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Review Article

Review on Spatial Hearing Processing Disorder and Its' Rehabilitation Methods among Elderly in Iran

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ABSTRACT

Background: The hearing system can detect the location of the sound source and help us pay attention to it. In the presence of the background noise, it helps detecting the desired signal (especially speech) and comprehend it. This ability is called spatial hearing processing. Spatial hearing processing disorder can adversely affect signal detection in noise, which is very important in the elderly. The aim of the present paper was reviewing the spatial hearing processing disorder and its 'rehabilitation methods in Iran for the elderly.
Methods: In this narrative paper, theoretically, all papers on spatial hearing processing disorder and its' rehabilitation methods among the elderly in Iran from 2000 to February 2021 were collected. The papers with the following keywords in Medline, Google scholar, Proquest, science direct, Scopus, and Magiran were studied after discarding duplicated papers: spatial stream, binaural advantage, spatial release of masking, spatial hearing segregation, rehabilitation, aging, elderly, speech in noise, localization, training, and Iran.
Results: Aging adversely affects the spatial hearing processing and especially in complex environments, so rehabilitation of spatial hearing disorders can potentially improve comprehending speech in noise for the elderly.
Conclusion: The results of this study showed that there is absolutely necessary to develop different rehabitation programs for different elderly groups base on their needs.

Background

Spatial hearing refers to the ability of the hearing system in using spatial cues to detect the location of the sound source, pay attention to it, and receiving the desired signal in the presence of the background noise. Using spatial hearing, the hearing system can determine the location of sound source or enhance signal recognition via masking release [1, 2]. The underlying mechanisms of spatial hearing enable us to choose desired sounds from the background noise based on the directions, so spatial hearing helps in the detection and identification of sound source [3, 4]. Spatial hearing can also switch the attention to a selected sound source or deviate the attention from it. Age-related changes in structure and neurochemistry occur in different parts of auditory nerve system. These changes affect different aspects of the spatial hearing processing, and have various functional manifestations among the elderly such as impaired speech in noise comprehension and localization difficulties. Spatial hearing rehabilitation methods can potentially enhance the speech in noise comprehension ability and therefore improve social interactions via neural plasticity in the underlying structures even in elderly [5, 6].

Since the population is aging and senescence is one of the priorities of the healthcare system, rehabilitation needs of this population require special attention. One

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of the diminished abilities in the elderly is the spatial hearing processing which leads to impaired speech in noise comprehension. Meanwhile, plasticity following rehabilitation is a proven fact which leads to improvement of the processing abilities of the elderly. Thus, spatial hearing rehabilitation can improve the communication abilities of the elderly. To the best of our knowledge, so far there are no review study on spatial hearing rehabilitation methods of elderly in Iran.

Methods

The keywords used for the search were as follow: spatial release of masking, spatial hearing, spatial streams segregation, binaural advantage, rehabilitation, aging, elderly, speech in noise, localization, training, and Iran in different combinations across Medline, Google scholar, Proquest, science direct, Scopus, and Magiran databases.

Discussion

Considering the importance of this issue and the variety of spatial hearing rehabilitation methods in the elderly, this paper dealt with spatial hearing processing disorder and three spatial hearing rehabilitation methods among the elderly.

Spatial Hearing Models

The spatial hearing functions are conducted through comparing the Interear intensity difference (IID) and Interear time difference (ITD) of the signal reaching the two ears; so far, three models have been put forward for localization mechanism and spatial hearing [7].

In the first model, the inputs from two ears are cross-correlated in medial superior olive (MSO) level and the time differences are expected such that they would create maximum response in the encoding canals for the source of sound. This phenomenon explain the low-frequency localization [8, 9].

For the stimuli within the phase-locked frequency range, difference in the time of arrival of the stimuli into the two ears leads to differences in the binaural stimulation phase. In the Jeffress model, it is provided through comparing the input of one ear with the various time displaced input versions from the other ear [10]. Brand et al. proposed that precise and rapid contralateral inhibitory input is involved in adjusting this coincidence detection [11].

