Research Paper

Spatial Hearing Questionnaire: Psychometric Properties of Turkish Version and Correlations with Hearing Skills

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Objective: Self-report questionnaire is informative to assess general hearing disability. The aims of this study were to investigate the reliability of Turkish version of spatial hearing questionnaire (SHQ) and to analyze the validity of the SHQ by the correlation with speech, spatial, and qualities of hearing questionnaire (SSQ) and Turkish matrix sentence test (TMST).

Methods: The first part of the study was the psychometric properties of the SHQ with 192 participants (137 with normal hearing, 55 with hearing loss). In the second and main part of the study, we applied two questionnaires (SHQ and SSQ) and TMST to people other than those included in the first part of the study (88 participants with bilateral sensorineural hearing loss). We compared the results of these two questionnaires and the TMST with the speech discrimination (SD) scores.

Results: Turkish spatial hearing questionnaire's internal consistency was 0.94 and 0.97 for individuals with normal hearing and for individuals with hearing loss, respectively. Moderate, positive, statistically significant correlation was observed between the SHQ and SSQ ($r = 0.606$, $p = 0.001$ in individuals with hearing loss who do not wear any hearing aid, and $r = 0.627$, $p = 0.001$ in hearing aid users), and SHQ and SD ($r = 0.561$, $p = 0.032$ in hearing aid users). According to TMST, moderate, positive, statistically significant correlation was found between SSQ and adaptive TMST in individuals with hearing loss who do not wear any hearing aid ($r = 0.330$, $p = 0.033$ for S0N90 and $r = 0.364$, $p = 0.018$ for S0N270).

Conclusions: Turkish SHQ is a valid and reliable questionnaire for assessing hearing functions. SHQ, SSQ, and TMST are clinically beneficial measuring tools in planning the process of hearing rehabilitation and follow-up.

Keywords: spatial hearing questionnaire; speech, spatial, and qualities of hearing questionnaire; Turkish matrix sentence test; hearing loss.

1. Introduction

Hearing impaired people have more difficulty in understanding speech, especially in noisy environments than those with normal hearing (KILLION *et al.*, 2002; WILSON, STROUSE, 2002) lack of spatial discrimina-tion of the source of speech and noise (DUBNO *et al.*, 2002), and impairment in other binaural hearing skills (NOBLE *et al.*, 1995). Localization and binaural hearing skills that are impaired in individuals with hearing loss can be determined only through the evaluation of understanding of speech (ZHANG *et al.*, 2015). Spatial

hearing is described as a skill of speech intelligibility in background noise, determining the distance of the sound source, sound localization, etc. (Allen *et al.*, 2008; Glyde *et al.*, 2013; Best *et al.*, 2010). Binaural hearing is typically described as a skill that applies to both of our ears, our skill to localize sounds and to discriminate between speech and noise sources when different sources of sound and noise are present (Glyde *et al.*, 2013). Binaural hearing facilitates spatial hearing skill based on interaural time difference and interaural level difference (Tyler *et al.*, 2009; Ahlstrom *et al.*, 2014). Individuals with unilateral or bilateral hearing loss might have impaired spatial hearing skills because they are not able to make use of the advantage of binaural hearing (Ou *et al.*, 2017).

Speech recognition, which is an important factor for high quality of life and successful communication, is partially associated with auditory sensitivity (Cruice *et al.*, 2006). To restore speech intelligibility affected by decreased audibility (threshold of hearing), to minimize the effects of the impairment present in the hearing systems of individuals with hearing loss, and the difficulties that they experience in their daily communication skills, devices that will improve hearing such as hearing aids (Ahlstrom *et al.*, 2009; Bertoli *et al.*, 2010) and cochlear implants are used with the aim of increasing efficiency of communication skills (Tyler *et al.*, 2009). Particularly in individuals with high frequency hearing loss, speech understanding are impaired due to the lack of discrimination of spatial differences of noise and the changes in interaural level differences generally between 2.0 and 5.0 kHz (Tonning, 1971; Festen, Plomp, 1986). Decreased spatial perception in individuals with normal hearing or with hearing loss might result in distortions in speech recognition in noise (Cameron, Dillon, 2008; Schafer *et al.*, 2012), impaired skill to localize and discriminate cues in space in individuals with hearing loss (Lorenzi *et al.*, 1999; Drennan *et al.*, 2005), and distortions in spatial discrimination of speech source in noise (Peissig, Kollmeier, 1997; Dubno *et al.*, 2002).

