Indian J Otolaryngol Head Neck Surg
https://doi.org/10.1007/s12070-019-01674-2

ORIGINAL ARTICLE

The Correlation Analysis Between the Spatial Hearing Questionnaire (SHQ) and the Psychophysical Measurement of Spatial Hearing

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Received: 2 March 2019 / Accepted: 27 May 2019

Abstract The aim of the present study was examining the relationship between a psychophysical spatial hearing test (spatial word in noise test) and Spatial Hearing Questionnaire. Sixty-six adults (18–40 years old) were divided in three groups: normal subjects, subjects with mild and moderate hearing loss. Spatial word in noise test and Persian version of the spatial hearing questionnaire were evaluated and compared among these groups. According to Pearson's test, there was a significant positive correlation between the scores of spatial word in noise test and Persian version of the Spatial Hearing Questionnaire in three groups (r = 0.64–0.89). Hearing loss can deteriorate spatial hearing ability. Both objective and subjective spatial hearing tests are shown to be effective in detecting spatial hearing disorder.

Keywords Spatial hearing · Speech-in-noise perception · Questionnaire · Hearing loss

Introduction

The spatial hearing is the ability of the auditory system for detecting the direction of sound source [1] based on the monaural and binaural cues and helps us separate target speech from competing signals and improves the speech-in-noise skill [2, 3]. Spatial hearing defects might contribute to some disorders such as (central) auditory processing disorder ((C)APD) [1, 3, 4]. The importance of this function has urged researchers to conduct more studies on spatial hearing in the last few decades. The most important spatial cues are the interaural time and intensity differences (ITDs and ILDs). The ITD refers to the difference in the time of the arrival of a sound signal between the two ears, while ILD refers to the difference in the intensity of the received sound signal between the two ears. These parameters are frequency-specific. ITD tends to be more effective in the lower frequencies [5].

Various behavioral (psychophysical) tests have been introduced for the assessment of spatial hearing including the Masking Level Difference (MLD), the Dichotic Digits test (DDT), the minimum audible angle (MAA), the Listening in Specialized Noise test (LiSN), and the spatial word recognition score [6–8]. On the other hand, various self-report assessment tools have been introduced for investigating the spatial hearing disabilities including the Spatial Hearing Questionnaire (SHQ) and the Speech, Spatial and Qualities of Hearing Scale (SSQ) [9–11]. In general, questionnaires are useful valid and reliable supplementary tools for psychophysical tests such as MLD or spatial word recognition test for more comprehensive evaluation of spatial processing ability and they can provide more realistic insight into functional consequences of spatial processing disorders [12].

The aim of this study was to determine the relationship between the SHQ scores and the results of the spatial word in noise test. SHQ was designed by Tyler et al. in the late 1990s. SHQ is composed of 24 questions about 8 dimensions and has a total score of 100. The zero score indicates the difficulty 100 indicates the ease of the item. These eight dimensions include the female's voice, male's voice, child's voice, music, localization of the sound source, and

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Published online: 06 June 2019

speech recognition in the silence and in noise with and without spatial separation. Tyler et al. showed that SHQ has a high reliability (alpha Cronbach 0.89) and a high structural validity. SHQ also has been shown to have an appropriate relationship with other functional spatial hearing tests [11]. The psychometric properties of the Persian version of this questionnaire (P-SHQ) were evaluated by Delphi et al. 2015. The reliability of P-SHQ was 0.99 (by alpha Cronbach). In addition, the score of P-SHQ was a significantly different in different types of hearing loss, which indicates the high validity of the questionnaire [12].

Generally for examining the capability of a psychophysical test to determine the degree of hearing handicap and disability, it is useful to investigate the correlation between the test results and the scores of the self-assessment tools. In the present study, we used spatial word in noise test to measure spatial hearing of the subjects. In this test, monosyllabic words are presented in 7 spatial locations (0°, 30°, − 30°, 60°, − 60°, 90°, − 90°-azimuth) by applying ITD. The words are presented in noise with signal to noise ratio of 0 dB [2]. In the study of Zamiri et al. and Delphi et al. [2, 13], this test was used to measure the psycho-physical aspect of spatial hearing. In the present study, the scores of SHQ and spatial word in noise test were compared among three groups of participants: (a) normal-hearing subjects, (b) subjects with mild hearing loss, and (c) subjects with moderate hearing loss.

