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RESEARCH ARTICLE

Comparison between the auditory lateralization ability of normal hearing elderly and youth with filtered noise

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Abstract

Background and Aim: Aging affects the auditory lateralization function that is achieved through processing binaural cues. One of the most important benefits of this process, along with getting informed of sound location, is increasing signal to noise ratio and improvement of speech comprehension in crowded environments, which is one of the most common hearing complaints in the elderly. This study aimed to compare the performance of the lateralization function under the headphone conditions between the elderly and the youth, with a filtered noise stimulus.

Methods: This study was performed between 22 elderly aged 60−80 and 22 young people aged 20−30. The auditory threshold was less than 25 dB HL in 250 to 4000 Hz frequencies in both groups. By applying a time delay of −880 to +880 microsecond and the intensity difference of −10 to +10 dB between the two ears, and with high-pass and low-pass noise stimulus, the lateralization function was examined. For description of the lateralization function, scatter diagram and in order to compare the results, paired t-test and independent t-test were used.

Results: Findings showed that the elderly's errors were increased in all tests compared to those of the youth group. There was a significant difference ($p < 0.05$) between the two groups in lateralization by time clues with low-pass and high-pass noise.

Conclusion: Results confirm the impairment of the lateralization and processing of binaural cues in the elderly differently.

Keywords: Elderly; lateralization; low-pass noise; high-pass noise

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Introduction

Elderly, based on World Health Organization (WHO), is defined as age 60 or higher [1]. With age, structure and function of almost all levels of the auditory system from the external ear to auditory cortex are affected, and these changes are manifested as presbycusis. In most cases, peripheral and central disorders happen simultaneously, but occasionally there is an auditory information processing defect in spite of normal hearing level [2]. Peripheral and central processing disorders have significant effects on the elderly’s communication ability, and their common complaint is speech perception difficulty especially in noisy environments [3]. Age-

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related changes in the central auditory system can affect important aspects of auditory processing such as binaural auditory processing. One of the essential abilities that happens as a result of the binaural hearing is sound source lateralization and localization in the auditory space [4] which helps animals in survival and humans in danger awareness and distance perception [5]. Lateralization and localization in the horizontal plane take place by comparing interaural time difference (ITD) and interaural intensity difference (IID) information between two ears. According to duplex theory, both binaural cues are frequency specific in a way that ITD is related to low frequencies (lower than about 2 kHz) and IID is related to higher frequencies (above 2500 Hz). In middle frequencies (1500−3000 Hz), there is a vague relation between these cues and frequencies. The duplex theory is specific to pure tones. Evidence shows that ITD is used for localization of complex high frequency stimuli (above 1500 Hz) such as filtered noise. In this case, the location of the stimulus is determined by envelope instead of fine structure [6]. These binaural cues are the base for all binaural processing and spatial hearing which are important for auditory localization, environmental sounds awareness, separating the auditory target from background non-relevant sounds and selective attention. In humans, all of these capabilities are important for increasing signal to noise ratio improvement and speech perception in noisy situations or in presence of multiple talkers (cocktail party effect) [7,8]. The first stage of binaural processing is superior olivary complex (SOC) in low brainstem consisting of two nuclei: medial superior olive (MSO) and lateral superior olive (LSO). ITD and IID are processed differently in these regions which are accounted as bottom-up or data-driven processing. This processing pathway relies on input information and central auditory integrity [9]. Top-down or concept-driven processing contributes to precise localization and streaming which is dependent on higher order sources such as attention and memory [10]. There is evidence that shows the elderly with normal hearing have difficulties in lateralization and localization in comparison with young subjects that they do not benefit from binaural hearing [11]. Researchers have tested lateralization in the elderly by different methods. Delphi et al. have pointed out that Dobreva et al. used the wide band, high-pass and low-pass noise, with a loudspeaker to test localization precision and accuracy and showed that elderly show lower precision and accuracy compared with young and middle-aged subjects [12]. Based on Moosavi et al., Bobkoff et al. tested lateralization using click in 78 subjects aged from 21 to 88 years old with a normal hearing under headphone and showed that lateralization ability is diminished by age [13]. Strouse et al. examined 12 young and 12 elderly with normal hearing level, monaural gap detection and ITD threshold for click under headphone and reported that elderly have higher gap detection and ITD threshold than youngsters [14].

