Research Article

Auditory Spatial Training-Induced Changes in the Release of Informational Masking in Older Adults

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Highlights

- The older adult benefits less than the younger adult from spatial hearing
- We examined the effect of auditory spatial training on the elderly
- This kind of training could help the elderly population with better SIN communication

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ABSTRACT

Background and Aim: Generally, in noisy environments more informational masking occurs. Older adults benefit less than younger adults from spatial hearing and they have more problems of understanding speech in the presence of distracting speeches. This study was conducted to examine the effect of auditory spatial training on informational masking release in the elderly.

Methods: Thirty-two 60-75-year-olds with normal hearing, who complain about difficulty in speech perception in noise, participated in control and intervention groups (16 people in each group). The intervention included fifteen sessions of auditory spatial training. The informational masking measurement test scores were compared before the intervention, one session after the intervention, and one month after between the two groups.

Results: There was a significant improvement in informational masking measurement scores in the intervention group compared to the control ($p<0.02$). The results showed no significant differences between the informational masking measurement scores before and after the intervention in the control group ($p>0.05$) and a significant difference in most signal to noise ratio i.e. 0, -5 and -10, in the intervention group ($p\leq0.006$). No significant difference was found between the results of the two assessments one session and one month after the intervention in any of the positions ($p>0.05$), which suggests that both groups' scores remained highly stable one month after the intervention

Conclusion: This study introduced a spatial training program to improve speech perception in noise in normal-hearing elderly listeners. It was recommended that this kind of training be included in geriatric population auditory rehabilitation programs.

Keywords: Informational masking; energetic masking; elderly; speech perception in noise

Introduction

The ability to carry out effective verbal communication is one of the main requisites of independent living in old age. Older adults usually have more problems in tracking speech when several speakers talk at the same time and this inability occurs for different reasons, such as peripheral auditory impairment, change in cognitive capabilities and processing defects [1]. In general, speech in noise perception problems worsens when the target speech is masked by a meaningful competing noise. This scenario involves not only energetic masking (EM) but also informational masking (IM) of sorts [2]. EM is the result of the spectro-temporal overlap of the target and competing speech at low levels of the peripheral auditory system [3, 4]. Nonetheless, recent studies have shown that another kind of masking occurs when the competing stimulus emerges randomly, or when the target and competing stimuli are highly similar (e.g. when both are speech). This kind of masking is referred to as IM or non-energetic masking [5, 6], and is the result of cognitive and perceptual processing interference between the target and competing stimuli [3, 4].

Moreover, several studies have demonstrated that the adverse effects of competing noise increase significantly with age [1, 2, 7, 8], and as already noted, these effects can be due to peripheral auditory impairment and cognitive disorders associated with aging. Some studies conducted on people with sensory-neural hearing impairment have shown that these people are not affected much by the IM [9, 10]. Furthermore, many studies have shown that the ability to use acoustic and phonetic cues to separate speech from noise diminishes in older adults with normal hearing compared to young people and they thus experience more IM [2, 9].

Since speech recognition problems limit older adults' social relationships and their active living, it is very important to develop effective rehabilitation programs to improve their quality of life and increase their social participation [1]. In day-to-day life, a young adult with normal hearing is largely released from IM by the use of different cues such as spatial separation between the target and competing stimuli [11-13], increased signal to noise ratio (SNR) [11], noticing the differences or similarities between the target and competing stimuli [13], the gender differences between the target and competing stimuli [8, 14], and the meaningfulness or meaninglessness of the competing stimulus [8]. Spatial auditory processing is very important in understanding speech in complex noisy environments [15] since it enables the listener to spatially separate the target and competing stimuli and therefore analyze the auditory scene. By the auditory scene analysis, auditory streams are formed, and the target stimulus is ultimately separated from the competing stimuli [16]. Importantly, although spatial auditory processing leads to release from both kinds of masking, the release caused by the spatial separation of the target and competing stimuli is much higher in the case of IM than in EM. The results of various studies have thus shown that the most important cue in the release from IM is the spatial separation of target and competing stimuli [12]. It has been proven that the spatial auditory processing ability is lower in older adults with normal hearing than in young people, and it has been demonstrated that the loss of localization accuracy, the less use of the benefits of spatial auditory processing and the subsequent reduction in binaural processing are not specific to peripheral hearing loss [17, 18], and they lead to poorer speech comprehension in noisy environments in older adults with normal hearing [15]. Older adults have been shown to have problems in binaural processing and the use of its significant cues, such as attention to interaural time difference (ITD) and interaural level difference (ILD) when the competing stimuli are symmetrically placed around the target stimulus [19]. Older adults have also been shown to need a higher SNR to understand speech than young people [7]. In general, the ability to use spatial and non-spatial cues to be released from IM reduces in older adults due to their reduced cognitive processing abilities [7, 8], temporal processing defects [2], defective communication between the hemispheres, and reduced ability to separate simultaneous sounds [7].

