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Research Article

Development of a Shortened Version of the Spatial Hearing Questionnaire (SHQ-S) for Screening Spatial-Hearing Ability

Hua Ou,[a] Ann Perreau,[b] and Richard S. Tyler[c]

Purpose: The Spatial Hearing Questionnaire (SHQ) was developed to address how to measure spatial-hearing ability in complex listening situations (Tyler, Perreau, & Ji, 2009). It has been translated and validated into various languages, including Chinese, Dutch, French, and Persian. Although the SHQ contains only 24 items, it could be time-consuming in a busy clinic to administer. The purposes of this study were to develop and validate a shortened version of the SHQ (SHQ-S) and to compare self-perceived spatial-hearing ability across adults with normal hearing (NH), hearing loss (HL), and cochlear implants (CIs).
Method: This was a retrospective study. The full version of the SHQ was administered to measure self-perceived spatial-hearing ability for 51 adults with NH at Augustana College, 47 adults with essentially mild to moderately severe sensorineural HL at Illinois State University, and 72 adult CI users at the University of Iowa. Exploratory factor analysis was performed for the full version for the data collected from adults with NH and HL. Appropriate items were chosen to develop the SHQ-S from the results of the exploratory factor analysis. Confirmatory factor analysis was then applied to test the factor structure of the SHQ-S for all participants. One-way analysis of variance was used to compare the self-perceived spatial-hearing performance scores between the 3 groups.
Results: The exploratory factor analysis revealed scores loaded on 2 factors. Six items from the full version were chosen accordingly. The results of the confirmatory factor analysis indicated that that a shortened version of 6 items is sufficient to measure spatial-hearing ability. The internal consistency reliability of the SHQ-S was high. The main effect of the one-way analysis of variance was significant for the groups, $F(2, 167) = 36.0$, $p < .0001$. The comparisons with the Tukey adjustment indicated that the NH group reported significantly better spatial-hearing ability than either the HL or the CI group (both adjusted p values < .05). There was no significant difference between the participants with HL and CI users.
Conclusions: The psychometric characteristics of the 6-item SHQ-S were similar to those of the full version of the SHQ. We conclude that the SHQ-S is a reliable and valid tool for measuring spatial-hearing ability and screening for spatial-hearing difficulties. Participants with NH reported better spatial-hearing ability than those with HL or with CIs, whereas the CI users and participants with HL perceived similar spatial-hearing ability in the present study.

Unlike the visual system, the auditory system is able to simultaneously recognize signals from all surrounding directions, which is important for survival and communication. This ability, termed *spatial hearing,* provides the listener with an awareness of sound in the environment, such as knowing the location of birds chirping or a car passing by while the listener is on a walk. In this way, spatial hearing, or sound localization, enables the listener to accurately locate a sound source in space and to more precisely perceive speech in more complex listening situations, such as conversation with multiple talkers (i.e., binaural squelch effects; Blauert, 1997). Related to spatial hearing is binaural hearing, which requires two ears to process important auditory cues and provides additional advantages over monaural hearing, including improved sound loudness and better sound quality (Zurek, 1993). Due to the impact of hearing loss (HL) in one or both ears, the spatial-hearing abilities of individuals with HL are often compromised, and the

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individuals are unable to make use of these binaural-hearing advantages.

A few questionnaires have been developed for the purpose of documenting subjective spatial-hearing ability, including the Speech, Spatial, and Qualities of Hearing Scale (SSQ; Gatehouse & Noble, 2004) and the Spatial Hearing Questionnaire (SHQ; Tyler, Perreau, & Ji, 2009). The SSQ has 49 items with three distinct subscales, or domains, to assess spatial hearing as well as speech perception and quality of hearing (e.g., sound clarity and listening effort). The SSQ can help assess binaural-hearing abilities and is sensitive to differences in binaural hearing among individuals with asymmetric and symmetric HL (Gatehouse & Noble, 2004), using unilateral and bilateral hearing aids (Noble, 2010; Noble & Gatehouse, 2006), and with unilateral and bilateral cochlear implants (CIs; Noble, 2010; Noble, Tyler, Dunn, & Bhullar, 2008). Related to CI use, in one study the SSQ was administered before and after implantation to 70 unilateral CI users, 36 bilateral CI users, and 39 bimodal users (Noble et al., 2008). Results indicated that for all users, self-rated spatial-hearing abilities were worse for more challenging tasks, including sound localization and distance and movement of sounds, than for easier listening tasks, such as speech perception in quiet. Comparing across groups, bilateral CI users had the highest subjective ratings of all participant groups, especially for items from the Spatial-hearing and Quality domains. Results from the unilateral CI users and bimodal users were relatively similar across subscales. Overall, this study suggests that the items from the Spatial-hearing domain of the SSQ were more sensitive to performance differences between groups with bilateral and unilateral implants than were the items from the Speech scale (Noble et al., 2008).