Materials and Methods

This study was approved by the ethics committee of the Ahvaz Jundishapur University of Medical Sciences by the registration number of AJUMS.REC.1396.499.

This descriptive-analytic study investigated three groups with normal hearing, mild and moderate hearing loss, with an age range of 18–40 years. The mean age in the normal hearing group was 28.07 ± 5.530, in the group with the mild hearing loss was 26.07 ± 7.43, and in the moderate hearing loss group was 30.54 ± 6.93 years old. The sample size according to the previous studies was calculated and 22 subjects were included (with the power of 80% and an error of 5%) [14]. Inclusion criteria for the normal-hearing group was PTA < 25 dB in both ears, for mild hearing loss group PTA = 25–40 dB, for moderate hearing loss group PTA = 40–55 dB. All cases had symmetric hearing level (threshold difference between two ears ≤ 5 dB). Audiometry was conducted via the Interacoustics AC40audiometer (Denmark). All participants had normal middle ear function (tympanogram type A). Immittance acoustic audiometry was performed by Interacoustics AT235. Other inclusion criteria were right-hand dominance (by Edinburgh Handedness Inventory), mono-linguality (Farsi language), and literacy defined as the ability to read and write (in Farsi). Before the beginning of the tests, the informational sheets for explaining the study conditions and procedure were distributed among the participants. A written informed consent was obtained from the participants.

In the next step, the spatial word in noise test was conducted on all participants. Monosyllabic words were presented with ITD of 880, 660, 220, 0, − 220, − 660 and − 880 µs (at − 90°, − 60°, − 30°, 0°, + 30°, + 60°, + 90° Azimuth) in at the comfortable level of 30 dB SL. The negative and positive signs are representative of the left and right ear. For each spatial location, 5 monosyllabic words were presented randomly in the presence of white noise, with a zero signal-to-noise ratio (SNR), and the word recognition score was calculated for each spatial location (20% for each word). A total of 35 monosyllabic words were presented randomly. After the presentation of each word, the person was asked to repeat the word. The total score for each spatial location was calculated in percentage [2]. Then participants were asked to complete the SHQ questionnaire. Participants received comprehensive instruction about the questionnaire beforehand.

The statistical analysis of this study was performed using SPSS software version 22. For data analysis, data distribution was first analyzed by Kolmogorov–Smirnov test; all data had a normal distribution, so the one-way ANOVA test was used to compare the results among the three groups. In addition, for assessing the relationship between the scores obtained from the P-SHQ questionnaire and scores of spatial word recognition in noise, the Pearson correlation test was used.

Results

In this study, 66 participants (37 females and 29 males) were selected based on the inclusion criteria. Mean and standard deviation of hearing thresholds (in dBHL) at different frequencies in three groups are presented in Fig. 1. Mean P-SHQ score was compared with scores of spatial word in noise test in both sex by using independent *t* test and the results showed no significant differences: normal hearing group (*P* value = 0.902), mild hearing loss (*P* value = 0.547), and moderate hearing loss (*P* value = 0.902).

In the Table 1, mean and standard deviation of word recognition scores (in percent) in 7 spatial locations (at − 90°, − 60°, − 30°, 0°, + 30°, + 60°, + 90° Azimuth) in three groups are shown. Comparison of mean scores by ANOVA showed a significant difference among the three groups (*P* value = 0.001). The results showed that the