Since recent studies suggest that the central auditory nervous system has strong auditory spatial plasticity [20, 21], and given the demonstrated effectiveness of short and long-term rehabilitation programs in older adults [22], it seems that by designing a rehabilitation training based on the key principles of release from IM (including separation of target and competing stimuli, attention to the SNR, attention to the similarities and differences between target and competing stimuli and attention to the target and competing speakers' gender), older adults can show less IM and therefore have better speech tracking in noisy environments. Therefore, assuming that rehabilitation and training lead to plasticity in neuronal populations [23] and considering the important role of IM for older adults to understand speech in noise, the present study was designed to assess the amount of IM release in older adults with normal hearing by providing training based on spatial hearing. The main hypothesis of the study was that providing an intervention based on spatial processing can improve speech perception in noise in older adults.

Methods

In the present simple randomized clinical trial, the participants were randomly divided into control (without auditory spatial training) and intervention (with auditory spatial training) groups. The random allocation was applied by a random number table and all the participants were given a number by one of the audiology clinic staff who did not have any role in the study, and those with odd numbers were assigned to the control group and those with even numbers to the intervention group. The clinical trial registration number of this study was ID IRCT20190118042404N1.

This research was carried out in three stages: before, during and after the auditory spatial training.

Part one: assessments before auditory spatial training

1) taking participants' history to check whether they met the inclusion criteria; Initial clinical examinations, including otoscopy and tympanometry; 2) pure tone audiometry: auditory thresholds ≤25dB within the 250–4000 Hz frequency range considered as normal; 3) ensuring the absence of clear cognitive problems using the mini mental state examination (MMSE) by obtaining a minimum score of 21 [24]; 4) complaint about difficulty in understanding speech in noisy environments by asking participants that if they have difficulty in understanding speech in noisy situations or not? Those who answered yes participated in the study; and 5) determining the IM score using the IM measurement (IMM) test. This test was developed by Amiri et al., to evaluate the speech perception in the presence of different background noises in elderly normal pure tone audiogram listeners. In the IMM test, the amount of IM was measured under a total of 20 conditions: five SNRs, two spatial conditions and two genders of background noise [25].

Part two: providing auditory spatial training

The auditory spatial training was designed according to five important cues involved in the release from IM, including spatial separation between the target and competing stimuli [11-13], the SNR, similarities and differences between the target and competing stimuli [20], same or different gender of the target and competing stimuli [8, 14], and the meaningfulness or meaninglessness of competing stimulus [8]. In the auditory spatial training stage, to prevent the impact of learning through the target stimuli, a sentence different from the stimuli used in the IMM test was used. To this end, the Persian versions of the sentences in the quick speech-in-noise (QuickSIN) test were used [26, 27]. The training sessions were divided into several general stages based on the type of competing stimuli. In stage one, meaningless competing stimuli (i.e. white noise) were used. In stage two, to make the training process more difficult, meaningful stimuli such as babble stimuli consisting of four speakers [26], were used. In the last stage, sentence stimuli (the Persian version of the sentences in the QuickSIN test) with female and male speakers were used [26, 27]. In all the stages of the training, the target stimulus was always provided from a loudspeaker at 0-azimuth degree and the competing stimuli at ±90-azimuth degree. The angles were chosen according to the LiSN & Learn program [28, 29]. Accordingly, the training became harder in each stage as the competing stimuli were co-located with the target stimulus [30]. In the final stage of the training, meaningful competing stimuli of sentences spoken by male and female voices were used. The reason for using the gender factor was that noticing gender similarity or difference between the target and competing stimuli is one of the cues that young adults use for IM release [8, 14].

Each training stage was performed as follows: The intensity of the competing stimuli was kept constant at 60 dB SPL, and the intensity of the target stimuli was initially set at 70 dB SPL. Three sentences were first provided as a practice run, and the main sentences were then provided. More practice sentences were provided if the participant needed more practice.