The SHQ was developed to specifically evaluate spatial-hearing abilities in individuals with HL and those using hearing aids and CIs (Tyler et al., 2009). This is a 24-item questionnaire that assesses self-rated hearing ability in different listening situations where listening with two ears is emphasized. The questionnaire items correspond to different types of meaningful sounds with different frequency content, including men's, women's, and children's voices. Scores can be obtained by calculating an average of all 24 items or by comparing responses across the eight subscales: Men's Voices, Women's Voices, Children's Voices, Music, Sound Localization, Understanding of Speech in Quiet, Understanding of Speech in Noise with Target and Noise Sources from the Front, and Understanding of Speech in Noise with Target and Noise Sources Spatially Separate. During the psychometric evaluation of the SHQ, it was found that the questionnaire is a reliable and valid measure of spatial hearing and can be completed by most individuals in about 10 min, making it a valuable tool for clinicians and researchers.

Perreau, Ou, Tyler, and Dunn (2014) investigated how self-reported spatial-hearing abilities differ across various CI profiles, along with the subjective benefit following implantation. The SHQ was administered before and after implantation to four different CI groups, including 99 unilateral CI users, 49 bilateral CI users, 32 bimodal users, and 37 unilateral users with a short-electrode CI. Results of this study showed that spatial-hearing ability was rated significantly higher for bilateral and short-electrode CI users. Comparing the subjective spatial-hearing ability of the unilateral and bimodal CI users, there was no significant difference. All users reported significant improvement in spatial-hearing ability following cochlear implantation, but the highest scores were found for the bilateral CI users. In sum, this study suggested that the SHQ is sensitive to substantial differences in spatial-hearing ability between unilateral and bimodal users when compared with users with bilateral and short-electrode CIs.

A Chinese version of the 24-item SHQ (C-SHQ) and the shortened 12-item version of the C-SHQ have both recently been validated with 91 individuals with HL and 55 with normal hearing (NH; Ou, Wen, Perreau, Kim, & Tyler, 2016). The severity of the HL across participants ranged from mild to severe in one or both ears. Exploratory factor analysis (EFA) and reliability tests were performed using the full version to identify items that should be retained in the shortened version of the SHQ. Items from the Speech-in-Quiet subscale were excluded in the short version because there were difficulties regarding a ceiling effect (scores were clustered toward 100%) along with problems related to low variance (4.6%), suggesting a weak relationship between this subscale and the construct of spatial hearing. A confirmatory factor analysis (CFA) was also performed using the shortened version of the C-SHQ to investigate the validity of the items. The number of subscales in the short version was reduced from eight to two: Speech and Music in Noise with Spatially Separate Noise Sources and Localization. The total scores of the shortened version of the C-SHQ (78.4%) and the full C-SHQ (80.6%) were similar. For the shortened C-SHQ, results revealed good internal consistency reliability (Cronbach's $\alpha = .98$). Overall, results of the shortened C-SHQ were comparable to those for the full C-SHQ, suggesting that the shortened version has good sensitivity to self-perceived localization ability and speech perception with spatially separate noise.

Here we propose a shortened version of the English version of the SHQ to be used for screening purposes or as a quick assessment of spatial-hearing ability in busy clinics. This screening tool would help to identify those individuals who are struggling in more complex everyday environments, such as restaurants, or when trying to locate their spouse at home. In this way, this clinical tool could be used to quickly assess overall self-reported ability related to spatial hearing. In addition, it could be used to track individuals' progress regarding spatial-hearing abilities with their CIs or hearing devices. However, to date the psychometric properties of the English shortened SHQ, such as reliability and validity, have not been assessed. The purposes of this study were to develop and validate a shortened version of the SHQ (SHQ-S) and to compare the self-perceived spatial-hearing ability across adults with NH, HL, and CIs using the SHQ-S.