In the second model, intensity difference creates the maximum response in the encoding canals for the source of sound. The difference in the stimulus intensity in the two ears is greater for high frequencies, astheir sound waves are bent around the head and has less refraction. IID is extracted by lateral superior olive (LSO) [12, 13].

In the third model, the general level of the neural activity in inputs is compared from the two sides with each other. This model states that the direction of sound is evaluated from the relative values of the total activity in a hypothetical neural population launched by sounds on the left or right side of the head [14]. This model requires neural networks capable of comparing the level of activity of the two sides. The lateral lemniscus (LL) seems to be one of these processing stations. LL receives inputs from SOC bilaterally and from cochlear nucleus (CN) contralaterally [7].

Localization in all of the above mentioned models occurs in a horizontal plane and based on comparing inputs from the two ears. On the other hand, localization in the vertical plane and front/back requires other mechanisms.

The Effect of Age on Spatial Hearing

There are different hypotheses for central auditory processing disorders among the elderly. In a compensable review study by Hume et al., three hypotheses have been presented to explain the impairments in the central hearing system of the elderly [15].

A: environmental hypothesis; In this hypothesis, the speech recognition problems are related to interpersonal differences in encoding sounds from the external ear to the internal ear and the eighth nerve [15]. The environmental hypothesis has two aspects. In the first one, failure of the signal's energy to reach the auditory comprehension threshold of the person is the cause of impaired speech recognition. In the second aspect, due to aging, diminished cochlear processing ability creates distortion, which is beyond the auditory sensitivity reduction. These distortions may reducespectral, temporal, and intensity clarity [15].

B: Central hearing hypothesis: This hypothesis deals with age-related changes in the central auditory structures such as the inferior colliculus. This hypothesis examines the central impact of aging from two point of views:

1. Central impact of senescence. In this view, the environmental hearing is normal, and the communication and speech comprehention disorders are resulting from impaired processing of the central hearing structures from cochlear nucleus to cortical auditory pathways [15].
2. Central hearing changes are assumed to arise from environmental disorders [15].

C: Cognitive hypothesis: In this hypothesis, the higher centers in the auditory pathways are introduced as the source of interpersonal differences in cognitive abilities and the underlying reason for reduction in these functions. Cortical functions known in these regions include processing, storing, and retrieval of information. These functions are key mechanisms in speech recognition [16]. Cognitive defects are not merely related to hearing modality, rather it affects other modalities as well. The most notable changes in the cognitive function affecting the speech comprehension include attention deficit, diminished speed of mental processing and comprehension, disorders in active memory, as well as impairments in executive functioning [16, 17]. Thus, the problem of the speech in noise recognition during elderly can be partly related to decreased hearing, though speech understanding problem in noise has also been reported among the elderly with normal hearing [18, 19]. Other areas of spatial hearing function that show impairment among the elderly includ sound localization, precedence effect, and binaural processing [20].

Reduction in myelin and brain connections can affect temporal encoding and spatial segregation, whereby the person finds problem in spectral and temporal processing

[21]. Thus, hearing loss among the elderly can only explain a part of their problem in speech processing, and disorders of spatial hearing can aggravate the impairments in the speech processing in the elderly [22].

Beising and Koenke conducted a review study on the effect of aging on spatial hearing. By collecting the results of different studies, they found that with aging, the ability of determining the location of sound source, ability of speech in noise comprehension, and detectability of speech in noise with binaural cues and the ability of temporal as well as intensity segregation between the two ears decrease [23].

A clinical retrospective study by Curri and Goncales was performed to investigate the auditory processing among the elderly with no apparent complaint of hearing loss. They used speech in noise and staggered spondee word (SSW) tests for examining these people. The results indicated that in both tests, there was no difference between the men's and women's performance, while the elderly with 65 years of age and above showed a weaker performance compared to 55-64-year-old elderly [24]. Nazeri et al. also showed the same results in a review paper [25].