The participant was asked to identify the words heard in the target sentences. Depending on whether his identification was correct or wrong, he received the necessary feedback. The sentence was considered correct if the participant identified more than 50% of its words. A total of five sentences were provided at this SNR, and if the participant correctly identified more than 50% of the sentences, the SNR would be reduced in steps of 5 dB, and five more sentences were provided. If the participant failed to correctly identify more than 50% of the sentences in each SNR, the training continued for 20 minutes based on an adaptive method, so that when every sentence was correctly identified, the intensity was reduced in steps by 1.5 dB and the next sentence was provided. If the participant was incapable of correct recognition, the intensity was increased in three stages in 2.5 dB steps until he was able to correctly recognize the sentence. In this stage, the participant was provided with visual feedback of the sentence if required. At each intensity level in which the person was able to correctly recognize the sentence, the next sentence was provided, and the above process was repeated.

To determine the validity of the designed training, explanations about the way it is performed, and its flowcharts were sent to five audiologists. Together with the explanations about the training and its flowcharts, these people were also provided with a table for scoring the content validity of the training, in which they were asked to choose either fully appropriate, appropriate, or inappropriate for the following items: ability to strengthen auditory spatial processing skills, help getting released from IM, the adequacy of the duration of each training session (30 minutes), and the adequacy of the total number of the training sessions (fifteen sessions, held three times a week). The dosage and duration of training were extracted from Humes et al., a study in which training 2x/3x week lasting five to fifteen weeks was suggested for auditory training for older adults [31].

The optimal perceptual training-auditory learning consists of active listening to several repeats of a series of stimuli during successive training sessions held over a short period and considering that prolonged training is not clinically appropriate [22], the training was performed twice weekly in fifteen sessions.

Part three: assessments after the auditory spatial training

The IMM test [25] was repeated one session after the completion of training and one month later, and the results were compared with those before the training. This test was conducted at five SNRs as follows: ±5, 0, and ±10, with the target and competing signals being co-located and at 90-degree separation. The tests were repeated one month after the intervention to determine the reliability of the results of the intervention on IM release.

The amount of IM release was determined as the difference between the sentence's recognition score (in each of the different SNRs and with the different spatial angles and both genders) in both noise modes (meaningful and meaningless).

To determine the effectiveness of the training in terms of improvement, durability, and overall effect, the results from each of the three noted assessments were measured as follows:

The results before the intervention–the results one session after the intervention=improvement

The results one session after the intervention–the results one month after the intervention=durability

The results before the intervention–the results one month after the intervention=overall effect

Central and dispersion indicators (mean, standard deviation, median and first and third quartiles) were used for the descriptive analysis of the data. The normal distribution of the data was assessed using the Kolmogorov-Smirnov test. Given the non-normal distribution of the data of IM, the effect of the auditory spatial training on IM release was assessed using Friedman's test and Wilcoxon's test with Bonferroni's correction for the intragroup improvement comparisons, and Mann-Whitney's test for the inter-group comparisons. Bonferroni's correction coefficient was used in Wilcoxon's test for the pairwise comparisons at a significance level of 0.006 since three comparisons had to be made. Data were analyzed in SPSS 17, (IBM Corporation, New York, USA) at a significance level of 0.05 for all the tests.

Results

A total of 32 older adults with normal hearing who complained of difficulty understanding speech in noise took part in this stage, including 16 in the control group (nine women and seven men, with a mean age of 66.56 years and SD of 4.93) and 16 in the intervention group (seven women and nine men, with a mean age of 67.93 years and SD of 5.03). The independent t-test showed no significant differences between the two groups in terms of age ($p>0.1$). There was no significant difference between the two groups before the intervention in the amount of IM ($p>0.11$). Therefore, it can be concluded that the intervention and control groups were matched in terms of IM before the intervention.

Intragroup comparisons

The results showed no significant differences between the IM scores before and after the intervention in the control group ($p>0.05$) (Table 1). Clinically, this finding means there has been no change in the control group's results one and two months after the first assessment. Nonetheless, as shown in Table 2, there were significant differences in the IM scores before and after the intervention in most SNRs, i.e. 0, -5 and -10, in the intervention group.

