Original Article

Reliability of Interaural Time Difference-Based Localization Training in Elderly Individuals with Speech-in-Noise Perception Disorder

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What's Known

• Some people are referred to audiology clinics with normal hearing thresholds but with complaints of problems regarding perception of speech in noisy conditions.
• Lateralization rehabilitation improves speech perception in noise.

What's New

• Lateralization rehabilitation program based on the ITD ENV and its application in the elderly is novel.
• This study investigated the reliability and effectiveness of this rehabilitation program in the elderly.

Abstract

Background: Previous studies have shown that interaural-time-difference (ITD) training can improve localization ability. Surprisingly little is, however, known about localization training vis-à-vis speech perception in noise based on interaural time difference in the envelope (ITD ENV). We sought to investigate the reliability of an ITD ENV-based training program in speech-in-noise perception among elderly individuals with normal hearing and speech-in-noise disorder.

Methods: The present interventional study was performed during 2016. Sixteen elderly men between 55 and 65 years of age with the clinical diagnosis of normal hearing up to 2000 Hz and speech-in-noise perception disorder participated in this study. The training localization program was based on changes in ITD ENV. In order to evaluate the reliability of the training program, we performed speech-in-noise tests before the training program, immediately afterward, and then at 2 months' follow-up. The reliability of the training program was analyzed using the Friedman test and the SPSS software.

Results: Significant statistical differences were shown in the mean scores of speech-in-noise perception between the 3 time points (P=0.001). The results also indicated no difference in the mean scores of speech-in-noise perception between the 2 time points of immediately after the training program and 2 months' follow-up (P=0.212).

Conclusion: The present study showed the reliability of an ITD ENV-based localization training in elderly individuals with speech-in-noise perception disorder.

Introduction

Environmental sounds are produced by different sources and arrive at our ears concurrently or in slight sequences. A key role for the auditory system is to correctly localize these stimuli. The localization of the sound source in busy environments prompts individuals to turn their face to the source so as to increase their use of visual cues and as such enhance their speech-in-noise perception.[1,2]

Localization is the first cue for segregating the target auditory data from the non-target ones. It is a prerequisite for the function

of the auditory system. The sound location processing pathway plays an important role in the performance of the auditory system.[3,4] Researchers emphasize that if correct localization is achieved, individuals with normal auditory thresholds can comprehend conversation at a lower signal-to-noise ratio. They also assert that localization confers 2- to 3-dB improvements in the signal-to-noise ratio and also 10-dB increments in spatial dominance.[5-8]

The human auditory system utilizes 2 cues to localize the sound. Horizontal-plane localization for sounds <1500 Hz is carried out based on interaural time difference (ITD), while for sounds at frequencies >2500 Hz, it is based on interaural level difference (ILD) and spectral cues. These spatial cues and spectral data are used for auditory streaming and contribute to improvement in speech perception.[9] In sound localization, ITD carries a greater significance.[10] In unmodulated signals, ITD is processed only up to 1500 Hz, and it is known as fine-structure ITD (ITD FS).[11-13] At higher frequencies, a slow modulation (low frequency) of the carrier processes the ITD information, and it is known as ITD in the envelope (ITD ENV).[14] As a kind of modulated signals, speech contains 2 different types of ITD: ITD ENV and ITD FS.[15]

Studies and behavioral evidence have indicated a decrement in localization ability as a result of aging. According to a study in 2011 by Dobreva et al.,[16] the precision of localization in the elderly subjects was less than that in the young and middle-aged ones. The authors also reported that ITD-based localization in the range of 1250 to 1575 Hz had decreased in the elderly cases, which was indicative of temporal processing disorder in them. Likewise, a 2001 study by Koehnke et al.[17] showed that the ability of their elderly subjects in localization, speech-in-noise perception, masking level difference, and ITD/ILD differentiation decreased with age. In the elderly, due to the increase in temporal jitter, reduced binaural masking level difference[18] and elevated ITD threshold occur for low sensation levels.[19] Prolonged neural refractory times, loss of myelin integrity, decreased brain connectivity, and eventually deficits in spectro-temporal processing contribute to neural processing slowdown in the elderly.[20]

The emphasis of recent studies on the role of ITD ENV in spatial hearing and speech-in-noise perception has been more than was expected.[15,21,22] The frequency range where ITD FS information begins to become ambiguous is where ITD ENV starts to dominate.[12,22] The study by Majdek et al.[15] corroborates the contribution of ITD ENV to localization and speech-in-noise

perception. Considering the importance of ITD ENV-based localization and the decrease in ITD discrimination capability among the elderly compared to normal individuals,[23] ITD ENV training is emphasized in the present study. On the other hand, a previous study concluded that ITD rehabilitation was more efficient and more reliable than other localization training programs.[23]

Rehabilitation is one of the effective methods for improving speech-in-noise perception and contributing to brain plasticity.[24,25]

Past studies have rarely dealt with localization training programs. Wright et al.[23] investigated the effectiveness of ITD and ILD training programs using headphones and showed improvements in ITD and ILD discrimination ability after the training. Also, a study by Kuk et al.[26] proved the reliability of the localization training program in hearing impaired individuals.