As lateralization and binaural processing are the base for very important and complex processing of auditory system including speech perception in noise and in presence of competing sounds, precise and comprehensive examination of lateralization in elderly is important to understand the processing to plan right rehabilitation methods to meet their communication needs [15].

As mentioned, studies have used different methods for the examination of auditory lateralization. As click is a transient stimulus, it contains a wide spectrum that provides a lot of frequency information for lateralization and makes lateralization easy [16]. On the other hand, as most natural sounds such as speech have a wide frequency range, a study using pure tones cannot provide precise information about everyday lateralization performance [17]. Therefore, we tried to use a stimulus with much similarity to everyday sounds.

In the lateralization test under headphone, subject points to the source with attention and focus [13]. With this behavioral and non-invasive test, we can examine binaural hearing processing at the brainstem level [9]. Low-pass noise has fast spectral changes so it is an easy stimulus for sound source discrimination. Low-frequency signals have very precise temporal information for localization and provide ITD. Perception of high-pass noise is mostly based on the envelope, it is harder to discriminate, and it is more sensitive for differentiating normal subjects from impaired ones (unlike low-pass noise which due to being simple to identify, it has low sensitivity for detecting patients with brainstem impairment). The reason for selecting 2 kHz cut-off point is that in the middle frequencies (1500−3000 Hz), ITD and IID are vague [18]. The aim of the present study was a more precise examination of ITD and IID processing for low-pass and high-pass noise with 2 kHz cut-off frequency under headphone.

Methods

This cross-sectional study was carried out between 22 elderly 60 to 80 years old with mean age of 63.36 years and a standard deviation of 2.27, including 13 (59.09%) women and 9 (40.91%) men, and 22 young 20 to 30 years old with mean age of 25.05 and a standard deviation of 1.63, including 12 (54.55%) female and 10 (45.45%) male with normal hearing and being monolingual (speaking only Persian). The number of samples was obtained based on the most similar researches and studies carried out globally [14]. The sampling method was the convenience one in which the young people were selected from the students at the University of Social Welfare and Rehabilitation, and the elderly were chosen from the elderly people referring to the cultural centers of several regions in Tehran. After receiving consent letters from the individuals, their personal information including age and medical history were recorded in the history form. Then, in order to assess the mental health status of the elderly, the Persian version of the mini-mental state examination (MMSE) test was used. The inclusion criterion was a score of 25 or more [19], and in both groups, Edinburgh manual excerpt scale test was used for right-handed endorsement. Next, for the aim of examining the auditory condition at first, external ear examinations were performed using otoscope Rister 2010, in order to examine the middle ear condition the Zodiac 901 tympanometer (manufactured by Madsen of Denmark), the tympanometric benchmark of An type and hearing assessment (hearing threshold in both ears at frequencies of 250 to 4 kHz less than 25 dB HL and difference of threshold in each frequency between two-side 5 dB or less) using a midimate 622 audiometer (GN otometrics company, Denmark) speech audiometry (single-syllable recognition score of better than 80% in both ears) was used to confirm the normal hearing of samples. Finally, the subjects who were eligible for research were selected and lateralization valuations was conducted under headphones for these people. In this study, the responses for each individual, in four situations of interaural time difference with high-pass noise (ITDHPN), interaural time difference with low-pass noise (ITDLPN), interaural intensity difference with high-pass noise (IIDHPN) and interaural intensity difference with low-pass noise (IIDLPN) tests were evaluated.