Method

The SHQ

The original full version of SHQ has 24 items across eight subscales (Tyler et al., 2009). For all items, scores range from 0 (*very difficult*) to 100 (*very easy*).

Participants

The full version of the SHQ was administered to three separate groups in this study: 51 adults with NH at Augustana College, 47 adults with essentially mild to moderately severe sensorineural HL at Illinois State University, and 72 adult CI users (47.2% bilateral, 52.8% unilateral) before and after implantation at the University of Iowa.

Table 1 displays the demographic information for the NH, HL, and CI groups. Average air-conduction thresholds (with standard deviations) for the 47 HL participants are displayed in Figure 1. Due to differences in severity between the ears for the HL group, hearing symmetry was defined as an interaural difference of < 15 dB HL across the frequencies of 500, 1000, 2000, and 4000 Hz. Of the total 47 participants in the HL group, 33 (70.2%) were found to have symmetrical HL, and 34 (72.3%) were hearing-aid users. Of the total 34 hearing-aid users, 32 (94.1%) wore hearing aids in both ears. This project was approved by the local institutional review board at all three sites.

Procedure

Pure-tone air-conduction (octave frequencies of 250–8000 Hz) and bone-conduction (octave frequencies of 500–4000 Hz) audiometric testing was performed bilaterally for all participants in a sound-treated booth at Augustana College and Illinois State University, respectively. Following the hearing testing, the participants completed the full version of the SHQ. Those who wore hearing aids were asked to complete the SHQ in both unaided and aided conditions. Participants with CIs completed the full version of the SHQ at the University of Iowa after having used their devices for at least 12 months. The SHQ was routinely administered to the research participants in the CI group at the University of Iowa as part of an ongoing research protocol starting in the early 2000s. If multiple responses were gathered for a given participant, only the most recent data points were analyzed in this study. SHQ data from before CI implantation were gathered as well. Participants from all three groups completed the questionnaire using paper and pencil, and data were entered and stored in a database for later retrieval.

Table 1. Demographic information for the groups with normal hearing (NH), hearing loss (HL), and cochlear implants (CI).

Group	Value
NH (n = 51)[a]	
Men/women (%)	13.7/86.3
Age (years)	34.2 (14.2)
Education level (years)	15.4 (3.8)
HL (n = 47)	
Men/women (%)	48.9/51.1
Age (years)	57.8 (18.3)
Pure-tone average in the better ear (dB)	40.1 (18.9)
Hearing-aid users/bilateral hearing-aid users (%)	72.3/68.1
Symmetrical/asymmetrical HL (%)	70.2/29.8
Education level (years)	16.6 (3.0)
CI (n = 72)	
Men/women (%)	39.2/60.8
Age at implantation (years)	60.4 (14.2)
Length of auditory deprivation (years)	8.6 (8.9)
Length of device use (months)	46.8 (24.5)
Type of implant: Nucleus/Clarion (%)	48.6/51.4
Bilateral/unilateral use of the device (%)	47.2/52.8
Previous hearing-aid experience (years)	21.9 (14.3)
Education level (years)	14.2 (24.5)

Note. Numbers in the parentheses under the Value column indicate standard deviations.

[a]The details of the demographic information for the participants in the NH group can be found in Perreau, Spejcher, Ou, and Tyler (2014).

