (92.8 and 84.3 respectively with $p<0.001$). In focused attention to right, there was no statistically significant difference between mean of performance of the two age groups ($p=0.407$); however, aged group obtained significantly lower mean score in focused attention to left ear ($p<0.05$).

Conclusion: Random presentation of one-, two- and three-pair of dichotic digits resulted in diminished performance of both ear of aged group in free attention and left ear performance in focused attention conditions. Lower score of aged group in randomized dichotic digits test can be better explained by combinatory (structural and attentional) model of dichotic listening.

Keywords: Free attention; focused attention; randomized dichotic digits test; dichotic listening; elderly

[*] **Corresponding author:** Department of Audiology, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Damavand Ave., Tehran, 1616913111, Iran. Tel: 009821-77542057, E-mail: mahdavime@sbmu.ac.ir

Introduction

Many studies suggest that auditory cognitive capacities change as age increases [1-3]. Aged persons show lower recognition scores than younger listeners especially in the presence of background noise or competing message. In addition to the peripheral auditory sensitivity decline, aging makes changes in the central auditory nervous system, so dichotic listening test is an appropriate procedure to assess age-related reduction in cognitive functions as its

results reflect attention and memory performance [1,2,4].

Dichotic listening test is a non-invasive behavioral test that can evaluate interhemispheric interactions and attentional processes [5]. In dichotic listening test, subjects are asked to listen to two different auditory stimuli presented simultaneously to the right and left ears [2]. Generally, aging leads to reduction in left ear performance [6]. The interpretation of dichotic test results basically depends on the right ear advantage (REA) scores. There are some different models; e.g., Kimura structural model, Kinsbourne attentional model and combinatory model (structural and attentional), all of which consider the left hemisphere dominance in speech signal processing [7-9]. Dichotic listening is evaluated using different kinds of stimuli such as nonsense syllables, digits, monosyllabic words, spondee, and sentences. Digits are more appropriate for the elderly as test materials, because digits are relatively resistant to the influence of mild to moderate cochlear hearing loss, and have high level of inter-test reliability for both young and old persons. Moreover, digits are usually familiar to all listeners and performing the test as well as score calculation is done in a short time [1,3].

Strouse and Wilson used two list of English one-, two-, and three-paired dichotic digits tests (DDTs) with semi-randomized distribution [1]. One and two digit pair do not produce a clear right ear advantage in dichotic listening. Ear asymmetry is better revealed as the number of digit pairs increases [1,10-12]. Some authors indicated that for the test materials presented to the left ear, recognition scores decreases as a function of aging and the scores do not change for test materials presenting to the right ear [13]. Such results are still controversial, since some studies have not reported these effects. It can be inferred that auditory laterality may not be based on only one mechanism and it is also necessary to consider individual differences in auditory processing [5].

Bottom-up processing deficits may cause some limitation in sensory input processing, while impairments in top-down processing may lead to reduction in flexibility and cognitive control accompanied by memory capacity loss. Therefore, it is not yet clear whether decline due to age in dichotic digit task in the elderly is because of bottom-up processing disorder or attentional impairments of facilitation of top-down processing, or both [4]. On the other hand, functional magnetic resonance imaging (fMRI) confirmed that dichotic listening not only depends on temporal lobe integration and interhemispheric interaction, but also it needs intrahemispheric relations [14]. Memory function, attention, and the speed of information processing are affected by cognitive age. Mild memory impairments are also more prominent in the elderly especially when top-down processes are checked. However, the exact nature of age-related changes has not been understood yet [13].

Strouse and Wilson studied semi-randomized DDT test (presented in one-, two-, and three-pairs respectively) in different age groups, under the condition of free recall and directed attention. They showed recognition scores decrease as age increases [1]. Anderson et al. assessed dichotic listening on free and focused attention by consonant-vowel materials. There was no significant difference between young and the elderly in free attention and directed attention to the right ear. However, when attending to the left, younger listeners showed left ear advantage but such results were not observed in elderly persons. It is inferred that aging causes reduction in top-down attentional control. Right ear advantage was also significantly higher in male group than female group [4].