Speech understanding that is impaired in noisy settings might not be completely described by determining pure-tone hearing threshold level and speech discrimination test in silent setting (Smoorenburg, 1992). It is therefore important to make clinical use of the tests that are adapted to individuals' native language to assess speech understanding in noise. Matrix Sentence Test (MST) developed by (Hagerman, 1982) to assess speech intelligibility in noise, was created using the words that are frequently used in daily life in Swedish and by paying attention to familiarity with words and semantic neutrality for different age groups. MST has been adapted in various languages including Turkish, and can be performed in different listening settings with headphones or speak-

ers (Hagerman, 1982; Hochmuth *et al.*, 2012; Dietz *et al.*, 2014; Houben *et al.*, 2014; Warzybok *et al.*, 2015; Zokoll *et al.*, 2015).

Self-reported questionnaires can be used to assess the individuals with hearing loss benefit from rehabilitation process. The questionnaires such as Speech, Spatial, and Qualities of Hearing Questionnaire (SSQ) and Spatial Hearing Questionnaire (SHQ) can be used to assess binaural hearing skills (Gatehouse, Noble, 2004; Tyler *et al.*, 2009). SSQ questionnaire consisting of 49 items is used to assess the daily listening status of individuals who using hearing aids or cochlear implants in three separate areas such as localized hearing, speech recognition, and hearing quality (for example sound clarity and listening effort) (Gatehouse, Noble, 2004; Akeroyd *et al.*, 2014). On the other hand, SHQ is used to assess spatial hearing skill in individuals who used cochlear implants and hearing aids (Tyler *et al.*, 2009). SHQ is a questionnaire consisting of 24 questions aiming to evaluate the sound localization and speech understanding in noise and quiet environments (Tyler *et al.*, 2009). Validity and reliability study of SSQ for Turkey was conducted by Kılıç (2017); however, the SHQ test has not been still studied for its validity and reliability in Turkey.

The purpose of our study was to investigate the reliability of SHQ in individuals with normal hearing and hearing loss and to analyze the validity of the spatial hearing questionnaire by correlating the data from the SSQ, SD, and Turkish Matrix Sentence Test (TMST) scores in individuals with hearing loss.

2. Methods

The study was approved by the institutional ethical committee and performed in accordance with the Declaration of Helsinki (Approval No. 423/84). Written informed consents were obtained from all the individuals who volunteered for the study using informed consent form. Our study consisted of two parts in order to analyze its reliability on different patients after adapting the SHQ questionnaire to Turkish.

Individuals in the first part of the study: To conduct the SHQ Turkish reliability study, 137 individuals between the ages of 18–45 years with normal hearing threshold (< 20 dB at the octave frequencies 0.125, 0.25, 0.5, 1, 2, 4, 6, and 8 kHz) and 55 individuals between the ages of 18–75 years with bilateral mild and moderate sensorineural hearing loss filled the SHQ. Mini Mental Test was performed prior to the administration of the SHQ, and those who scored ≥ 21 in the test were included. The demographical information of individuals in the first study is shown in Table 1.

Table 1. Characteristics of individuals who participated in the first part of the study.

Normal hearing	
N (Male/Female)	137 (66/71)
Male age [years]	23.1 ± 3.2
Famale age [years]	24 ± 5.1
Right PTA* [dB]	10.5 ± 1.25
Left PTA [dB]	11.2 ± 1.8
Hearing loss	
N (Male/Female)	55 (29/26)
Male age [years]	42.1 ± 3.1
Famale age [years]	44 ± 6.7
Right PTA [dB]	36 ± 8.18
Left PTA [dB]	35.6 ± 9.4

* PTA – mean of 4 frequencies in dB HL (0.5, 1, 2, and 4 kHz).

Individuals in the second part of the study.
The SHQ, SSQ and TMST were performed to 88 individuals with bilateral sensorineural hearing loss (42–80 years) including 48 who had not been using hearing aid (unaided group) and 40 who had been using bilateral hearing aid for at least 6 months (aided group). The patients in this part of the study are different from the patients we recruited for normalization of SHQ. Mini Mental Test was performed for each individual participating to the second part of the study and those who scored ≥ 21 in the test were included. The demographic characteristics of the individuals in the second study are shown in Table 2.

Table 2. Characteristics of individuals who participated in the second part of the study.

Unaided group	
N (Male/Female)	48 (19/29)
Male Age (years)	57.5 ± 7.8
Famale Age (years)	59.6 ± 8.4
Right PTA*	44 ± 9.6
Left PTA	45.6 ± 10.4
Aided group	
N (Male/Female)	40 (22/18)
Male Age (years)	62.5 ± 9.6
Famale Age (years)	60.7 ± 10.1
Right PTA	52.5 ± 10.1
Left PTA	54.2 ± 6.1

*PTA – mean of 4 frequencies in dB HL (0.5, 1, 2, and 4 kHz).

Following the ear-nose-throat (ENT) examination of all individuals with hearing loss included in the present study, their audiological assessments were performed by Hacettepe University, Faculty of Health Sciences Audiology Department. To perform speech audiometry of the individuals, four different lists of 25 monosyllabic words that were phonetically balanced were recorded digitally and given to the individuals in a randomized manner in a double-walled, sound-attenuating booth without noise at 40 dB sensation level. The speech discrimination (SD) scores were obtained in percentage by the number of words that were correctly heard (the total score is calculated by multiplying the number of words repeated correctly by 4).