Data Analysis

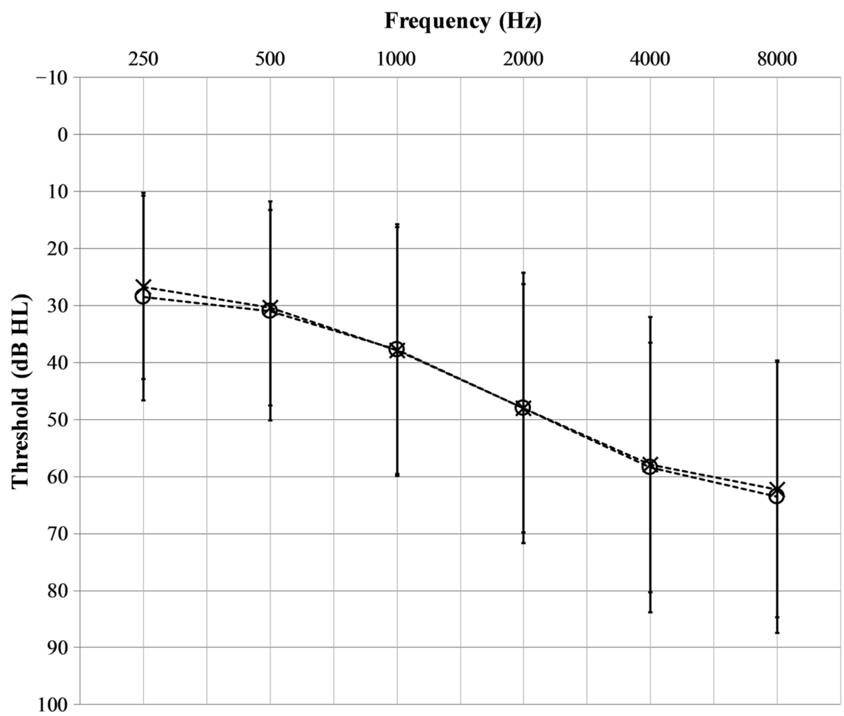
The questionnaire scores for the subscales and the total score were reported separately for all participants for the full version of the SHQ. The inventory responses of the full version for the NH and HL groups comprised the source data for the EFA. The unaided SHQ scores for those hearing-aid users were applied for the purpose of the factor analysis. It is a method to identify the latent structure of a set of variables. The primary model was established from the EFA results. Arbitrary but conventional thresholds of 0.40 for the factor loadings and 1.0 for eigenvalues were applied in interpreting and labeling the factors. The eigenvalue for a given factor measures the variance in all the variables that is accounted for by that factor. A varimax rotation was then used, after the initial factoring method of principal component analysis. This rotation method assumes factors to be uncorrelated. The Kaiser–Meyer–Olkin measure of sampling adequacy was performed first to determine if the EFA was appropriate for the data. Appropriate items were chosen to develop the SHQ-S from the EFA results. CFA was then applied to test the factor structure of the SHQ-S from the NH, HL, and CI groups. The Cronbach's alpha and item-total correlation coefficients were used to assess internal reliability for the SHQ-S. The sensitivity (i.e., construct validity) was assessed between individuals with symmetrical and asymmetrical HL. One-way analysis of variance was used to compare the self-perceived spatial-hearing performance score between the three groups.

For all tests, statistical significance was defined as $p < .05$. Data were analyzed using SAS (Version 9.4).

Results

The average total SHQ score was 86.8% (SD = 8.9%) for the participants with NH, 58.0% (SD = 23.3%) for the participants with HL, and 58.8% (SD = 21.6%) for the participants with CIs. The average SHQ item scores and

Figure 1. Mean thresholds for the left (X) and right (O) ears for the group of participants with hearing loss. The error bars show 1 *SD*.



subscale scores for each group are displayed in Table 2. Subscale 6 (Speech in Quiet) received the highest scores across the three groups. The subscale scores across groups indicated that both the NH and CI groups had the lowest ratings on Subscale 5 (Localization), whereas the HL group had the lowest score on Subscale 8 (Speech in Noise–Separate). The average item scores ranged from 76.7% (*SD* = 19.3%) to 98.8% (*SD* = 1.6%) for the NH group, 44.9% (*SD* = 25.5%) to 77.3% (*SD* = 26.0%) for the HL group, and 47.9% (*SD* = 28.3%) to 90.9% (*SD* = 10.0%) for the CI group.

EFA

The EFA was administered on the basis of the principal component analysis for the NH and HL data. The overall Kaiser–Meyer–Olkin score was .92, which suggested that the factor analysis was appropriate to conduct using the current data set. A scree plot (i.e., a simple line-segment plot to show the eigenvalues and the associated number of factors) was used to determine the number of factors for the study. Two factors (eigenvalue > 1.0) were extracted, accounting for 91.5% of the variance from the factor analysis. Factor 1 (eigenvalue = 17.8) is referred to as Source Localization, including items 13–24. This factor accounted for 78.0% of the variance. Factor 2 (eigenvalue = 3.1; 13.5% of variance), referred to as Speech and Music Perception, encompassed 12 items (1–12). This factor is related to how well listeners are able to listen in quiet and to parse out speech and music when background noise is present and spatially separated from the signal. Table 3 displays the rotated loadings of each item for the two factors of Source Localization and Speech and Music Perception.