Randomized dichotic digit test (RDDT) has a unique structure with one-, two- and three-pair digits that each item demands different degrees of memory and cognitive ability [1,3,8,11,12]. Persian version of RDDT developed by Mahdavi et al. is relatively free of ceiling effect even in young adults that make it appropriate for studying the effect of attention on dichotic listening. Our previous research on Persian RDDT showed that REA of young adult is not

Table 1. Mean (standard deviation) of right and left scores in percent correct for digit-pair components and total score of randomized dichotic digits test in free attention

	One-pair digits		Two-pair digits		Three-pair digits		Total score	
Age group	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**
Young	99.6 (1.5)	98.8 (2.6)	96.8 (3.1)	88.7 (6.2)	87.9 (5.6)	76.5 (7.8)	92.8 (3.2)	84.3 (5.4)
Aged	95.4 (7.2)	86.8 (15.2)	87.9 (8.2)	62.1 (14.5)	75.7 (12.1)	52.7 (8.7)	83.1 (9)	61.5 (1.4)
p	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

significantly different from REA of three-pair dichotic digits [15]. This study aimed to compare the effect of free and focused attention on dichotic listening in young and elderly listeners using RDDT.

Methods

Fifty young (age range: 18-25 year) and fifty aged individuals (age range: 60-80 year) with equal number from both sex participate in this comparative cross-sectional study. An easy sampling method was applied. This sample size was determined considering type I α=0.05 and type II errors, β=0.02 (power=80%).

The participants had no history of neurologic and psychological disorders, ear disease, diabetes, alcohol abuse, and cigarette smoking. All participants also signed a written consent form. Hearing thresholds of young group were within normal limits (≤20 dB HL in frequencies 500-4000 Hz) and of aged group were ≤25 dB HL in 500-2000 Hz and ≤40 dB HL at 4000 Hz. Hearing threshold asymmetry between ears was 10≤dB HL in 500-4000 Hz. Edinburg test was performed to assess handedness and strong right-handed individuals (≥9) were selected [16].

At first we calibrated the headphone (Philips SHM 6500/10) attached to lap top (Dell Inspiron 6400, Ireland) by 1000 Hz tone. Persian RDDT which is consists of two equivalent lists was used [12]. Before starting the test, we explained the aim of the test and participants were instructed how to perform the test. Participants got familiar with test procedure as practiced with seven pairs including one-, two- or three-pair digits before starting the test. Persian RDDT performed on 50 dB HL for young group and on 70 dB HL for the aged group. The study was carried out in two phases. In phase I, both group listened dichotically to digits under free attention using list 1. In phase II, dichotic listening to digits was performed under focused attention to the right and then to the left using list 2. A five-minute resting time was considered between the phases. Using raw score of each ear, laterality index under free attention calculated by a formula as follows [16]:

Laterality index=100 × (Right ear scores–Left ear scores/Right ear scores+Left ear scores)

All raw data converted to rationalized arcsine unit (Studebaker, 1985) and statistical analysis using SPPS 21 performed on converted values [17], however table and figures contain the results in percent. In order to assess normal distribution of data, non-parametrical Kolmogorov-Smirnov test was used. The interaction effect of inter-group variable (age effect) and intra-group variables (sex and ear effects) were assessed with multi-factorial repeated measures two-way ANOVA. In this study 0.05 significance level was considered for all statistical tests.

Results

Young and aged groups had mean (standard deviations) age of 21.5 (2.3) and 65.6 (4.4) years respectively. Table 1 show mean and standard deviations of percent correct scores in the right and the left ear of the age groups for RDDT and separately for different digit-pairs under free attention.