It is supposed that ITD ENV-based localization training is reliable and may enhance speech-in-noise perception in the elderly. Accordingly, the aim of the present study was to investigate the effectiveness and reliability of an ITD ENV-based localization program in the elderly.

Materials and Methods

The present study investigated the reliability of an ITD ENV-based training program in the elderly. To evaluate the reliability, we assessed speech-in-noise perception at 3 time points of before the training program, immediately after the program, and at 2 months' follow-up.

Sixteen elderly men, aged between 55 and 65 years, with speech-in-noise perception disorder participated in this study during 2016. The hearing thresholds were <20 dB at below 2000 Hz and <40 dB at below 4000 Hz. The interaural threshold difference was <10 dB at below 2000 Hz. The subjects' consent was obtained prior to the test. All the participants had normal IQs and were right-handed. The autoscopic and tympanometric results were also normal. The participants had no history of neurological disease or injury. The individuals did not receive any auditory rehabilitation program throughout the assessment and training. The participants were selected from the audiometry clinics in Ahvaz, Iran. The elderly entered into the test had the clinical diagnosis of speech-in-noise perception disorder according to the Farsi version of the temporal jitter test.[27] Oral stimuli and continuous noise were used for this test. The oral stimuli consisted of a list of 50 monosyllabic words that were presented with continuous noise (100–8000 Hz) at a 0 signal-to-noise ratio before

the correct score percentage was calculated.[27,28] The list was composed of Farsi words, with the required validity and reliability.[27] All the tests were performed under controlled test conditions in a sound-treated room with an ambient noise level <30 dB. The present study was approved by the local Ethics Committee of the University of Social Welfare and Rehabilitation Sciences, Tehran, Iran (#IR.USWR.REC.1394.3).

Training stimuli were generated using MATLAB and Sound Forge (v.10 by Sonic Foundry), with a sampling rate of 44.1 kHz. The training program consisted of presenting the stimulus envelope in different ITDs. The subjects were seated comfortably in a chair and were instructed to look straight ahead without movement during the presentation of the acoustic stimuli. For each stimulus, a pair of stimuli at 500-ms intervals was presented. The 1st stimulus was a standard binaural signal, without any delay differences, corresponding to a central position. The 2nd stimulus was the test signal, which could be perceived on the right or left side. The interval between the signal pairs was 5 seconds. The subjects were instructed to "ignore" the standard signal and to point to the perceived position of the test signal presented on the right or left. All the listeners were trained on the task before testing until they were comfortable with the tasks. ITD ENV was designed in 10-ms steps in a 10- to 100-ms range and in 50-ms steps in a 100- to 350-ms range. First, ITD ENV was started based on the results obtained in the evaluations prior to the program and was decreased gradually. Each ITD ENV stimulus was exercised repeatedly until the elderly individual was able to properly distinguish it. After the training was completed, speech-in-noise perception was assessed among the subjects again and the effectiveness level of the rehabilitation was investigated. The localization training program was based on the fact that a change in ITD will cause the sound to move from the midline to the left or to the right. The Farsi non-word "bamash" was chosen from a list of Farsi non-words. The non-word had a

duration of 1.5 seconds and a rise/decay time of 25 milliseconds. The level of presentation to both ears was 75 dB. The program lasted for 9 training sessions of 45 minutes. Using the Farsi version of the temporal jitter test, we examined the speech-in-noise perception of the individuals immediately after the training program and 2 months after its completion and investigated its reliability.

All the analyses were conducted using SPSS (version 16). The reliability of the training program was examined using the Friedman test. The Wilcoxon test was applied to conduct pair-wise comparisons. The significance level adopted was 0.05 (5%), with CIs of 95%.

Results

The average age of the participants in the current study was 60.52±2.52 years. Table 1 shows the mean and SD of the participants' auditory threshold (in dB HL).

The speech-in-noise perception test was conducted at 3 time points of before the training program, immediately after the program, and at 2 months' follow-up for the elderly individuals. The Kolmogorov–Smirnov statistical test revealed the abnormal distribution of the data in the speech-in-noise perception test. The analysis of variance test with Friedman indicated significant differences in the scores between the 3 time points (P=0.001) (table 2).

The Wilcoxon test, utilized for the comparison of 2 mean scores of speech-in-noise perception, demonstrated significant differences in the scores between the 2 time points of before and after the training program (P=0.001), while no difference was observed in the scores between the 2 time points of immediately after the training program and 2 months' follow-up (P=0.212).