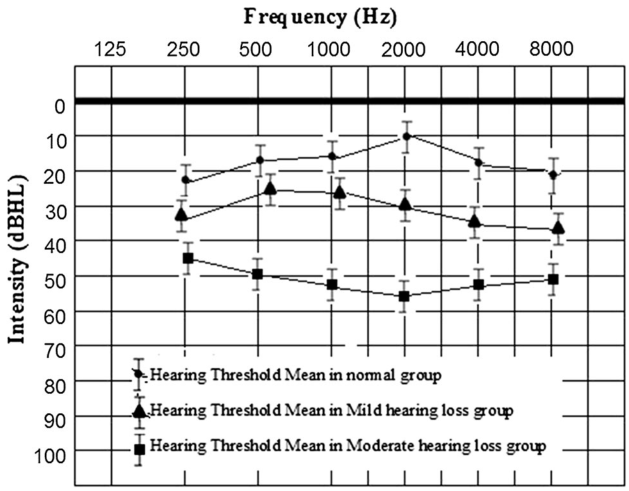

Fig. 1 The mean and standard deviation of hearing thresholds (dBHL) at different frequencies in three groups

spatial word in noise score decreased with increasing the hearing loss. Table 2 also shows the comparison of the total P-SHQ scores among the three groups, analyzed by ANOVA. As it is shown, the mean scores had a significant difference among the three groups (*P* value = 0.001), and P-SHQ scores decreased with increasing hearing loss.

Finally, Pearson correlation test was used to examine the relationship between the total P-SHQ scores and scores of the spatial word in noise test. As shown in Table 3, there was a strong positive correlation between them. The total P-SHQ score showed a reduction with a recognition score of the spatial word in noise test.

Discussion

The present study aimed to examine the relationship between psychophysical tests and self-assessment questionnaires in spatial hearing. For this purpose, the Pearson test was used to assess the relationship between P-SHQ score and the score of the spatial word in noise test among three groups. For the interpretation of these results, it should be noted that the relationship between the objective and self-assessment tests depends on their validity [7, 13]. In this study, the tests with high levels of reliability and validity were selected [12].

To date, several studies have addressed the importance of the spatial SRT (Speech Recognition Score) as well as P-SHQ scores [15, 16], but the relationship between these tests and the self-assessment questionnaires has not been studied sufficiently. In the present study, there was a significant difference in mean scores of spatial word in noise test among the three groups. The highest scores were in the group with normal hearing and the lowest in the moderate hearing loss group. This finding is in line with the study of Van Esch et al. [14], which showed that the ability of spatial speech recognition is related to pure tone average, and as the pure tone average increases, the spatial hearing function reduces.

In the present study, the total mean of P-SHQ score for mild and moderate hearing loss groups was 79.43 ± 8.56 and 65.70 ± 9.45, respectively, which is close to Delphi t al. report in 2015. Delphi et al. [12] showed that the mean P-SHQ scores in the mild and moderate hearing loss group were 73.48 and 66.87, respectively. In addition, the mean P-SHQ score was significantly different among the three groups. This finding has also been confirmed in previous

Table 1 Comparison of mean scores of word recognition scores in 7 spatial locations in three groups

Spatial locations	Moderate hearing loss	Mild hearing loss	Normal hearing	*P* value
0°	66.90 ± 14.89	83.25 ± 10.80	98.50 ± 7.50	0.001
+ 30°	52.57 ± 12.76	81.30 ± 9.20	98 ± 7.44	0.001
− 30°	52.57 ± 12.76	84.45 ± 8.67	95.80 ± 9.09	0.001
+ 60°	60.80 ± 15.39	85.11 ± 10.90	96.54 ± 7.89	0.001
− 60°	59.81 ± 16.12	86.43 ± 9.04	97.60 ± 7.90	0.001
+ 90°	54.39 ± 12.80	80.98 ± 12.59	97.62 ± 8.04	0.001
	58.50 ± 13.82	82.75 ± 13.76	98.40 ± 9.29	