Creation of the SHQ-S

To create the short questionnaire, items in each subscale (except for Subscale 6, Speech in Quiet) with the highest loading (i.e., items 6, 9, 13, 14, 16, and 19) were chosen. All loadings were equal to or greater than .88. Similar to what was done by Ou et al. (2016), the items relating to the sixth subscale (1 – 4) were removed from the short version of the SHQ due to the ceiling effects and the low percentage of variance that was accounted for in these items.

CFA for the SHQ-S

A CFA was performed to investigate the validity of the short version for all the participants (*N* = 170). The number of subscales in the short version was reduced from the original eight to two. Because the short version is intended to be used as a screening tool, it is logical to keep it brief. In the current analysis of the short version, the subjects-to-variables ratio was 28:1 (170 subjects/6 items = 28.3), which indicates that the data were appropriate for the factor analysis. We expected a relationship between the observed variables and the underlying two latent constructs on the basis of the previous EFA. That is, we hypothesized that items 6 and 9 would be loaded

Table 2. Mean and standard deviation for Spatial Hearing Questionnaire item, subscale, and total scores for participants with normal hearing (NH), hearing loss (HL), and cochlear implants (CI).

Item	NH (*n* = 51)		HL (*n* = 47)		CI (*n* = 72)	
	M	*SD*	*M*	*SD*	*M*	*SD*
1. Man's voice in quiet	98.8	1.6	77.3	26.0	90.9	10.0
2. Woman's voice in quiet	98.7	1.9	72.7	26.8	89.7	11.5
3. Child's voice in quiet	97.1	3.9	65.6	27.3	73.9	22.4
4. Music in quiet	98.4	2.6	76.2	24.1	69.5	29.3
5. Man in front, noise behind	86.8	10.4	54.0	23.3	63.8	24.0
6. Woman in front, noise behind	86.5	10.5	50.4	23.8	61.4	24.8
7. Child in front, noise behind	82.9	13.0	46.2	25.8	50.3	27.2
8. Music and noise in front	82.9	13.4	54.1	25.5	47.9	28.3
9. Man in front, noise to side	87.1	10.6	55.7	24.5	61.8	24.4
10. Woman in front, noise to side	86.8	10.3	51.2	23.6	60.3	24.7
11. Child in front, noise to side	83.4	12.7	44.9	25.5	48.2	27.9
12. Music in front, noise to side	85.1	10.9	52.0	25.3	49.6	27.9
13. Location of man's voice	86.7	12.3	58.9	31.7	57.9	29.0
14. Location of woman's voice	86.9	11.9	58.4	32.1	55.4	28.7
15. Location of child's voice	85.0	13.2	55.7	32.4	47.8	29.5
16. Location of music	85.1	13.5	59.8	32.8	53.3	29.0
17. Location of man's voice, behind	88.2	13.0	59.0	30.0	58.0	28.6
18. Location of woman's voice, behind	88.2	12.8	58.0	30.7	56.2	28.4
19. Location of child's voice, behind	86.6	13.9	54.5	30.5	49.2	29.5
20. Location of music, behind	87.0	13.5	58.5	31.4	50.4	28.3
21. Location of airplane	77.5	16.8	54.7	31.3	51.1	28.1
22. Direction of car	76.7	19.3	55.0	31.8	52.1	29.0
23. Movement of car	83.3	18.0	62.2	32.2	58.8	30.4
24. Distance of sound source	78.1	19.8	57.8	32.0	53.8	27.3
Subscale 1: Men's Voices	89.5	7.3	61.0	22.7	66.5	19.5
Subscale 2: Women's Voices	89.4	7.1	58.1	22.8	64.6	20.0
Subscale 3: Children's Voices	87.0	9.2	53.4	23.4	53.9	24.3
Subscale 4: Music	87.7	8.8	60.1	23.2	54.2	25.0
Subscale 5: Localization	84.1	13.2	57.7	30.1	53.7	26.6
Subscale 6: Speech in Quiet	98.3	1.8	72.9	24.8	81.0	14.8
Subscale 7: Speech in Noise–Behind	84.8	11.0	51.2	22.8	55.8	23.8
Subscale 8: Speech in Noise–Separate	85.6	10.7	50.9	23.1	55.0	24.1
Total	86.8	8.9	58.0	23.3	58.8	21.6

Note. Each short description for the subscale name was from Ou et al. (2016).

on one factor, Speech in Noise–Separate, and items 13, 14, 16, and 19 would be loaded on the other factor, Source Localization.