It was noted that the hearing configuration of individuals with bilateral hearing loss were symmetrical and those with hearing levels worse than 70 dB HL were excluded. The interaural severity differences of <15 dB between two ears of those individuals with hearing loss at the frequencies of 500, 1000, 2000, and 4000 Hz were described as symmetrical hearing loss (Hua *et al.*, 2017). Each questionnaire was filled by all individuals in a silent setting during a single session under the supervision of an audiologist.

2.1. Turkish speech hearing questionnaire

The questionnaire was translated in accordance with the questionnaire administration method of the World Health Organization 2017 (WHO, 2017). The SHQ (24 items) scored between 0 (not easy at all) and 100 (quite easy), expressed the best hearing with the highest score and the most unsatisfactory hearing with the lowest score as a percentage (Tyler *et al.*, 2009). The SHQ was translated into Turkish by a professional translator of English language who was bilingual in English and Turkish, and it was back-translated into English by another professional translator of English language who was also bilingual. Finally, the translated versions of the questionnaires were reviewed by five different professional translator than the previous ones of English language followed by some changes in the reviewed versions and the Turkish SHQ was finalized. This questionnaire answered the following eight different states that are significant for binaural hearing loss and the total score equals the average of 24 items (Tyler *et al.*, 2009):

1) male sound (items 1, 5, 9, 13, and 17);

2) female sound (items 2, 6, 10, 14, and 18);

3) child sound (items 3, 7, 11, 15, and 19);

4) music (items 4, 8, 12, 16, and 20);

5) source localization (items 13–24);

6) understanding speech in silence (items 1–4);

7) understanding speech in noise when object and noise source are in the front area (items 5–8);

8) understanding speech in noise when object or noise source are in different directions (items 9–12).

2.2. Speech, spatial and qualities of hearing questionnaire

SSQ is a questionnaire that assesses components of direction, distance, and motion in hearing, speech, and spatial hearing. It reflects the actual hearing skill of an individual in daily life by assessing individual's skill to discriminate sounds and simultaneously take part in speech flows. SSQ questionnaire comprises three sections: hearing speech (14 items), spatial hearing (17 items), and other characteristics of hearing (18 items). Each item is scored on a scale of 0 to 10 (0 indicating that the situation mentioned is not possible and 10 indicating that the specific situation is perfect). The items included in the first section of the SSQ test that assessed the level of hearing speech have been created considering whether sounds arrive simultaneously in cases of different backgrounds (silent, stable noise, reflection, etc.), visibility of other speakers, and number of people speaking (SSQ-S). The second section that assesses spatial hearing includes the items about direction and distance (SSQ-L). In the last section, where other properties of hearing are assessed, there are items concerning listening effort, neutrality, and sound discrimination (SSQ-Q). All the three sections included in this test (SSQ-S (Speech hearing), SSQ-L (Spatial (Locationally) hearing), and SSQ-Q (Qualities of hearing)) can be separately scored, and a total score (SSQ) can also be obtained based on the answers provided for all the sections (GATEHOUSE, NOBLE, 2004).

2.3. Matrix Sentence Test (MST)

We used the Turkish Matrix Sentence Test (TMST) in the present study to assess individuals' understanding speech in noise (ZOKOLL *et al.*, 2015). The TMST (adaptive/nonadaptive) was used to measure the individuals' speech intelligibility in quiet and noise. This test was performed with individuals instructed to repeat the words in each sentence that is administered using a computer in the sound-attenuating booth. Test lists (5 different lists, each item with different sentences) is composed of 20 sentences are frequently used in daily life were used as test material. The level of the next sentence to be administered is determined based on the number of words that an individual repeats in the current sentence. The noise stimulus used in TMST was a bubble noise starts at 65 dB sound pressure level (SPL) fixed noise level with 0 dB signal to noise ratio (SNR) and the level of the next sentence to be administered gradually changes when the number of words correctly repeated is > 50% of the total number of the words administered in the current sentence (BRAND, KOLLMEIER, 2002; WARZYBOK *et al.*, 2015). There was no one with the hearing level over 55 dB HL in our study, 80 dB SPL fixed noise level would have to be used as the starting level, if the hearing level was greater than 55 dB HL.

The speech recognition level (SRT) average was -7.1 ± 0.2 dB SNR in the German Matrix test (KOLLMEIER, WESSELKAMP, 1997), -9.7 ± 0.7 dB SNR in the Finnish matrix test (DIETZ *et al.*, 2014), and 6.2 ± 0.8 dB SNR in the Spanish matrix test (HOCHMUTH *et al.*, 2012), -7.2 ± 0.7 dB SNR in Turkish MST (ZOKOLL *et al.*, 2015).