Figure 1 illustrates the mean score percentage of speech-in-noise perception. As can be seen in the figure, the mean scores of speech-in-noise perception exhibited a considerable improvement after the training program.

Table 1: Auditory threshold mean at different frequencies (N=16)

Frequency	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Right ear threshold	15.20±2.86	12.94±3.25	18.31±5.10	19.20±8.30	30.90±10.86	37.76±5.79
Left ear threshold	15.30±5.02	15±5.90	15.21±3.50	15.04±9.32	32.90±7.16	37.02±8.62

Table 2: Speech-in-noise perception mean scores before the training program, immediately afterward, and at 2 months' follow-up (N=16)

	Before training	After training	Two months after training	df	P value
Speech-in-noise perception mean (%)	51.50±7.57	67.50±5.03	68±4.61	2	<0.001*

Data are presented as means±SDs. *Friedman

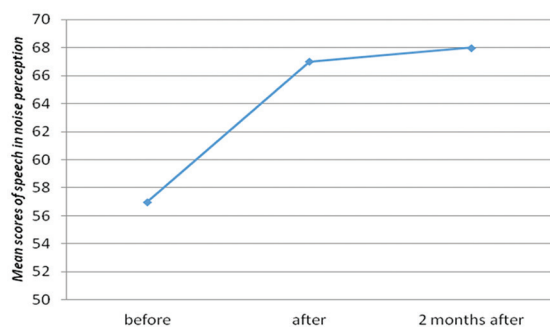Delphi M, Lotfi Y, Moossavi A, Bakhshi E, Banimostafa M

Figure 1: Speech-in-noise perception mean scores before the training program, immediately afterward, and at 2 months' follow-up.

Discussion

The elderly often tend to complain of speech perception without the presence of considerable hearing loss. Their speech problems are often observed in unfavorable auditory conditions and challenging environments such as high background noise in the environment.[29] Speech perception is a high-level auditory activity.[30] Based on the existing evidence, speech-in-noise perception decreases as a result of diminished localization ability.[31-33]

In the present study, localization training via envelope stimuli in ITD was utilized. Although there was extensive evidence indicating improvement in hearing skills as a result of long-term training, this type of training was not deemed suitable in clinical settings and investigators, therefore, developed further short-term training strategies.[20] Moreover, parts of such trainings have been corroborated as contributing to improvement in speech-in-noise perception.[20]

The mean scores of speech-in-noise perception in the current study showed a significant difference between the 2 time points of before and after the training program, indicating improvement in speech-in-noise perception following localization rehabilitation. This finding supports the effectiveness of the ITD ENV-based training program in triggering changes in the behavioral performance of the elderly. These results are consistent with the results from a study by Cameron et al.,[34] who showed an improvement of 10 dB in speech perception threshold in listening in spatialized noise (LiSN) during a spatial hearing training program. It also corresponds with a study by Tyler et al.,[32] who demonstrated the effectiveness of localization training in improving speech-in-noise perception.

To assess the effectiveness of our localization training program, we repeated the speech-in-noise perception test 2 months following the completion of the program. The mean scores of speech-in-noise did not show a significant difference between the 2 time points of immediately after the program and 2 months' follow-up, which confirmed the reliability of ITD ENV-based localization. Kuk et al.[26] conducted a localization training study in 2014 on 3 groups of individuals with hearing loss who were examined before the commencement of the training program and then at 2 weeks', 2 months', and 3 months' follow-up periods. The training program was completed in the 2nd month, and the assessment in the 3rd month was for evaluating the reliability of the outcome. Their results showed that there was no significant difference in the localization abilities 2 and 3 months following the program. The reliability of localization training in that study is consistent with the findings of the present study.

Our results demonstrated that ITD ENV-based localization training was quick. In addition, not only did it improve localization ability, but it also enhanced the mean score of speech-in-noise perception. This type of learning involves behavioral plasticity, auditory cortex, and subcortical processing.[35] It can, thus, be concluded that localization training can affect spatial processing at different levels of the auditory system.

First and foremost among the limitations of the present study is that our elderly subjects became tired early, leading to the postponement of the test or the exclusion of some cases. Additionally, it was difficult to find elderly individuals with normal hearing. Another weakness of note is that our training program was performed for a limited time of only 9 days. Further research is needed to be able to generalize these findings.

Conclusion

The present study investigated the reliability and effectiveness of an ITD ENV-based localization training program on the speech-in-noise perception capability of elderly individuals with normal hearing. No difference was found in the subjects' mean scores of speech-in-noise perception between the 2 time points of immediately after the training program and 2 months' follow-up. This finding confirms the reliability of this rehabilitation program.

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Conflict of Interest: None declared.

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