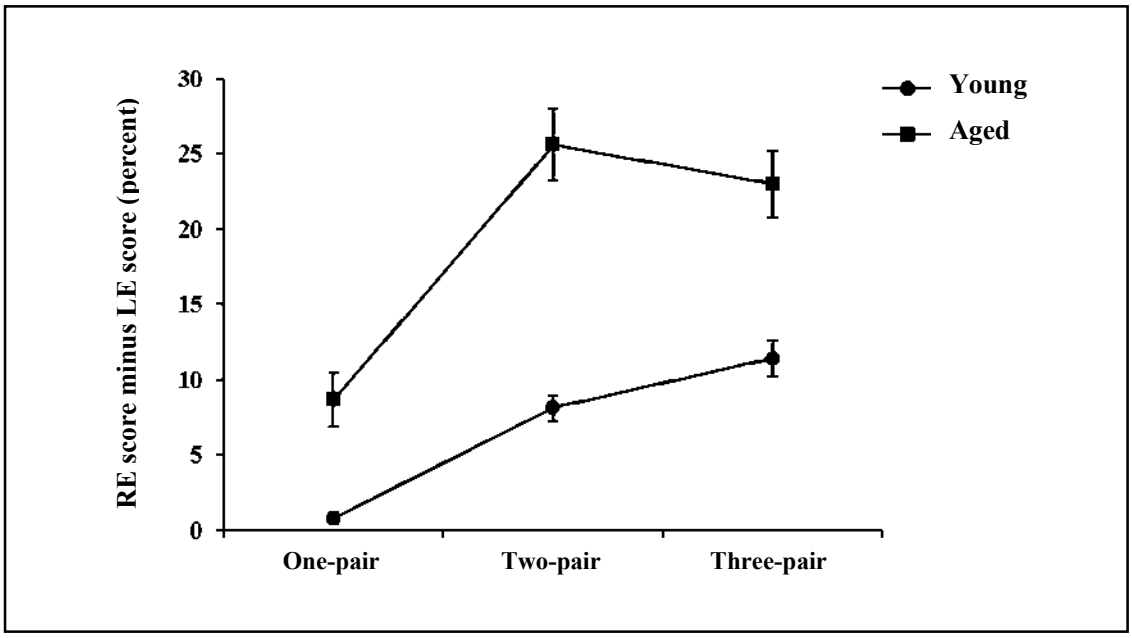

Fig 1. Mean (SEM) of ear asymmetry of age groups for dichotic digits of one-, two- and three-pair under free attention condition.

Mean right and left ear scores of Persian RDDT in young group were 92.8% and 84.3%, and the scores were 83.1% and 61.5% respectively for aged group. Aged group obtained significantly lower score than young group in their right and left ears under free attention for total score of RDDT and for various digit pairs ($p<0.001$). All digit pairs and total RDDT score showed a significant REA in age and young groups except for one-digit pairs that did not produced significant ($p=0.7$) REA in young group (Fig. 1).

For performance of ears in free attention, there was no significant difference between the two sex groups ($p=0.061$) and no interaction was seen between age group and sex ($p=0.104$).

However, in young group, mean total score of left ear on free attention showed significant difference between the two sex groups ($p=0.004$). There was no significant interaction between age groups and sex ($p=0.364$). There was no significant differences between the two sex groups for all digit pairs (for one-, two-, and three- pairs, $p=0.589$, $p=0.176$, $p=0.443$, respectively). No significant interaction was observed between age group and sex except for three-pairs (for one-, two-, three-pair; $p=0.674$, $p=0.806$, and $p=0.005$ respectively). There was significant difference in laterality index between the two age groups ($p<0.001$). However, no significant difference between sex groups ($p=0.211$). Also, no interaction between age groups and sex ($p=0.282$).

