Auditory and Vestibular Research

A Persian cross-cultural validation and adaptation of the Hearing Implant Sound Quality Index Questionnaire for cochlear implant adult users

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Highlights
- The Persian version of HISQUI19 (P-HISQUI19) is a valid and reliable measure
- The P-HISQUI19 is useful for assessing the sound quality of implanted patients
- The effect of age at surgery and duration of deafness on sound quality is negligible

Abstract
Background and Aim: Cochlear implants (CIs) successfully improve speech and auditory skills for patients with a severe-to-profound degree of hearing loss. The psychometric properties of the Hearing Implant Sound Quality Index Persian version (P-HISQUI19) were examined to measure auditory benefits in CI recipients in everyday life.
Methods: Seventy post-lingual CI users, aged 18-64 years, completed the P-HISQUI19. Cross-cultural adaptation of the P-HISQUI19 was performed. Internal consistency and test–retest reliability were measured by Cronbach's α and intra-class correlation coefficients. The content and construct validity of the questionnaire were also examined.
Results: The P-HISQUI19 average total score in implanted cases was 78.22, representing a moderate sound quality. The P-HISQUI19 indicated excellent internal consistency reliability (Guttman's split-half-coefficient = 0.912; Cronbach's α =0.956) and test–retest reliability (r = 0.962). Our data proceeded to factor analysis, and the questionnaire items were loaded on three factors. In addition, factors such as age at implantation, duration of deafness, side of implantation, and gender factors did not significantly affect sound quality perception.
Conclusion: The P-HISQUI19 is a valid and reliable measure, which should be beneficial in both research and clinical settings for evaluating the auditory benefits of those using CI during listening.
Keywords: Adult, cochlear implant, Persian, Sound quality

INTRODUCTION
Cochlear implants (CIs) have successfully provided access to auditory information for patients with severe-to-profound degree of hearing loss [1]. CI recipients usually experience improved speech production and speech comprehension abilities [2,3]. Despite recent advances in CI technology, there are still major perceptual limitations. Some of these constraints affecting the daily life of CI users include the use of the telephone, auditory discrimination in noisy contexts, sound localization, and music perception [4,5]. Another important limiting perceptual construct in implanted patients is the sound quality, that is, the perceived richness of an auditory stimulus [4].

It has been shown that CI users may experience some restrictions in their ability to detect sound quality degradations due to limited high-bandpass filtering and low-bandpass filtering, reduced fine-structure processing, and increased reverberation [6]. In addition to technical limitations, structural changes in central auditory pathways due to auditory deprivation may also lead to various auditory system dysfunctions that could affect the device's performance.

Currently, sound quality assessment in the CI recipients is largely carried out using self-reported questionnaires that require the individual to rate the sound pleasantness or likeability in a wide-ranging listening situation. These instruments can provide insights into CI-mediated sound perception in real-life situations and environments. It seems that the individual's rated likability of sounds is greatly affected by factors, like the listening situation (room acoustics), the complexity of the stimulus, and the listener's individual characteristics (musical training, and familiarity with the musical piece) [7].

The Hearing Implant Sound Quality Index (HISQUI$_{19}$) as a quantitative self-assessment instrument, was designed specifically for adults with CI. It determines the levels of auditory benefits for implanted patients in everyday listening situations [8-10]. The HISQUI$_{19}$ examines various aspects of sound quality in CI recipients, such as sound localization, music identification, speech perception in competing situations, and differentiation between different talkers [11]. The original HISQUI$_{19}$ questionnaire was developed and validated by Amann and Anderson [10] and has been validated in several languages, including Spanish [9], Dutch [8], and Turkish [12]. There is a paucity of data to correctly evaluate sound quality in cochlear implanted adults, and no standard tool has been developed to understand the subjective experiences of Persian-speaking CI users. Therefore, the study objectives were 1) to assess the reliability and validity of the Persian HISQUI$_{19}$ (P-HISQUI$_{19}$) as a quantifiable self-assessment sound quality scale in Persian adult CI users, and 2) to investigate the association of subjective auditory benefits with the demographic and clinical characteristics of the adult CI users.

METHODS

Participants

The present study included 70 postlingually deafened CI users (mean age: 33.87 ± 11.49 years; age range: 18–64 years). All patients were recruited from the three CI centers between 2019 and 2022. All collaborating centers were affiliated with a public hospital. All cases met our inclusion criteria: (1) being native in the Persian language, (2) suffering from bilateral severe to profound sensorineural hearing loss, (3) at least 6 months of CI use, (4) regularly attending postsurgery mapping and auditory verbal therapy (AVT) rehabilitation sessions (at least 100 sessions), (5) keeping the complete insertion of the CI electrodes confirmed by postoperative computed tomography (CT) scan, and (6) having normal cochlear anatomy confirmed by postoperative CT scan. On the other hand, the participants were excluded if they had a psychological or a neurological disorder, as determined by an experienced neuropsychologist. All subjects were provided with a unilateral multi-channel MED‐EL implant system (CONCERTO Mi1000 or SONATA Ti100 audio processors, MED‐EL, Austria).

Data collection instrument

The HISQUI$_{19}$ consists of 19 questions with a seven-point Likert scale, where 1 represents the situation is never attainable and 7 represents the situation is always attainable [10]. If a specific statement/ situation is inapplicable, the subject is requested to choose the ''N/A = not applicable'' option, and the item is considered a missing value [11]. The total scores of HISQUI$_{19}$ range from 19 to 133. According to the total score, the auditory benefit can be classified into five categories as very poor (<30 points), poor (30–59 points), moderate (60–89 points), good (90–109 points), and very good (110–133 points). The HISQUI$_{19}$ is easy to score and takes about 10 minutes to complete.