After performing non-adaptive TMST in silence using Sennheiser HDA200 headphones adaptive TMST in noise were performed with and without hearing aids with speaker in free field at different azimuths (S_0N_0, S_0N_{90}, and S_0N_{270}). Speakers were placed in front and on the right side of the individuals with 1m distance At the angle of S_0N_0, speech and noise were simultaneously presented through the speaker in front of the patient (azimuth of 0); at S_0N_{90}, speech stimulus was presented from across the patient, while noise stimulus was presented from the right side of the patient; and at S_0N_{270}, speech stimulus was presented from across the patient and noise stimulus was presented from the left side of the patient after the patient was moved to a position where she/he faced the speaker on the right side.

2.4. Statistical analysis

The data were statistically analyzed using SPSS 23.0 (SPSS 23.0 for Windows; SPSS Inc., Chicago, IL, USA). Cronbach's alpha and item-total correlation internal consistency was performed for factor analysis. Kaiser-Meyer-Olkin (KMO) test was conducted to measure adequate modeling for SHQ questionnaire, and those with a KMO value of > 0.70 were considered good, whereas those with a KMO value of > 0.90 were considered perfect. The number of factors was assessed; eigenvalue and scree plot were used to determine the factors presenting high correlation in the SHQ test items, and those factors with an eigenvalue of > 1 were included in the assessment (KAISER, 1960). The correlation between varimax rotation SHQ scores and age for each factor was set based on the Pearson's correlation coefficient. Independent *t*-test and correlation analysis were performed to compare independent variables, whereas Chi-square test was conducted to analyze categorical changes. Independent *t*-test was used to compare the data from individuals using and not using hearing aids and to perform inter-sex comparison. The hedges effect size was calculated in the comparison between the two groups, and the correction factor was not used because of the effect size between the group means was high. The correlation between groups was set based on Pearson's correlation test and a *p* value of < 0.05 was considered significant.

3. Results

Turkish SHQ validity and reliability. Mean SHQ was 85.56 ± 8.03 for females and 84.65 ± 6.78 for males with normal hearing whereas mean SHQ was 82.90 ± 8.69 for females and 81.20 ± 7.58 for males with hearing loss. There was no statistically significant gender difference between the SHQ scores for normal hearing ($p = 0.615$) and hearing loss ($p = 0.212$). Questionnaire reliability was assessed by performing internal reliability coefficient Cronbach's alpha, which was 0.94 for individuals with normal hearing and 0.97 for those with hearing loss. Inter-item correlation was between 0.54 and 0.86 for individuals with normal hearing and between 0.68 and 0.99 for those with hearing loss. KMO value, measured in the factor analysis, was 0.83 for individuals with normal hearing and 0.76 for those with hearing loss. Kaiser normalization and varimax rotation were used to easily interpret the data; the data were analyzed based on multiple factors and calculations were separately made for individuals with normal hearing and those with hearing loss. Factor analysis of individuals with normal hearing and hearing loss is shown in Table 3. Rotated component matrix was created for the components. Four of the

Table 3. Turkish Spatial Hearing Questionnaire factor structure for participants with hearing loss and normal hearing.

Participants with normal hearing	
Factors Items (Factor Loadings of the Items)	
Factor 1	**Q13** (0.73), **Q14** (0.80), **Q15** (0.84), **Q16** (0.78), **Q17** (0.81), **Q18** (0.84), **Q19** (0.76), **Q20**(0.67)
Factor 2	**Q5** (0.79), **Q6** (0.86), **Q7** (0.86), **Q8** (0.68), **Q9** (0.78), **Q10** (0.83), **Q11** (0.74), **Q12** (0.55)
Factor 3	**Q21** (0.62), **Q22** (0.61), **Q23** (0.54), **Q24** (0.73)
Factor 4	**Q1** (0.83), **Q2** (0.68), **Q3** (0.66), **Q4** (0.64)
Participants with hearing loss	
Factor 1	**Q13** (0.80), **Q14** (0.79), **Q15** (0.85), **Q16** (0.88), **Q17** (0.89), **Q18** (0.93), **Q19** (0.93), **Q20** (0.91), **Q21** (0.65), **Q22** (0.73), **Q23** (0.82), **Q24** (0.84)
Factor 2	**Q5** (0.82), **Q6** (0.83), **Q7** (0.86), **Q8** (0.85), **Q9** (0.86), **Q10** (0.89), **Q11** (0.92), **Q12** (0.78)
Factor 3	**Q1** (0.88), **Q2** (0.90), **Q3** (0.86), **Q4** (0.75)

Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) = 0.76 for hearing loss and 0.83 for normal hearing, *Extraction Method: Principal Component Analysis, Rotation Method: Varimax with Kaiser Normalization.*