Fig. 2, compares dichotic listening performance between the age groups in free and focused attention. In focused attention condition, mean (standard deviation) right ear score of young and aged was 97.7% (2.5) and 96.9% (3.3) respectively ($p=0.407$). However, mean left ear score of aged group (91.4% (7.4)) was significantly ($p=0.04$), lower than mean score for left ear of young group (94.7% (4.0)). Focused attention to right ear resulted in significantly higher score than left ear score in both age group ($p<0.001$). There was no significant difference between performance sex groups ($p=0.618$) and no interaction between age group and sex was seen ($p=0.351$).

Difference between free and focused attention show an ear effect. In both groups, focused

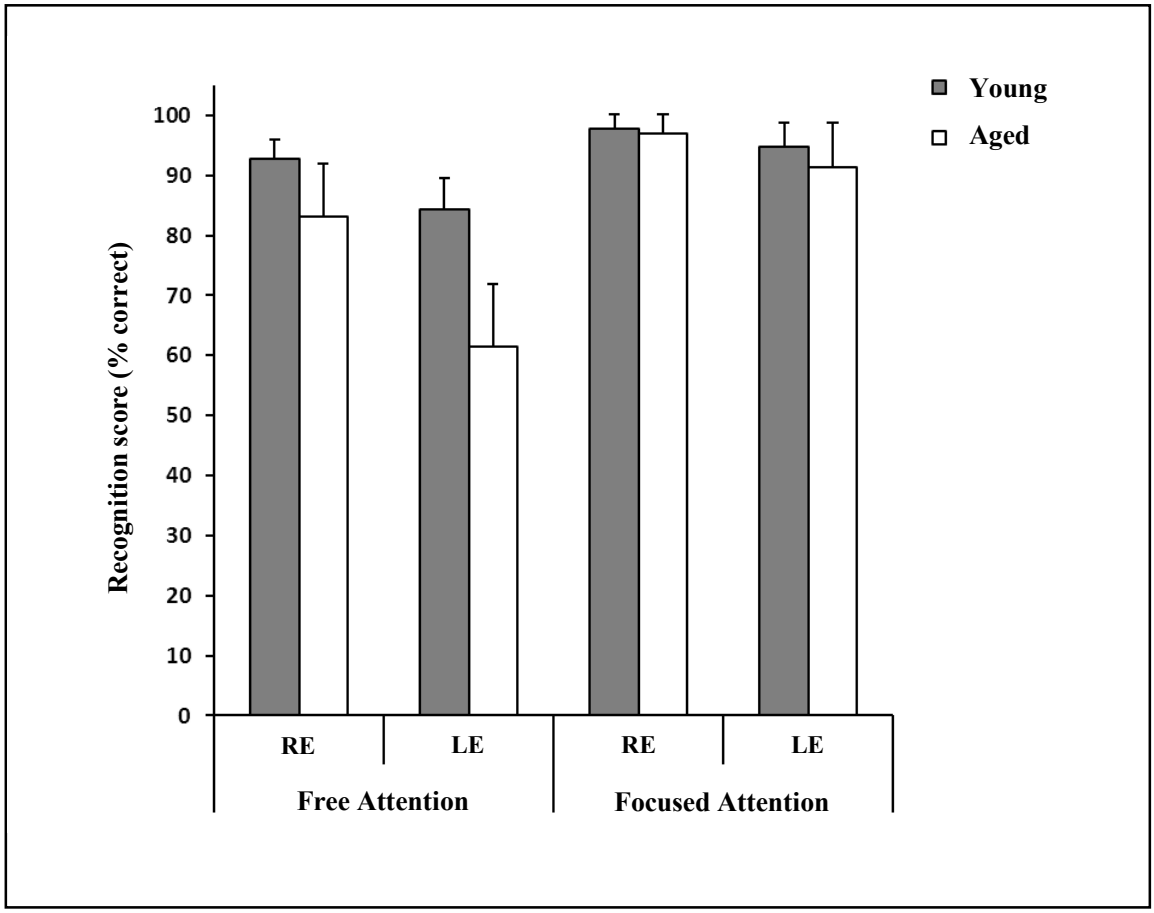

Fig 2. Mean (+SD) of right and left ear score of the age groups under free and focused attention conditions for randomized dichotic digits test.

attention to left ear enhanced the score more than focused attention to right ear, ($p<0.001$). Mean (standard deviation) of augmentation of left ear score by focused attention was 29.9% (8.6) in aged group and 10.5% (6) in young group ($p<0.001$). The corresponding values for right ear was 13.9 % (8) and 4.9% (3.8) respectively ($p<0.001$).