Table 1. Comparison of informational masking scores in three-time frame before, one session and one month after the intervention in the control group (n=16)

	SNR	+10	+5	0	−5	−10
IMDS90	Before training	0.00	1.25	7.50	11.87	15.62
	One session after training	0.62	2.50	7.50	11.87	15.00
	One month after training	0.62	1.87	6.25	12.50	15.62
	p	0.368	0.368	0.135	0.949	0.607
IMDS0	Before training	0.00	1.25	10.00	16.87	22.50
	One session after training	0.00	1.25	10.00	16.25	24.37
	One month after training	0.00	1.25	9.37	15.00	21.87
	p	------	------	0.779	0.417	0.074
IMSS90	Before training	0.00	3.75	16.25	24.37	22.50
	One session after training	0.00	3.12	15.00	26.87	24.37
	One month after training	0.00	2.50	16.25	28.12	22.50
	p	------	0.549	0.513	0.091	0.267
IMSS0	Before training	0.00	8.75	23.75	25.62	15.00
	One session after training	0.00	9.37	24.37	28.12	15.00
	One month after training	0.00	7.50	22.50	26.87	15.62
	p	------	0.174	0.368	0.368	0.779

SNR; signal to noise ratio, IMDS90; informational masking amount for different-gender talkers at 90-degree azimuth separation, IMDS0; informational masking amount for different-gender talkers in the co-located condition, IMSS90; informational masking amount for same-gender talkers at 90-degree azimuth separation, IMSS0; informational masking amount for same-gender talkers in the co-located condition

As shown in Table 3, in some positions, there were significant differences in the mean IM scores before the intervention and immediately after and one month after the intervention ($p<0.006$). Meanwhile, the p-values were small in many of the positions, and significant differences are expected to be observed in these positions as the sample size increases. Moreover, as shown in Table 1, the IM score has reduced after the intervention in the SNRs of 0, -5, and -10, which clinically indicates an improvement in understanding speech in noise in the subjects. Another point extracted from Table 1 is that there has been no significant difference between the assessments immediately and one month after the intervention in any of the positions.

Intergroup comparisons

To determine the effect of auditory spatial training, the IM scores were measured immediately and one month after the intervention. Table 4 shows a significant difference between the intervention and control groups at most SNRs, i.e. 0, -5, and -10, in terms of the improvement rate in IM scores ($p<0.02$). Nonetheless, this finding was mostly seen in positions where the target and competing speakers were of different genders. For instance, it did not occur when the target and competing speakers were of the same gender at a 0-azimuth degree in the negative SNRs. No significant differences were observed between the two groups in the durability level in any of the examined positions ($p>0.07$). In general, one month after the second assessment, the amount of difference in the IMM test results was approximately the same in both groups, and there was good stability in the scores of both groups.

Finally, the overall effect related to the IM scores in the two groups was compared and the results are shown in Table 5.

Table 2. Comparison of informational masking scores in three-time frame before, one session and one month after the intervention in the intervention group (n=16)

	SNR	+10	+5	0	−5	−10
IMDS90	Before training	0.00	0.62	5.62	7.50	16.87
	One session after training	0.00	0.00	1.87	2.50	10.62
	One month after training	0.00	0.00	1.87	2.50	10.62
	p	------	0.368	0.007	0.001	<0.001
IMDS0	Before training	0.00	1.25	8.12	12.50	16.25
	One session after training	0.00	0.00	0.00	5.62	13.12
	One month after training	0.00	0.00	0.00	5.62	13.12
	p	------	0.368	<0.001	0.002	0.038
IMSS90	Before training	0.62	3.12	28.12	22.50	16.87
	One session after training	0.00	0.62	13.75	14.37	16.25
	One month after training	0.00	0.62	14.37	16.25	16.25
	p	0.368	0.018	<0.001	0.003	1.000
IMSS0	Before training	2.50	10.62	32.50	20.00	8.75
	One session after training	0.00	1.87	16.87	20.00	10.00
	One month after training	0.00	1.87	16.87	19.37	9.37
	p	0.135	<0.001	<0.001	0.846	0.368

SNR; signal to noise ratio, IMDS90; informational masking amount for different-gender talkers at 90-degree azimuth separation, IMDS0; informational masking amount for different-gender talkers in the co-located condition, IMSS90; informational masking amount for same-gender talkers at 90-degree azimuth separation, IMSS0; informational masking amount for same-gender talkers in the co-located condition

The results in Table 5 were compared to the corresponding data related to the improvement rate shown in Table 4, and the same trend was observed here as well, except that the number of significant positions in the Table 5 was less than that in Table 4.