24 items had an eigenvalue of >1 in the group of individuals with normal hearing, and the first, second, third, and fourth factors accounted for 44%, 14.8%, 9.18%, and 4.8% of the total variance (eigenvalue = 10.65, 3.57, 2.2, and 1.52), respectively. Factor 1 correlated with 12 items (13–20) concerning source localization, factor 2 with eight items (5–12) concerning speech intelligibility in noise and a noise-free setting (intelligibility in the presence of object located in the front and in noise, music in silence, intelligibility in spatial noise and object source, etc.), factor 3 with four items (21–24) concerning localization of object source, and factor 4 with items one through four concerning intelligibility of male and female and child sounds in silence (state of easy listening). The cohort α values for each factor were $\alpha = 0.95$, $\alpha = 0.94$, $\alpha = 0.80$, and $\alpha = 0.75$ for factors 1, 2, 3, and 4, respectively, whose reliability was well. Three of the 24 items had an eigenvalue of >1 in the group of individuals with hearing loss, and the first, second, and third factors accounted for 70.2%, 11.8%, and 4.2% of the total variance (eigenvalue = 16.8, 3.01, and 1.02), respectively. Overall 12 items (13–24) correlated with factor 1, nine items (5–12) with factor 2, and four items (1–4) with factor 3 in individuals with hearing loss.

Comparison of the SSQ, SHQ, SD, and TMST scores in individuals with and without hearing aid users and normal hearing. Total SHQ score was $83.56\% \pm 8.03$ in individuals with normal hearing, $49.38\% \pm 13.49$ in those with hearing loss with hearing aid users, and $70.4\% \pm 10.2$ in those with hearing loss who do not wear any hearing aid and was significant ($p = 0.001$). Furthermore, as expected statistically significant difference was observed between the SSQ subtest scores of individuals with and without hearing aid users ($p = 0.001$). The SHQ (including the subcales) values of individuals with and without hearing aid users, and normal hearing were showed in Fig. 1. To set the correlation between the mean SHQ and SSQ scores in individuals, the rate expressed between 0 and 10 in the SSQ test was transformed into a scale of scores between 0 and 100 (Zhang,
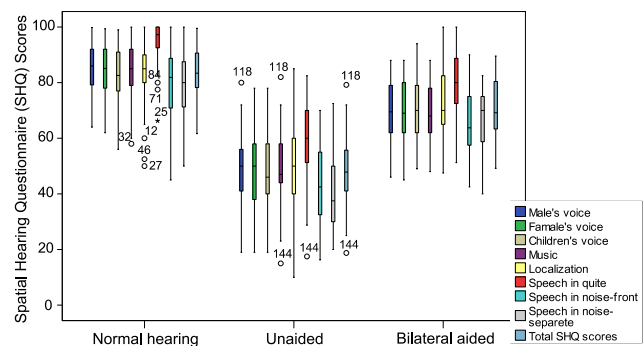

Fig. 1. Mean performance for normal hearing (137), unaided (48) and aided (40) groups on the Spatial Hearing Questionnaire (SHQ) for eight subscales and the total score. Error bars represent standard errors.

Tyler *et al.*, 2015). According to Preston and Colman (2000), there was no significant difference between the scales consisting of 7–10 options and the 101-options scale.

The adaptive TMST scores of the unaided group were lower than the scores of the aided group; this difference was statistically significant at S_0N_0 ($p = 0.029$), S_0N_{90} ($p = 0.001$), and S_0N_{270} ($p = 0.001$). No statistically significant difference was observed between the non-adaptive TMST in quite test scores of the aided group (89.23 ± 8.11 dB SPL) and unaided group (89.7 ± 5.92 dB SPL) ($p = 0.664$); however, statistically significant difference was observed in adaptive TMST in quite test ($p = 0.028$), in adaptive right TMST ($p = 0.026$), and left TMST ($p = 0.013$) between the aided and unaided groups.