The Effect of Age on Efferent System

One of the major problems of senescence is difficulty of hearing when background noise is present. Research has suggested that impairment of the medial olivocochlear complex (MOC) plays a role in this problem, as MOC is heavily involved in unmasking the sound signals [26-28]. MOC has cholinergic innervation on outer hair cells (OHCs) [27, 29]. Thus, MOC activation leads to improved sound localization in the presence of background noise [30-32].

Animal studies have shown that with aging, reduction occurs in the number of OHCs and efferent terminals on OHCs. It seems that the biological mechanisms of OHC reduction and efferent terminal reduction are different. This is because before OHCs reduction, in most cases, reduction of the efferent terminals of OHCs is observed, and it could be stated that these two issues have parallel mechanisms [33].

Meanwhile, animal studies suggest that with aging, changes occur in the efferent system. Lisowska et al. studied the elderly with normal hearing based on otoacoustic emission (OAE). They showed that the strength of MOC system diminishes with aging [34]. It seems that anatomical and functional changes related to the MOC system mostly initiate during the middle age [35].

Spatial Hearing Rehabilitation of the Elderly in Iran

In the elderly with normal hearing, the spatial hearing processing shows deterioration [22]. Thus, spatial hearing rehabilitation seems essential for overcoming the decline of speech in noise comprehension problem. This is because spatial hearing plays a significant role in speech in noise recognition [36, 37]. Meanwhile, considering the plasticity of the central nervous system, training improves auditory skills [38, 39].

In recent years, some research has been conducted with regards to spatial hearing rehabilitation, in Iran. These rehabilitations are as follow.

Dichotic auditory rehabilitation: In the late 1960s, with dichotic studies, researchers were able to study the difference in the functioning of the two hemispheres among healthy individuals. The results suggested that the right hemisphere is mostly involved in general processing of new data, while the left hemisphere is involved in linguistic functions as well as detailed analysis. The commonly used clinical speech tests to indicate the superiority of the right ear include dichotic digit test, Dichotic Fused Rhymed Word Test, Dichotic Consonant-Vowel Test, SSW test, and competing sentence test. Based on the studies performed by these tests, the right ear superiority/advantage in each of these tests is indicative of dichotic auditory problems [40]. One of the most important rehabilitation methods for dichotic listening are differential interaural intensity difference (DIID) and dichotic offset training (DOT). In the formal form of DIID, first the crossover point (CP) is determined. The presentation begins from 50 dB. For this purpose, the intensity of presentation to the stronger ear decreases with 5 dB steps; the point at which the weaker ear outperforms the stronger ear is the crossover point. After finding this point, the exercise begins. First, 50 dB is presented to the weaker ear and CP minus 5 (CP-5) is presented to the stronger ear. At the end of the session, the difference between the two ears decreases to zero, and the dichotic assessment is repeated. In subsequent sessions, the level of the stronger ear is increased by 5 dB if the function of the weaker ear remains unchanged (80% or more). At this level the exercise continues for 2-3 other sessions. If the function of the weaker ear following this significant change diminishes, only 1 dB is added to the presentation level for the stronger ear, and the exercise continues for other 2-3 sessions. This process continues until the performance of both ears reaches the normal range [41].

In a study by Gill, the effect of DIID auditory training on the auditory processing of hard-of-hearing adults was investigated using dichotic digit test. These researchers reported significant increase in the results of this test following the DIID auditory training [42].

In DOT method, four consonants and four vowels (consonant vowel) are used. The presentation method is as SSW test. In this method, at first there is a minor overlap between the two stimuli presented to the the left and right ears. The word presented to the left ear ends with more delay. Gradually and during consecutive sessions, the extent of overlap between the competitive words presented to the left and right ears increases, such that the two stimuli are completely presented in a dichotic manner. The extent of delay usually begins from 500 ms and is decreased with 100 ms steps. When the level of asymmetry reaches 10% or less, the dichotic function is considered normal and the rehabilitation stops [41]. To the best of our knowledge there was no paper on application of this method on the elderly.