By focused attention, twenty of aged group increased their left ear score to level of mean left ear performance of young group (94.8%) and the rest failed to show performance equal or better than 94.8%.

Discussion

Dichotic listening task depends on structural integrity of auditory system ascending pathways as well as auditory cortex inter-hemispheric connection and, allocation of sufficient cognitive resources such as attention and working memory [2,18]. The main purpose of current study was investigating aging effect on dichotic listening to randomly presented digit-pairs with various lengths. Given Persian RDDT depends more on working memory span than two digit-pair test, comparison of its results between age and young person might be informative regarding role of working memory in dichotic listening. In comparison to young group, aged group had inferior performance on dichotic listening under free attention in both ears. This finding may originate from reduced cognitive capability of aged persons for encoding, retention, and retrieval speech materials presented

simultaneously to right and left ears as well as attention switching between ears both of them can be consider a top-down processing deficit. This part of our results indicate the vital role of non-auditory factors such as memory and attention in dichotic listening as previously has demonstrated [1]. It seems that with advancing age, inhibitory executive function and mental flexibility especially in prefrontal lobe in the elderly attenuate and top-down attention control decreases so attentional facilitation in left attention shows more reduction [2,13,19].

Absence of significant REA for one-pair digits with minimal dependency to working memory in young group while presence of a left ear deficit for one-pair digits in aged group is consistent with an auditory or structural problem that can be explained by corpus callosum atrophy and decreased integrity reported in literatures [6,13,19].

Mean right ear score of aged group in free attention (83.1%) increased significantly in focused attention (96.9%) and reached to mean right ear score of young group (97.7%, $p=0.58$). Mean left ear of aged group in free attention (6.15%) increased to 91.4% in focused attention, however age group was not able to overcome their weaknesses in free attention by focused attention to the left ear and remained a significant difference between mean left ear score of age group (91.4%) and young group (94.8%, $p<0.05$). According to Jerger and Martin, when deficit of scores remain in focused attention, the deficit is categorized as [central] auditory processing disorder (pattern III). In comparison to mean left ear score of young group in focused attention (94.8%), 60% of aged group continue to show weakness of left ear score even in focused attention to left side. Jerger and Martin saw pattern III in 23% of 172 aged individuals (60-90 years) using normative data of English dichotic sentence identification (DSI) test [20].

Aged group was more successful than young group in enchantment of left ear score in focused attention. Hugdahl et al. suggested in young normal listener during focused attention to left ear, a confliction occurs between top-down and bottom-up processing. Since in attention to the left, top-down and bottom-up processes are in opposite direction, stimulus-driven bottom-up mechanism dominates top-down process and lead to overall decrease of left ear scores in focused attention [21]. It seems aged group have deficiency of auditory memory of heard materials and focused attention impose lower load for memory than free attention thereby a substantial increment of score is seen in focused attention to each ear. Moreover, left ear deficit in elderly may be because of attention deficit resulting from inability to switch attention between the two ears [9].

It is inferred from the results of current study that RDDT have enough difficulty for revealing ear asymmetry in dichotic listening and potential for discovering role of non-auditory top-down processes in dichotic listening in aged population.

Conclusion

Performance of aged persons was diminished bilaterally during dichotic listening under condition of free attention to randomly presented one-, two-, and three- pairs of digits. This weakness disappeared in focused attention to right ear. However, in majority of aged persons, left ear deficit remained in focused attention to left ear. Lower score of aged group in RDDT can be better explained by combinatory (structural and attentional) model of dichotic listening.

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