Correlation of the SSQ (SSQ total, SSQ speech factor (SSQ_S), SSQ spatial factor (SSQ_L), and SSQ quality factor (SSQ_Q) scores), SHQ, SD and TMST scores: Moderate positive correlation was observed between the SHQ and SSQ total scores of hearing loss who do not wear any hearing aid group ($r = 0.606$, $p = 0.001$), and hearing aided user group ($r = 0.627$, $p = 0.001$). In addition, significant correlations were found between SHQ and SSQ_S scores ($r = 0.578$, $p = 0.001$), SHQ and SSQ_L scores ($r = 0.625$, $p = 0.001$), and SHQ and SSQ_Q scores ($r = 0.526$, $p = 0.001$) in hearing aid users. Figure 2 shows the correlations of SHQ and SSQ (SSQ total, SSQ_S, SSQ_L, and SSQ_Q scores, respectively) at hearing aid users. Significant correlations were found between SHQ and SSQ_S scores ($r = 0.662$, $p = 0.001$), SHQ and SSQ_L scores ($r = 0.633$, $p = 0.001$), and SHQ and SSQ_Q scores ($r = 0.577$, $p = 0.001$) in individuals with hearing loss who do not wear any hearing aid. Figure 3 shows the correlations of SHQ and SSQ (SSQ total,
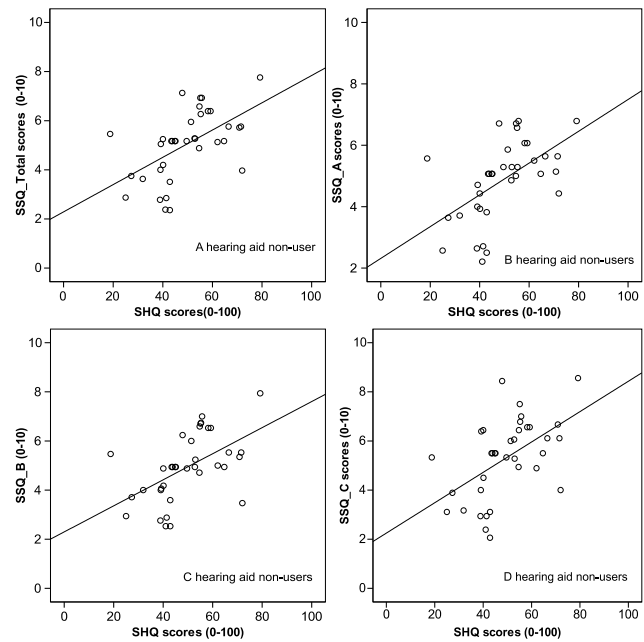

Fig. 2. Correlation between Spatial Hearing Questionnaire (SHQ) and Speech, Spatial and Qualities of Hearing Scale (SSQ) scores (SSQ total and SHQ scores (Panel A), SSQ speech factor (SSQ_S) and SHQ scores (Panel B), SSQ spatial factor (SSQ_L) and SHQ scores (Panel C), and SSQ quality factor scores (SSQ_Q) and SHQ scores (Panel D)) in individuals with hearing loss who do not wear any hearing aid.

SSQ_S, SSQ_L, and SSQ_Q scores, respectively) at hearing aid users.

The TMST score of the group using hearing aids in the S_0N_{90} ($r = 0.330$, $p = 0.033$) and S_0N_{270} ($r = 0.364$, $p = 0.018$) was positively correlated with the SHQ score at a moderate level. Figure 4 shows the correlations

Table 4. Averages scores and *t*-test results for participants with unaided, and aided groups.

Test	Unaided group	Aided group	t	df	p
SHQ total score	49.38 ± 13.4	70.4 ± 10.2	-7.876	66.78	**0.001**
SSQ total score	5.03 ± 1.38	7.37 ± 0.89	-8.978	58.18	**0.001**
SSQ–S	4.87 ± 1.28	7.22 ± 0.9	-9.441	61.77	**0.001**
SSQ–L	4.92 ± 1.35	7.31 ± 1	-8.926	63.44	**0.001**
SSQ–Q	5.3 ± 1.62	7.57 ± 0.91	-7.760	53.08	**0.001**
TMST non-adaptive in quite	89.7 ± 5.92	89.23 ± 8.11	0.436	74.73	**0.664**
TMST adaptive in quite	27.78 ± 8.5	23.49 ± 6.64	2.237	68.01	**0.028**
Right TMST adaptive in quite	1.51 ± 2.06	-2.53 ± 2.07	1.931	76.34	**0.026**
Left TMST adaptive in quite	-1.47 ± 1.63	-2.58 ± 2.02	2.127	76.74	**0.013**
TMST adaptive in noise (S_0N_0)	-0.63 ± 1.73	-1.8 ± 2.78	2.219	69.68	**0.029**
TMST adaptive in noise (S_0N_{90})	-0.93 ± 1.82	-2.94 ± 2.83	3.678	70.83	**0.001**
TMST adaptive in noise (S_0N_{270})	-0.78 ± 1.89	-3.71 ± 2.67	5.538	73.78	**0.001**