Figure 2 shows the CFA results, including the loading of each item on the factors, the correlation between Factor 1 (items 6 and 9) and Factor 2 (items 13, 14, 16, and 19), and the model-fit parameters. All of the loadings were greater than .85. The correlations were moderately high between the two factors (r = .66). Although there are no universally accepted criteria for judging model fit, Thompson (2004) recommended acceptable thresholds of fit for models with comparative fit index and Tucker–Lewis index values greater than .95. Acceptable thresholds of fit are expected to be less than .05 for the standardized root-mean-square residual and .06 for the root-mean-square error of approximation. These results suggest that three out of four criteria were met for the factor analysis, which provides an acceptable fit to the data. The r^2 value or percent of variance for each item was also determined; the range was from .85 to .99. Two items had $r^2 \geq .95$. The results suggest that the variation in items 13 (location of man's voice; r^2 = .96) and 14 (location of woman's voice; r^2 = .99) can be explained the most by the factor analysis.

Comparisons Across Groups

Although a small but statistically significant difference was found between the total average score of the short version and that of the full version of the SHQ across groups (mean difference = −1.6%, SD = 4.5%), $t(169) = -4.5$, $p < .0001$, it was essentially the same from a clinical point of view. Figure 3 displays the average item scores and total scores with standard errors for the SHQ-S across groups. The average self-perceived spatial-hearing performance was 86.5% (SD = 9.8%) for the NH group, 56.3% (SD = 25.3%) for the HL group, and 56.5 % (SD = 23.9%) for the CI group. The main effect of the one-way analysis of variance was significant for the groups, $F(2, 167) = 36.0$, $p < .0001$. The comparisons with the Tukey adjustment indicate that the NH group reported significantly better spatial-hearing ability than either the HL or the CI group (both adjusted p values < .05). There was no significant difference between the HL and CI groups. In addition, the results suggest that

Table 3. The factor loadings of the each of 24 items for the participants with normal hearing (n = 51) and hearing loss (n = 47).

Item	Factor 1	Factor 2
1. Man's voice in quiet	.32	**.81**
2. Woman's voice in quiet	.28	**.86**
3. Child's voice in quiet	.34	**.85**
4. Music in quiet	.28	**.81**
5. Man in front, noise behind	.38	**.87**
6. Woman in front, noise behind	.34	**.90**
7. Child in front, noise behind	.33	**.84**
8. Music and noise in front	.35	**.83**
9. Man in front, noise to side	.32	**.88**
10. Woman in front, noise to side	.38	**.87**
11. Child in front, noise to side	.42	**.84**
12. Music in front, noise to side	.46	**.81**
13. Location of man's voice	**.91**	.34
14. Location of woman's voice	**.90**	.36
15. Location of child's voice	**.88**	.36
16. Location of music	**.91**	.34
17. Location of man's voice, behind	**.88**	.39
18. Location of woman's voice, behind	**.89**	.41
19. Location of child's voice, behind	**.88**	.40
20. Location of music, behind	**.89**	.40
21. Location of airplane	**.78**	.40
22. Direction of car	**.87**	.34
23. Movement of car	**.89**	.27
24. Distance of sound source	**.87**	.32

Note. The short explanation for each question was from Perreau, Spejcher, et al. (2014). Boldface indicates the items that are included for that factor. Rotation method = varimax.

the use of hearing aids or CIs improved self-perceived spatial-hearing ability (both p values < .0001).

Reliability

In assessing reliability for the six-item SHQ-S, the results revealed a high Cronbach's alpha (.95), which indicates good internal consistency reliability. The item-total correlation ranged from .70 to .93. Cronbach's alpha was computed for the two factors, and the following results were obtained: Factor 1, α = .98; Factor 2, α = .90.