The lateralization test was performed at a comfortable listening level and in a quiet environment. ITDs signs in 220 microsecond steps (−880, −660, −440, −220, 0,+220, +440, +660, +880) and IID in steps of 2.5 dB (−10, −7.5, −5, −2.5, 0, +2.5,+5, +7.5,+10) were applied to the stimuli, and 9 hypothetical positions (in the form of 9 speakers in a semicircular plane) were simulated in the horizon (a positive sign indicating the reception and understanding of the stimulus on the right and the negative indicating understanding on the left and the zero indicating that there is no time and intensity delays in the presentation of the stimulus between the ears, in each case the stimulus is received from the front side). Initially, the necessary training about evaluation procedure was given to people. In the training stage, the sequence of stimulus presentation was such that the stimulus at first presented in head center (speaker 5) and then in the right (respectively, speakers 6, 7, 8, 9) and back to the center. It moved to the left (loudspeakers 4, 3, 2, 1). The training method was to put the picture of 9 speaker positions exactly in front of the subjects and play the stimulus through the headphones in the ear of the subjects, whenever a sound that was heard, its location of was taught by the trainer by reference to the image of corresponding speaker. In the next step, the subjects themselves referred to corresponding speakers. After complete assurance of learning how to execute and function in each ITDLPN, ITDHPN, IIDLPN, and IIDHPN tests, nine stimuli were presented. Each stimulus was repeated twice, randomly and in general, every person responded to 72 stimulations in 4 tests.

To describe and analyze statistical data, the scatter diagram [in this graph, the X-axis represents the applied ITD and IID (in ITD from −880 to +880 microseconds, and in the IID from −10 to +10 dB), and the Y-axis represents the position of the speakers (loudspeaker 1−9)]. In Excel software, and to separately compare the error rate of the responses in each group and also to compare errors between the two groups, independent and paired t-test were used, respectively. The calculation of the error rate of responses in each test was such that, for example, if the latency of +220 was given to a person's ear and instead of showing the speaker number 6, the loudspeaker 7 was shown, one error and if, the loudspeaker 9 was shown, three errors were counted. Then, errors were collected at each separate position (each speaker) and then, with the sum of all errors in each of the 9 positions the total error in each test was calculated. The response errors in the IID tests (IIDLPN and IIDHPN) were also obtained in the same way. Finally, statistical analysis was performed by SPSS software version 21.

Results

Mean and standard deviation of pure tone average in young subjects and the elderly were 7.50 ± 3.36 dB HL and 14.31 ± 4.95 dB HL, respectively. Fig. 1 depicts, the scatter plot for ITDHPN, ITDLPN, IIDHPN and IIDLPN in a young and an old subject.

Table 1 summarizes mean and standard deviation of errors in ITDHPN, ITDLPN, IIDHPN and IIDLPN tests for young and old subjects. In general, the ITD test showed more errors than IID. Comparing results in youngsters through paired t-test showed a significant difference between ITDHPN and IIDHPN (p = 0.048) and the average of error in the ITDHPN test was higher.

Comparing results with the paired t-test in the elderly showed a significant difference between ITDHPN and IIDLPN (p = 0.005) and IIDLPN and IIDHPN (p = 0.008). As shown in Table 1, comparing errors via independent t-test showed a significant difference for ITDHPN and ITDLPN between the two groups (p = 0.044 and p = 0.016, respectively). In general, mean and standard deviation for errors in elderly were higher than those in young subjects in four mentioned situations.

Discussion

Scatter plot of lateralization in the elderly and young group showed dispersed responses for both ITD and IID but the dispersion was more for the elderly. For good lateralization performance, both cues in addition to monaural spectral cues (provided by auricle) are needed. As this test was performed under headphone and sound location was not real, all auricle spectral information was omitted and that made responses more dispersed in headphone testing [20]. In both groups, dispersion and mean value of ITD test errors were more than those of IID. Studies have shown that ITD processing is more complicated than IID and needs precise temporal processing at SOC. For IID, different nuclei and pathways are responsible [21]. In the present study, errors and the dispersion were higher for elderly than for young subjects and this finding is in agreement with those of Zakari and Patuzzi based on Delphi et al.'s report. It is also in agreement those of Bobkoff et al. that showed age-related changes in peripheral and central auditory system is mostly temporal and elderly had higher gap detection and ITD threshold than young subjects [12,16]. Studies have shown that decreased neural activity and dyssynchrony are the main reasons for the temporal and spatial cue encoding deficits in elderly [22].