SHQ – Spatial Hearing Questionnaire; SSQ – Speech, Spatial and Qualities of Hearing Questionnaire; TMST – Turkish Matrix Sentence Test; $p < 0.05$.
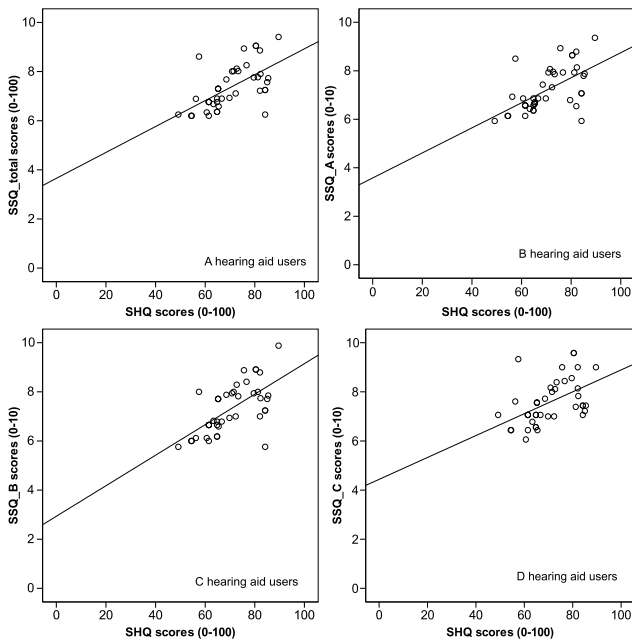
Fig. 3. Correlation between Spatial Hearing Questionnaire (SHQ) and Speech, Spatial and Qualities of Hearing Scale (SSQ) scores (SSQ total and SHQ scores (Panel A), SSQ speech factor (SSQ_S) and SHQ scores (Panel B), SSQ spatial factor (SSQ_L) and SHQ scores (Panel C), and SSQ quality factor scores (SSQ_Q) and SHQ scores (Panel D)) in hearing aid users.
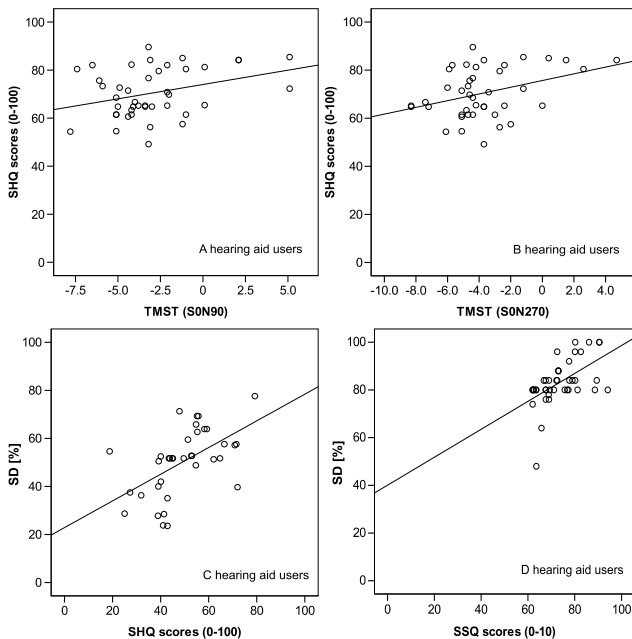

Fig. 4. Correlation between Spatial Hearing Questionnaire (SHQ) and adaptive Turkish Matrix Sentence Test (TMST) scores (S_0N_{90}) (Panel A), and Speech, Spatial and Qualities of Hearing Scale (SSQ) scores and TMST scores (S_0N_{270}) (Panel B) in hearing aid users. Correlation between SHQ and Speech Discrimination (SD) scores (Panel C), and SSQ and SD scores (Panel D) in hearing aid users.

of SHQ and adaptive TMST scores at hearing aid users. SD scores were moderately positive correlated

with SSQ ($r = 0.645$, $p = 0.021$) and SHQ ($r = 0.561$, $p = 0.032$) in the hearing aided users. No significant correlations were found between SD scores and SHQ/SSQ scores at individuals with hearing loss who do not wear any hearing aid. Figures 4C and 4D show the correlations of SHQ and SD, and SSQ and SD scores at hearing aid users.

4. Discussion

The present study includes the Turkish SHQ validity and reliability study followed by the self-reported SHQ and SSQ questionnaires administered to individuals using and not using hearing aids. The data retrieved from these questionnaires was compared with SD and TMST scores. Internal consistency coefficient Cronbach's alpha value of the Turkish SHQ questionnaire was 0.94 for individuals with normal hearing, whereas it was 0.97 for those with hearing loss. Cronbach's alpha value of > 0.70 indicates that the questionnaire used is valid and reliable (DRAAIJERS *et al.*, 2004; TERWEE *et al.*, 2007). It was therefore observed that the Turkish SHQ had a high level of validity and reliability. Inter-item correlation was between 0.74 and 0.98 for individuals with normal hearing and between 0.68 and 0.99 for those with hearing loss. The consistency that was observed between the inter-item correlation and the total scores in all individuals with or without hearing loss as well as the lack of a difference between the two sexes are consistent with that found in the literature (TYLER *et al.*, 2009; POTVIN *et al.*, 2011; PERREAU *et al.*, 2014; DELPHI *et al.*, 2015; KONG *et al.*, 2017). The number of factors for individuals with normal hearing was 4 in the Turkish SHQ, which is a result similar to that obtained by PERREAU *et al.* (2014). The number of factors for individuals with hearing loss was 3 in the Turkish SHQ, which is a result similar to that obtained by TYLER *et al.* (2009). However, in contrast, the number of factors was 2 and 4 as reported by DELPHI *et al.* (2015) and POTVIN *et al.* (2011), respectively. This difference in the number of factors for individuals with hearing loss is considered to stem from cultural differences or varying methods of questionnaire administration.