Table 2 Comparison of the total P-SHQ score among the three groups

Group	Moderate hearing loss	Mild hearing loss	Normal hearing	*P* value
P-SHQ	65.70 ± 9.45	79.43 ± 8.56	92.50 ± 4.34	**0.001**

p value ≤ 0.05

Table 3 Correlation between the word recognition in spatial noise test and P-SHQ

Spatial locations	Moderate hearing loss		Mild hearing loss		Normal hearing	
	P value	r	*P* value	r	*P* value	r
0°	0.001	0.690	**0.001**	0.750	**0.001**	0.856
+ 30°	0.001	0.824	**0.001**	0.679	**0.001**	0.809
− 30°	0.001	0.835	**0.001**	0.680	**0.001**	0.800
+ 60°	0.001	0.768	**0.001**	0.790	**0.001**	0.797
− 60°	0.001	0.698	**0.001**	0.772	**0.001**	0.825
+ 90°	0.001	0.645	**0.001**	0.763	**0.001**	0.890
− 90°	**0.001**	0.742	**0.001**	0.820	**0.001**	0.781

p value ≤ 0.05

studies [12, 17–21] revealing that the ability of spatial hearing process is influenced by hearing loss.

The correlation test showed a substantial positive correlation between the P-SHQ score and spatial word in noise score among the three groups (r = 0.64–0.81). In fact, with the increase of hearing loss, the spatial speech recognition function and the total P-SHQ score were decreased. The highest correlation was found in the normal hearing group (r = 0.78–0.89) and the lowest correlation in the group with moderate hearing loss (r = 0.64–0.82). It seems that by increasing the level of hearing loss, the influence of other factors such as cognition and memory on the spatial word in noise increases which leads to an unexpected decrease of the score. The results of previous studies have also confirmed this relationship. Van Esch et al. examined the relationship between psychophysical tests (MAA (Minimum Audible Angle), Spatial SRT) and SSQ questionnaire in hearing-impaired patients. The results indicated a significant relationship between these tests (r = 0.45–0.65) [14]. In 2013, Heo et al. also assessed the relationship between the SSQ questionnaire and the speech perception and localization test in 14 subjects with unilateral cochlear implants. Their results revealed a significant correlation between SSQ and localization test (r = 0.57) and between SSQ and speech recognition test (r = 0.55) [22]. Our study also showed a positive correlation between the psycho-physiological tests and self-assessment P-SHQ. It is notable that the relationship demonstrated by the current study was more evident than the previous studies, which can be due to difference in the type of the questionnaire and the speech recognition test. The domains which are included in the P-SHQ questionnaire are more capable of testing localization function than SSQ, and spatial word in noise test in 7 spatial locations also provides a good assessment of the spatial function.

Lastly, the results of this study might be useful in evaluating, prescribing, and fitting of hearing aid devices and also in counseling to patients with hearing problems. In this regard, by considering the decreased spatial hearing ability in patients with hearing loss, audiologists need to use measurement strategies (psychophysical or questionnaires) to assess this problem. Additionally, it is necessary to provide adequate explanations in consultation with the patient about the nature of spatial hearing difficulty and how it might potentially affect the speech processing and to provide information about the role of rehabilitation and auditory training to overcome these problems.

In the present study, the relationship between the scores of the spatial word in noise test and the total P-SHQ score was measured in three groups. The results showed a strong correlation between these two tests. Since pure tone audiometry and conventional speech recognition tests do not have the ability to detect and assess spatial hearing, it is recommended that audiologists use spatial word in noise test and P-SHQ questionnaire clinically to examine the extent of spatial hearing disorder. This can help audiologists in consultation, hearing aid fitting and auditory rehabilitation.

Acknowledgements We would like to thank all the individuals who participated in this study.

Funding This paper is extracted from a research project approved by the Musculoskeletal Rehabilitation Research Center, Ahvaz Jundishapur University of Medical Sciences (Grant Numbers PHT-9621). We would like to thank all the individuals who participated in this study.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Culling JF, Hawley ML, Litovsky RY (2004) The role of head-induced interaural time and level differences in the speech reception threshold for multiple interfering sound sources. J Acoust Soc Am 116(2):1057–1065