Sensitivity

The participants with symmetrical HL in the HL group reported better overall spatial-hearing ability (M = 82.5%, SD = 18.5%) than those with asymmetrical HL (M = 70.0%, SD = 26.3%). The results from a two-tailed independent-samples t test revealed a significant difference between these two subgroups of participants, $t(43.7)$ = 2.34, p = .02. The results were similar to those of the full version of questionnaire. Furthermore, self-reported performance was worse for the asymmetrical HL group than for the symmetrical HL group for both subscales.

Discussion

This study aimed to develop and validate a shortened version of the SHQ (SHQ-S) and to compare self-perceived

Figure 2. Confirmatory factor analysis results for the short version of Spatial Hearing Questionnaire (SHQ-S) for all participants. The loading for each item is shown above the horizontal arrow on the left side. The correlation coefficient between two factors is shown beside the vertical arrow between the factors. CFI = comparative fit index; TLI = Tucker–Lewis index; RMSEA = root-mean-square error of approximation; SRMR = standardized root-mean-square residual. The recommended threshold for each parameter is as follows: CFI > .95; TLI > .95; RMSEA < .06; SRMR < .05. "Q" in the figure represents the item number in the SHQ inventory.

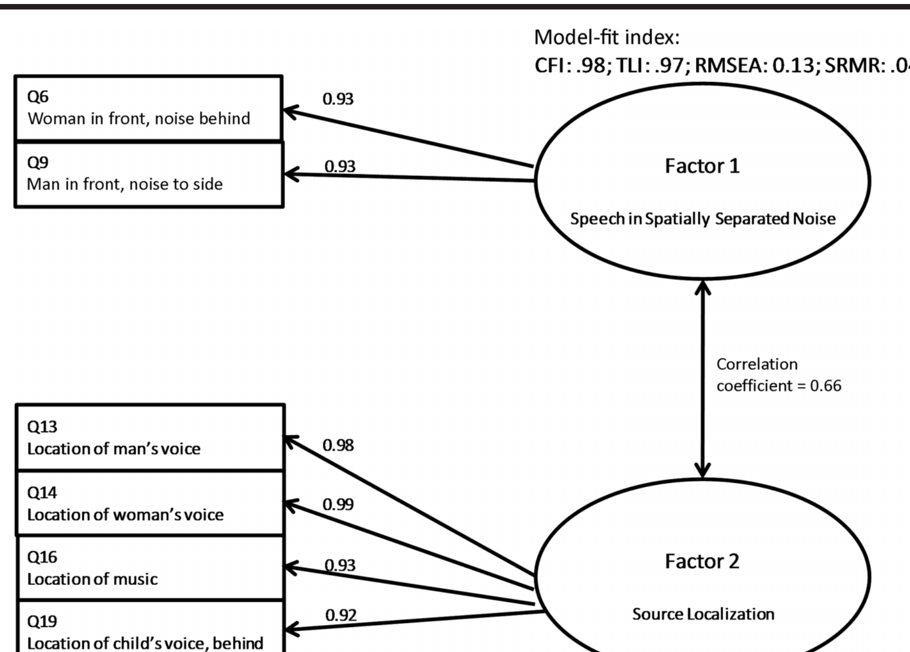
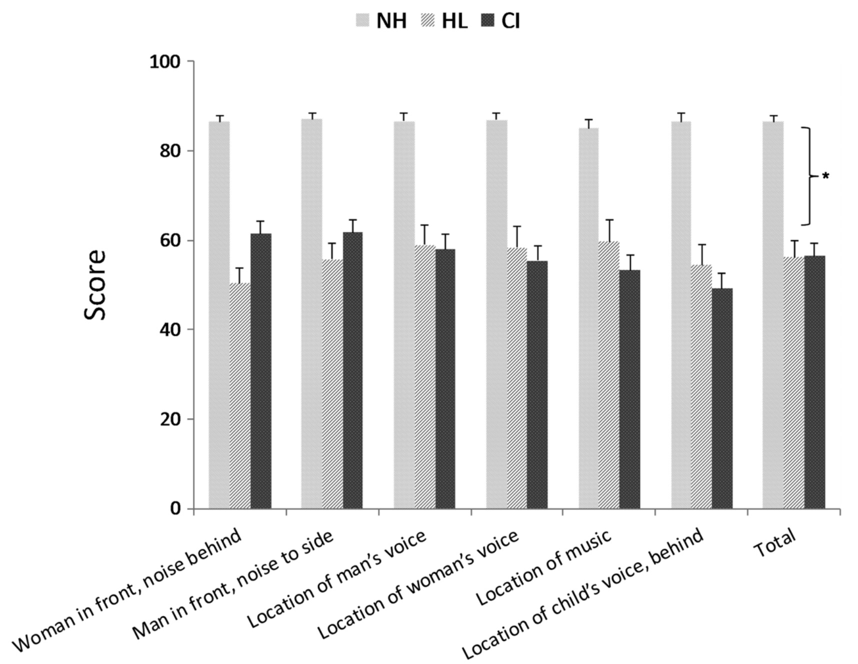