Discussion

The main hypothesis of this study was that providing an intervention based on spatial processing can improve informational masking release in the elderly. No significant differences were shown between the informational masking measurement scores before and after the intervention in the control group (p>0.05) and a significant difference was shown in most SNRs, i.e. 0, -5 and -10, in the intervention group (p≤0.006). This suggests the incidence of neural plasticity in the intervention group, which concurs with the study's main hypothesis and the results from some previous studies conducted on older adults [22, 32-34]. Given the lack of similar studies and since only a few studies have been conducted on spatial auditory training, studies with similar practical concepts (all conducted to improve speech in noise perception) conducted on older age groups were selected [22, 31, 32, 34-36]. The most important point extracted from these studies was that neural plasticity occurs in older adults through short-term training. It was expected for auditory training to activate the auditory and related systems in such a way that their neural and behavioral basis are positively altered [34]. The exact location where neural plasticity occurs cannot be precisely determined by behavioral tests alone, since understanding speech in noise involves various neural pathways. Based on the results of the few studies conducted on the neural basis of IM, top-down processing seems to have an important role in the occurrence of this type of masking. Nevertheless, considering that spatial hearing has a significant role in the release from IM, and since this phenomenon is dis-

Table 3. Results of Wilcoxon post hoc test to determine the difference between informational masking scores in three-time framework including before training, one session and one month after in the intervention group (n=16)

Condition	SNR	Before training with one session after		Before training with one month later		One session after training with one month later	
		p	Z	p	Z	p	Z
IMDS90	0	0.034	–2.121	0.034	–2.121	1.000	0.000
	–5	0.011	–2.530	0.011	–2.530	1.000	0.000
	–10	0.004*	–2.887	0.004*	–2.887	1.000	0.000
IMDS0	0	0.006*	–2.754	0.006*	–2.754	1.000	0.000
	–5	0.013	–2.484	0.013	–2.484	1.000	0.000
	–10	0.083	–1.207	0.564	–0.577	0.046	–2.000
IMSS90	+5	0.046	–2.000	0.046	–2.000	1.000	0.000
	0	0.001*	–3.275	0.001*	–3.256	0.317	–1.000
	–5	0.012	–2.511	0.020	–2.332	0.083	–1.732
IMSS0	+5	0.010	–2.565	0.010	–2.565	1.000	0.000
	0	0.001*	–3.473	0.001*	–3.360	1.000	0.000

SNR; signal to noise ratio, IMDS90; informational masking amount for different-gender talkers at 90-degree azimuth separation, IMDS0; informational masking amount for different-gender talkers in the co-located condition, IMSS90; informational masking amount for same-gender talkers at 90-degree azimuth separation, IMSS0; informational masking amount for same-gender talkers in the co-located condition

* $p \leq 0.006$

Table 4. Comparison of improvement rate of informational masking scores between two groups (n=32)

SNR		+10	+5	0	–5	–10
IMDS90	Intervention	0.00	–0.62	–3.75	–5.00	–6.25
	Control	0.62	1.25	0.00	0.00	–0.62
	p	0.317	0.164	0.017	0.025	0.003
IMDS0	Intervention	0.00	–1.25	–8.12	–6.87	–3.12
	Control	0.00	0.00	0.00	–0.62	1.87
	p	1.000	0.317	0.002	0.032	0.014
IMSS90	Intervention	–0.62	–2.50	–14.37	–8.12	–0.62
	Control	0.00	–0.62	–1.25	2.50	1.87
	p	0.317	0.338	<0.001	0.003	0.388
IMSS0	Intervention	–2.50	–8.75	–15.62	0.00	1.25
	Control	0.00	0.62	0.62	2.50	0.00
	p	0.151	0.001	<0.001	0.347	0.633

SNR; signal to noise ratio, IMDS90; informational masking amount for different-gender talkers at 90-degree azimuth separation, IMDS0; informational masking amount for different-gender talkers in the co-located condition, IMSS90; informational masking amount for same-gender talkers at 90-degree azimuth separation, IMSS0; informational masking amount for same-gender talkers in the co-located condition

Table 5. Comparison of overall effect of informational masking scores between two groups (n=32)