Spatial hearing rehabilitation based on informational masking release: Jarollahi et al. designed spatial hearing training based on informational masking release, so that they could examine the elderly with normal hearing who complained about speech in noise comprehension [43]. It seems that there are difficulties in using spatial clues for informational masking release and these difficulties play role in the speech recognition problem and auditory processing disorder in elderly [44, 45]. Jarollahi et al. performed a two-section studytwo sections. The first section deals with design and validation of the spatial test in young and elderly groups (100 subjects in each group), and the second section was a clinical trial in which two groups of 60-75-year-old subjects with normal hearing and complaining about speech in noise recognition were studied as the control and experimental groups respectively. In 15 sessions, the impact of spatial auditory training on these groups were investigated. The final results of this study have not been published at the time of this review paper.

Another research in Iran on training spatial hearing was performed by Lotfi et al. They examined 60-75-year-old elderly who had normal hearing and cognition to investigate the effect of spatial hearing training for five weeks. They used sentence materials and the training was performed directly on the spatial hearing processing. They used the Persian version of the speech, spatial, and qualities of hearing scale (SSQ), QuickSIN test and middle latency response (MLR). They found that when there was more binaural cues at the thalamocortical levels, speech in noise comprehension was better. They proposed assessment of the spatial hearing function for the elderly in audiology clinics [46].

Vowel auditory training: Heydari et al. studied subjects with 60-year-old and above who had normal cognitive function and hearing sensitivity who complained about speech in noise comprehension. They used vowel auditory training for 15 sessions (during five weeks, three times a week for 1 hour). Each of the six vowels (/æ/, /e/,/a/, /i/, /o/ and /u/) with syllabi such as / ʃæ / and / pæ / was presented at a comfortable level by a male speaker in a quiet environment with no echoes at 1 meter behind the person. The individuals must identified and repeat them, and their responses were recorded. The speech in noise (SIN) test , SSQ and speech ABT test were used as the evaluation tools. Previous studies have suggested that the first stage of speech comprehension involves identifying the fundamental frequency (f0)as well as the properties of the formants,pitch, vowels, and their harmonic relations [47-52], thus training using vowels can be effective for better speech differentiation. The result of their training was improvement in the speech in noise comprehension, which could be possibly associated with better encoding and reception of f0, which is related to plasticity in the auditory brainstem [53].

Spatial hearing rehabilitation based on stimulus push: Delphi et al. designed sound localization rehabilitation based on stimulus push and investigated its impact on auditory behavioral performance among 55 to 65-year-old elderlies with impaired speech-in-noise comprehension. The spatial segregation ability was examined by minimum discoverable threshold for ITD of stimulus push in the midline (Azimuth plane) using two-syllable English words (noise-vocoded speech) with two Alternative-Forced-Choice (2AFC) method as well as minimum audible angle (MAA) assessment [54]. Other tests in their research included sound localization test. In the localization test subjects must recognize the monosyllabic words in noise with signal-to-noise ratio of zero at seven different locations under the headphone. The formal localization rehabilitation sessions included 9 sessions which were held every day for 1 hour. The localization rehabilitation improved the ability of spatial segregation, increased the mean score of monosyllabic words recognition, and reduced errors of localization [55].

Conclusion

The results of this review study indicated that there a demand for having rehabilitation programs for different age groups in elderly. These programs might be beneficial not only for the elderly with hearing aid and speech comprehension difficulties in noise, but also to the elderly who have normal hearing and speech comprehension difficulties in noise). The fact that rehabilitation is still working in elderly shows that plasticity lasts even during senescence which is proved based on neuroscience research. The authors suggest that the same review be conducted on other age groups including children.

Conflict of Interest: None declared.

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