In both groups, lateralization pattern in ITD tests from −880 to +880 microseconds was sigmoid or S-shaped. From −220 to +220 microseconds (central loudspeakers number 4, 5, and 6), there was a linear component, from −440 to −880 (left loudspeakers number 1, 2, and 3) and

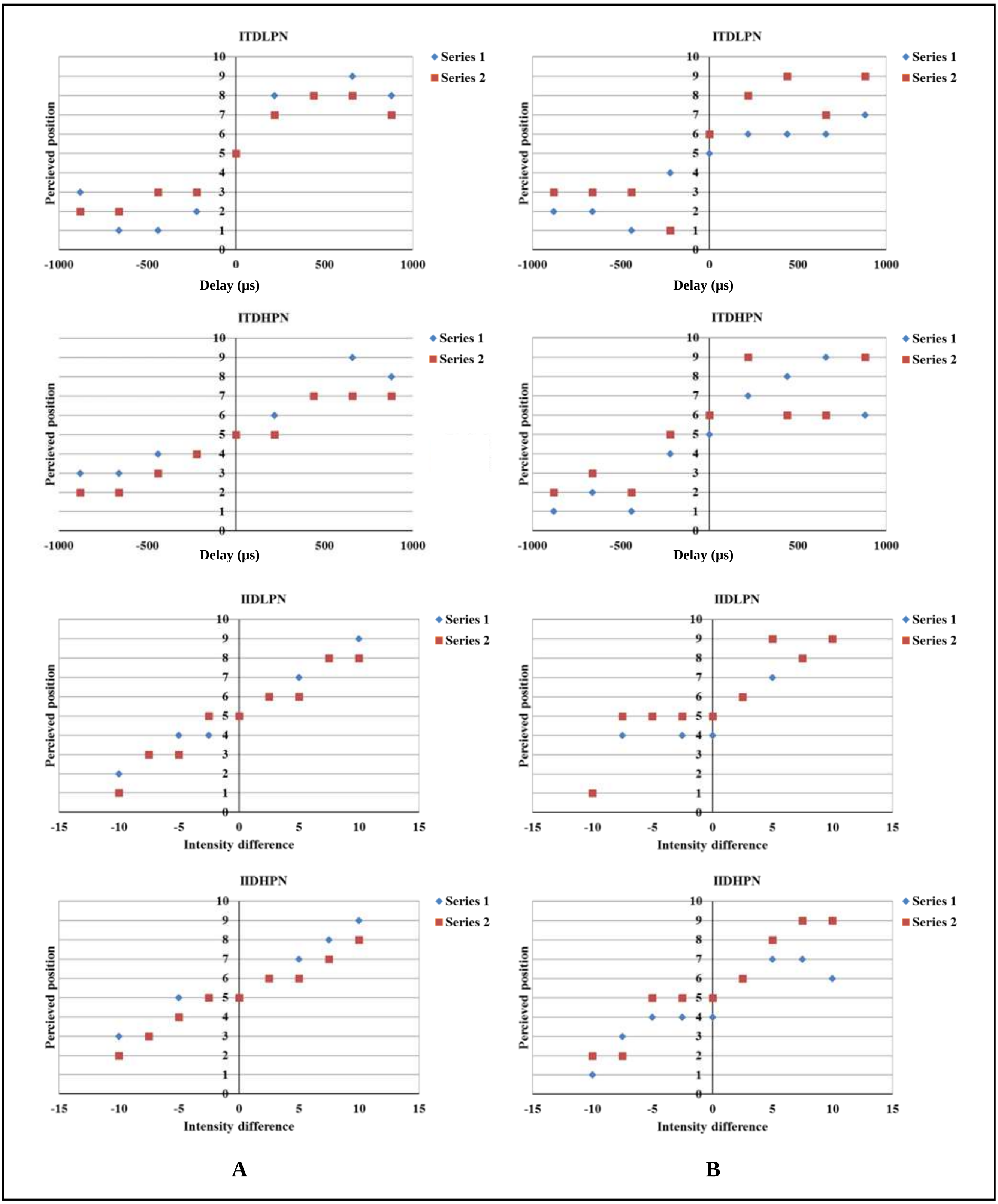

Fig. 1. Perceived position in four lateralization tests in A) a young female, and B) an old male. ITDLPN; interaural time difference with low-pass noise, ITDHPN; interaural time difference with high-pass noise, IIDLPN; interaural intensity difference with low-pass noise, IIDHPN; interaural intensity difference with high-pass noise.