SNR		+10	+5	0	−5	−10
IMDS90	Intervention	0.00	−0.62	−3.75	−5.00	−6.25
	Control	−0.62	0.62	−1.25	0.62	0.00
	p	0.317	0.164	0.190	0.025	0.002
IMDS0	Intervention	0.00	−1.25	−8.12	−6.87	−3.12
	Control	0.00	0.00	-6.25	−1.87	−0.62
	p	1.000	0.317	0.006	0.114	0.159
IMSS90	Intervention	−0.62	−2.50	−13.75	−6.25	−0.62
	Control	0.00	−1.25	0.00	3.75	0.00
	p	0.317	0.484	<0.001	0.002	1.000
IMSS0	Intervention	−2.50	−8.75	−15.62	−0.62	0.62
	Control	0.00	−1.25	−1.25	1.25	0.62
	p	0.151	0.025	<0.001	0.456	0.974

SNR; signal to noise ratio, IMDS90; informational masking amount for different-gender talkers at 90-degree azimuth separation, IMDS0; informational masking amount for different-gender talkers in the co-located condition, IMSS90; informational masking amount for same-gender talkers at 90-degree azimuth separation, IMSS0; informational masking amount for same-gender talkers in the co-located condition

cussed as bottom-up processing in most references, it seems that both top-down and bottom-up processing are involved in the occurrence of IM and subsequently in the effectiveness of the training applied in the present study.

Moreover, it was shown that the difference between the intervention and control groups in improvement rate mostly occurs in situations where the target and competing speakers are of different genders; meanwhile, in same-gender situations and when target and competing stimuli were co-located, this difference was only significant at SNRs of 0 and +5. This result could be somewhat comparable to the LiSN-S, which is clinically appropriate for assessing auditory stream segregation deficits. The present study was inspired by this approach. In this method, it was found that in the low cue speech reception threshold (where the target and competing speakers were the same and co-located), no change occurred in the results of either group. Meanwhile, in the high cue speech reception threshold (where the target and competing speakers were different and the target stimulus was provided at 0-azimuth degree and the competing stimuli at ±90-degree separation), the results before and after the intervention differed significantly in the intervention group [28]. Therefore, it can perhaps be concluded that improving speech in noise perception is very difficult when IM release cues were very weak, such as when same- gender speakers were used or when both stimuli were co-located, and further training sessions were probably required to overcome this difficulty.

The next important point is that the comparison of the overall effect of the intervention yielded results that were similar to those of the improvement rate. Per the study hypothesis, this result suggests that the effect of the training lasts for up to one month after the intervention. The factor of the durability of effects of auditory spatial training can be assessed in another way by finding the difference in the scores of the two assessments after the intervention (i.e. measuring the durability rate). No significant difference was found between the results of the two assessments immediately after and one month after the intervention in any of the positions, which suggests that both groups' scores remained highly stable one month after the intervention. In other words, it can be concluded that auditory spatial training has had good reliability. This result concurs with those obtained in some studies on older adults [32, 36], where the results were measured again two months after the intervention [32], and behavioral and electrophysiological tests were conducted again one month after the intervention [36]. It was shown that the results of all the tests lasted for a while after the intervention [32], but the durability of the results was observed in the behavioral tests only, and the electrophysiological test results showed no significant durability [32, 36].

Some of the limitations of this study were as below. First, due to lack of time, the results of this study did not offer long-term effects of spatial training. Also, this study was conducted on normal-hearing elderly people. Finally, the effect of gender on informational masking release was not considered in this study. So, it was suggested that the spatial training used in this study carried on hearing-impaired older people of different genders and the long-term effect of the training should be evaluated in future studies.

Conclusion

The ability to carry out effective verbal communication is one of the main facilitators of independent living in old age. This skill often becomes problematic in old age, especially in tracking speech when several speakers talk simultaneously. Older adults are hardly able to use auditory spatial cues to be released from the masking due to their reduced processing and cognitive abilities. The present study managed to improve speech in noise perception in older adults with normal hearing by presenting a new auditory spatial training, and the study hypothesis was proven, which means that auditory spatial training was effective on the release from informational masking in older adults.

Ethical Considerations

Compliance with ethical guidelines

Consent was obtained by all participants in this study. The local Medical Ethics Committee approved this study (IR.IUMS.REC.1397.1227).

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Authors' contributions

MA: Study design, acquisition of data, interpretation of the results; FJ: Study design, interpretation of the results; SJ: Statistical analysis, interpretation of the results; SJS: Study design, acquisition of data. All authors contributed in drafting manuscript.

Conflict of interest

The authors report no competing of interests.

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