2. Lotfi Y, Moosavi A, Abdollahi FZ, Bakhshi E (2018) Auditory lateralization training effects on binaural interaction component of middle latency response in children suspected to central auditory processing disorder. Indian J Otolaryngol Head Neck Surg 2018:1–5
3. Moossavi A, Abdollahi FZ, Lotfi Y (2017) Spatial auditory processing in children with central auditory processing disorder. Audit Vestib Res 26(2):56–63
4. Cameron S, Brown D, Keith R, Martin J, Watson C, Dillon H (2009) Development of the North American Listening in Spatialized Noise-Sentences Test (NA LiSN-S): sentence equivalence, normative data, and test-retest reliability studies. J Am Acad Audiol 20(2):128–146
5. Fonseca CBF, Iório MCM (2006) Application of the lateralization sound test in elderly individuals. Pró-Fono Rev Atual Cient 18(2):197–206
6. Cameron S, Glyde H, Dillon H (2011) Listening in Spatialized Noise-Sentences Test (lisn-s): normative and retest reliability data for adolescents and adults up to 60 years of age. J Am Acad Audiol 22(10):697–709
7. Delphi M, Lotfi M-Y, Moossavi A, Bakhshi E, Banimostafa M (2017) Reliability of interaural time difference-based localization training in elderly individuals with speech-in-noise perception disorder. Iran J Med Sci 42(5):437
8. Shemesh R (2008) Psychoacoustic tests for central auditory processing: normative data. J Basic Clin Physiol Pharmacol 19(3–4):249–260
9. Cameron S, Dillon H (2007) Development of the listening in spatialized noise-sentences test (LISN-S). Ear Hear 28(2):196–211
10. Galvin KL, Noble W (2013) Adaptation of the speech, spatial, and qualities of hearing scale for use with children, parents, and teachers. Cochlear Implants Int 14(3):135–141
11. Tyler RS, Perreau AE, Ji H (2009) The validation of the spatial hearing questionnaire. Ear Hear 30(4):466
12. Delphi M, Abdolahi FZ, Tyler R, Bakhit M, Saki N, Nazeri AR (2015) Validity and reliability of the Persian version of spatial hearing questionnaire. Med J Islamic Repub Iran 29:231
13. Delphi M, Lotfi Y, Moossavi A, Bakhshi E, Banimostafa M (2017) Envelope-based inter-aural time difference localization training to improve speech-in-noise perception in the elderly. Med J Islam Repub Iran 31:36
14. Van Esch T, Lutman M, Vormann M, Lyzenga J, Hällgren M, Larsby B et al (2015) Relations between psychophysical measures of spatial hearing and self-reported spatial-hearing abilities. Int J Audiol 54(3):182–189
15. Goverts ST, Houtgast T (2010) The binaural intelligibility level difference in hearing-impaired listeners: the role of suprathreshold deficits. J Acoust Soc Am 127(5):3073–3084
16. Johansson MS, Arlinger SD (2002) Binaural masking level difference for speech signals in noise: diferencia en el nivel de enmascaramiento binaural para señates vocales en ruido. Int J Audiol 41(5):279–284
17. Moulin A, Richard C (2016) Sources of variability of speech, spatial, and qualities of hearing scale (SSQ) scores in normal-hearing and hearing-impaired populations. Int J Audiol 55(2):101–109
18. Moulin A, Richard C (2016) Validation of a French-language version of the Spatial Hearing Questionnaire, cluster analysis and comparison with the speech, spatial, and qualities of hearing scale. Ear Hear 37(4):412–423
19. Ou H, Perreau A, Tyler RS (2017) Development of a shortened version of the Spatial Hearing Questionnaire (SHQ-S) for screening spatial-hearing ability. Am J Audiol 26(3):293–300
20. Ou H, Wen B, Perreau A, Kim E, Tyler R (2016) Validation of the Chinese translation of the Spatial Hearing Questionnaire and its short form. Am J Audiol 25(1):25–33
21. Ramakers GG, Smulders YE, Van Zon A, Van Zanten GA, Grolman W, Stegeman I (2017) Correlation between subjective and objective hearing tests after unilateral and bilateral cochlear implantation. BMC Ear Nose Throat Disord 17(1):10
22. Heo J-H, Lee J-H, Lee W-S (2013) Bimodal benefits on objective and subjective outcomes for adult cochlear implant users. Korean J Audiol 17(2):65