Figure 3. Average item scores and total scores (range = 0–100) of the shortened version of the Spatial Hearing Questionnaire for the participants with normal hearing (NH; *n* = 51), hearing loss (HL; *n* = 47), and cochlear implants (CI; *n* = 72). Error bars represent standard errors. Higher scores indicate better self-reported spatial-hearing abilities. *$p < .05$.



spatial-hearing ability across adults with NH, HL, and CIs using the SHQ-S. The factor structure of the SHQ-S in the present study was comparable to that of the full version of the SHQ. There are six items in the SHQ-S and two subscales in total. The internal consistency reliability was high. Further, the SHQ-S was found to be sensitive to differences in HL symmetry: Participants with symmetrical HL reported higher self-rated spatial-hearing ability than those with asymmetrical HL. Taken together, the SHQ-S is a reliable and valid inventory.

Comparing between the full and short versions of the SHQ, the results indicate that the total scores were comparable. The average difference was less than 2% across participant groups. The results from the CFA revealed two underlying constructs that are suitable to measure spatial-hearing abilities. That is, the short version of the questionnaire can quickly assess self-perceived localization ability and the ability to listen in spatially separated noise. Because the current SHQ-S data were extracted from the full version of the SHQ, future research should investigate the SHQ-S directly administered to a different group of listeners to observe for similar psychometric strength. It should be noted that the short version of the SHQ is different in structure from the shortened C-SHQ. The SHQ-S has six items, whereas the short version of the C-SHQ has 12. Four items overlap between these two versions (6, 9, 14, and 16). It is possible that the two studies involved participants with different characteristics to develop the shortened version of the SHQ. The participants with HL in the study by Ou et al. (2016) were the data source for the EFA, and they had never used hearing aids before. In the present study, we involved participants with both NH and HL. The majority were hearing-aid users, although only unaided data were used for the EFA. The reason for only using unaided data was that we intended to create a homogenous HL group. However, a limitation is that the hearing-aid users might have potential recall bias for the unaided condition. Due to potential language or cultural differences between the C-SHQ and English version of the SHQ, the loading of an individual item can be different on each factor. Another thought was that the difference in number of items between the two short versions might simply reflect the different sample sizes being used in the two studies. However, the subjects-to-variables ratios were high in both studies (12:1 for Ou et al., 2016, vs. 28:1 in the present study); different sample sizes should not significantly affect the results. In other words, the six-item shortened English version of the SHQ should be adequate to screen spatial-hearing difficulty.

Comparing across listeners across the NH, HL, and CI groups, we found, as expected, that listeners with NH rated higher spatial-hearing ability than those with HL or CIs. Although self-reported spatial-hearing ability was similar between participants in the HL and CI groups in the present study, the areas of difficulty were reportedly different across groups. To be specific, it appeared that the HL group reported the lowest scores when listening to speech in spatially separated noise (woman in front, noise behind, and man in front, noise to side), whereas the CI group reported the greatest difficulty in sound-source localization (location of man's voice, location of woman's voice, location of music, and location of child's voice, behind). We were able to differentiate different profiles for adults with NH, HL, and CIs by using the SHQ-S.

In conclusion, the SHQ-S shares similar psychometric characteristics with the original full version of the SHQ. It is a reliable and valid instrument, suitable for measuring spatial-hearing abilities related to sound localization and speech-in-noise perception as a screening tool in a busy clinic.

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