Table 1. Mean (standard deviation) error scores for lateralization tests in the young and elderly groups

Test	Mean (SD) error		p
	Young group (n = 22)	Elderly group (n = 22)	
Interaural time difference with low-pass noise	14.10 (4.11)	20.30 (6.43)	0.044
Interaural time difference with high-pass noise	14.29 (4.24)	19.20 (7.05)	0.016
Interaural intensity difference with low-pass noise	13.09 (4.06)	18.54 (6.39)	0.078
Interaural intensity difference with high-pass noise	12.40 (4.36)	18.68 (6.57)	0.095

from +440 to +880 (right loudspeakers number 7, 8, and 9) were leaned to asymptote. Asymptote showed that there was not a significant location perception with changing ITD from −440 to −880 and from +440 to +880 microseconds and location discrimination shows decrement. In the IID test, the function was an approximately straight line from −10 to +10 [20]. This linear function shows that with increasing IID from 0 to −10 dB for left loudspeakers and from 0 to +10 dB for right loudspeakers, location perception changes and IID discrimination is available up to 10 dB or more [23]. Lateralization plot showed no difference in IID test with low-pass and high-pass noise but for ITD test, the plot for high-pass noise was a little wider than low-pass noise and responses were a little leaned to central situations (loudspeakers 4, 5, 6). In comparison between IID (IIDLPN, IIDHPN) and ITD (ITDLPN, ITDHPN) situations, data dispersion in high-pass noise was higher and errors were higher in elderly than in young subjects. In several studies, it was shown that low-pass noise is easy to localize and lateralize but high-pass noise, due to lack of adequate energy for lateralization via ITD (ITDHPN) and lateralization through signal envelope instead of fine structure, is harder [18,24]. In the present study, wider plot for ITDHPN than ITDLPN is secondary to inadequate energy in HPN for lateralization using ITD. Also, it was shown that the elderly's lateralization ability was diminished for central positions (loudspeakers number 4, 5 and 6) mostly in ITD situations which are in agreement the findings of Bobkoff et al. [16]. Studies have shown that subjects with inferior colliculus (IC) and cortex disorders have problems with midline lateralization. As most inhibitory functions are in these regions and with aging these inhibitory functions decrease, more errors in discriminating locations in the midline and around it might be the consequence [13,18].

IID and spectral cues are dependent on high frequencies which are vulnerable to high frequency hearing loss but studies indicated that horizontal localization using IID shows no reduction with age [25]. In the present study, errors and IID dispersion in the elderly was higher than those in young subjects but the difference was not significant. The different effects of aging on ITD and IID lateralization might be indicative of different central processing for these two cues so that deficit in one mechanism is not essentially indicative of deficit in the other one [16].

In the present study, by comparing lateralization errors in two groups, it seems that spatial processing in elderly is affected and it is shown by localization and lateralization disability. Koehnke and Besing indicated that lateralization and localization deficit can make it hard for subjects to suppress unwanted information in noisy environments [11]. In general, the past studies, as well as the present one, show that lateralization tests have good abilities in testing elderly, and accompanying other central auditory tests can improve diagnosis process and provide beneficial information about lateralization and spatial processing in elderly with complaint of hearing in noisy places [12]. It is suggested that ITD test be added to auditory processing test battery for elderly and lateralization test be conducted on elderly with a proven speech in noise perception to ensure which mechanism of speech perception in noise is effective.

Conclusion

Response pattern in ITD test was sigmoid or S-shaped and IID test was approximately linear in elderly and young subjects. IID responses were more coherent than ITD which indicates that ITD is a harder cue than IID. Elderly showed different performance in all situations compared with young subjects. A significant increase in dispersion and errors in the elderly is indicative of lateralization and binaural hearing deficit. However, in general, there was a significant difference between the two groups in lateralization ability with low-pass and high-pass noise ($p < 0.05$).

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Conflict of interest

The authors declare that they have no conflict of interest.

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