TMST (with headphones), SHQ and SSQ values were significantly higher in the aided group than the unaided group in our study ($p = 0.001$), demonstrating that individuals benefit from using hearing aids (bilateral). In a study by (KÖBLER, ROSENHALL, 2002), although the lowest (70%) SD score was observed in individuals with bilateral hearing loss who did not use hearing aids, this score was 88% in those who used bilateral hearing aids and 83% in those who used unilateral hearing aids. Bilateral amplification improves speech understanding and boosts sound localization and sound quality (KÖBLER *et al.*, 2001; AHLSTROM *et al.*, 2009).

Spatial hearing may vary based on various factors such as the type and degree of hearing loss and use of hearing aid (cochlear implant, bone anchored hearing aids, and conventional hearing aid FM) (Ahlstrom et al., 2014; Gürses et al., 2020). In a study conducted with the elderly using bilateral hearing aids, despite the limited degree of benefit introduced in understanding speech, it has been reported that spatial perception further improved, which is considered to be associated with the fact that the elderly make use of binaural cues (Ahlstrom et al., 2009). Spatial perception tests are the tests obtained as a result of speech and noise originating from different locations (Zhang et al., 2015). SSQ and SHQ are the most common questionnaires used to assess spatial hearing. There was limited research in the literature that compare the correlations between SHQ and SSQ with objective results. In our study, a significant correlation was observed in the SSQ and SHQ questionnaires in both groups (with and without hearing aid users) with moderate hearing loss, although Zhang et al. (2015) found high correlation between SHQ speech factor and SSQ speech factor in long-term follow-up study on 19 individuals with cochlear implants. The fact that the correlation between the two questionnaires (SSQ and SHQ) is lower than the study done by Zhang et al. (2015) may be due to the correlation between the total score of the SHQ and the total and subscales of the SSQ score (SSQ total, SSQ speech factor, SSQ spatial factor, and SSQ quality factor). Although SHQ focuses only on spatial perception (not the quality of the speech and music), SSQ questions both spatial perception and the quality of speech perception (Tyler et al., 2009; Zhang et al., 2015). Using both questionnaires together in individuals with hearing loss will benefit a detailed assessment of the patient's hearing ability.

In a study on individuals with moderate hearing loss, it was shown that there is a moderate correlation between SHQ score and the spatial speech recognition function (r in the range between 0.64 and 0.82) (Abdollahi et al., 2019). Heo et al. (2013) also evaluated the relationship between the SSQ questionnaire and the speech perception in patients with unilateral cochlear implants, and found a significant correlation between the SSQ and the speech recognition test ($r = 0.55$). In our study, a significant correlation was found between SSQ/SHQ and SD and TMST scores in individuals using hearing aids (r in the range between 0.33 and 0.62). Our results showed that the combined use of objective and subjective tests in hearing aid users can be useful in determining the benefit of speech and spatial skills in these individuals. Because hearing loss can affect spatial hearing ability (Delphi et al., 2015). In our study, the fact that there was no correlation between SSQ/SHQ and SD and TMST scores of individuals with individuals with hearing loss who do not wear any hearing aid/s, it was thought that perceptual hearing impairment of patients who did not use a hearing aid might be worse than the mean pure tone audiometry.

Our results were consistent with the studies specifying that using hearing aids improves auditory performance (Tyler et al., 2009; Zhang et al., 2015). However, in most of the previous literature studies, the benefit of bilateral amplification had been shown with a single measurement method. However, in our study, we demonstrated the benefit of bilateral amplification in the same sample group by comparing 3 methods of evaluation with each other.

5. Conclusion

The Turkish version of the SHQ questionnaire was found to be valid and reliable. We found that the TMST and self-report questionnaire (SHQ and SSQ) results were moderately positively correlated. Because of the moderate correlation, we recommend that clinicians use the TMST and SHQ to evaluate spatial hearing impairment. Because pure tone audiometry and traditional speech recognition tests do not have parameters for diagnosing and evaluating spatial hearing ability.

Including self-report questionnaires (SHQ and SSQ) in the clinical routine instead of using only behavioral methods (SD and TMST) will be useful in the diagnosis and follow-up of the patient with hearing loss. In our study, the adaptive matrix test performed by giving speech or signal stimuli from three different directions (S_0N_0, S_0N_{90}, and S_0N_{270}) provided us with information about the spatial skills of the patients.

In future studies, it might be beneficial to use the hearing handicap inventory and spatial perception questionnaires together to solve the problems of adaptation to the environment of the person with hearing loss while planning hearing rehabilitation.

Acknowledgments

Declaration of Interest Statement

No competing financial interests exist.

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