Development of the Persian Hearing Implant Sound Quality Index

The P-HISQUI$_{19}$ was developed, based on the general rules and guidelines of the International Quality of Life Assessment (IQOLA) for cross-cultural translation [13]. First, two native Persian speakers with advanced English language skills independently translated the original questionnaire into Persian, but without any prior knowledge of the HISQUI$_{19}$. Only minor disagreements were found in the translation of the HISQUI$_{19}$ items among the two translators. Then, in a reconciliation meeting with the investigators, the translators approved the common preliminary translated version of HISQUI$_{19}$. Afterward, a native American–English speaker (translator 3) performed the back-translation of the preliminary translated Persian version into English. Then, the backward-translated scale was sent to the main authors of $HISQUI_{19}$ to compare the back-translated scale equivalence with the main one. Moreover, a pilot study was carried out as the pre-final test with 10 CI users (5 males and 5 females), who were asked to complete the P-$HISQUI_{19}$ to find any difficult or confusing items. We used a 1-to-4 rating scale to assess the clarity, relevance, and simplicity of each item.

Data analysis

The Kolmogorov–Smirnov test assessed the numerical data normal distribution. Test–retest reliability (reproducibility) was calculated by a two-way random-effects model of intra-class correlation coefficient (ICC) with a 95% confidence interval. The Cronbach's α coefficient was utilized to measure internal consistency. An exploratory factor analysis assessed construct validity. The content validity ratio (CVR) and content validity index (CVI) were assessed for the content validity analysis. The relationship between the total score of P-$HISQUI_{19}$, age at implantation and duration of deafness was measured by Spearman's rho correlation coefficient. In addition, the effects of side of implantation and gender factors on sound quality perception were measured by Mann–Whitney U test. The significance level of $P < 0.05$ was used for data analysis.

Reliability

For reliability estimations, 30 individuals were asked to complete the P-$HISQUI_{19}$ questionnaire, and after a 2-week interval, the data were collected again. Test–retest reliability was evaluated using the ICC method; it was considered acceptable if the ICC value was equal to or greater than 0.70. Furthermore, to determine the internal consistency reliability and the degree of homogeneity between the P-$HISQUI_{19}$ items, the Cronbach's α coefficient and its confidence intervals were measured. The internal consistency was considered satisfactory at 0.7–0.95 level.

Content validity

The questionnaire's final translated version was distributed among 10 experts in the field of cochlear implants (five audiologists, and five speech-language pathologists) in order to validate its content. The consensus among the specialists regarding the necessity of a particular item in the questionnaire was determined using CVR. The CVR was determined according to Lawshe's equation: CVR = ([ne - (N/2)]/(N/2), in which "N" is the number of panelists and "ne" represents the number of panelists indicating an item [14]. The CVI was calculated according to the expert's opinions in terms of relevance, simplicity, and clarity on a 4-point Likert scale (4 = very important, 3 = relevant, 2 = not important, and 1 = not relevant). To measure the CVI for each item (I-CVI), the proportion of experts giving a relevance rating of three or four to the total number of experts was calculated. To calculate the scale-level CVI (S-CVI), the I-CVI score average was determined for all items. The content validity indices were acceptable if S-CVI and I-CVI were, respectively, at least 0.90 and 0.79. The ceiling and floor effects, which exhibit the percentage of subjects receiving the highest and lowest total scores of the P-$HISQUI_{19}$ questionnaire, respectively, were also calculated for assessing the content validity; and values more than 15% were regarded as significant.

Construct validity

In this study, the construct validity was examined by conducting a factor analysis with rotated orthogonal factor analysis. To make sure that factor analysis is a suitable procedure for our data set, the correlation matrix sphericity and sampling adequacy were evaluated by, respectively, the Keiser–Meyer–Olkin (KMO) and Bartlett's tests. The former assesses the magnitude of the squared correlations between variables associated with the squared partial correlation between them with values ranging between 0 and 1. Overall, the KMO value is classified as follows: 0–0.49, unacceptable; 0.50–0.69, mediocre; 0.70–0.79, good; 0.80–0.89, great; and ≥0.9, superb. Bartlett's test measures the null hypothesis that the variables only correlate with themselves.

RESULTS

The CI recipients' demographic and clinical information are indicated in Table 1. The mean age at cochlear implantation was 33.87 years (24-70 years). The mean length of deafness before CI surgery was 6.5 years (1–15 years). The CI surgery was conducted at the right ear in 64.3% (n = 45) of the participants.

Reliability

The P-HISQUI 19 questionnaire showed high internal consistency and good reliability (Guttman's split-half-coefficient = 0.912; Cronbach's α = 0.956) [Table 2]. The overall test–retest reliability was also high and significant ($r = 0.962$, $P < 0.001$).

Content validity

The CVR values for all P-HISQUI$_{19}$ items were ≥0.8 (Table 3). Our findings revealed that all questions had I-CVI values >0.79 in terms of clarity, relevance, and simplicity. The S-CVI for the total P-HISQUI$_{19}$ was equal to 0.96. According to our results, all P-HISQUI19 items had satisfactory content validity. Our findings also indicated that none of the implanted adults obtained the floor effect/worst score (19) or the ceiling effect/best score (133). Therefore, the questionnaire did not show a floor or ceiling effect and was utilized as a valid measurement tool for outcomes reported by the patient.

Construct validity

Table 4 provides the construct validity assessment results. The KMO value of sampling adequacy was 0.89, showing that the calculated sample size was appropriate for factor analysis. The result of Bartlett's test was also statistically significant ($\chi 2 = 1254.43$, df = 171, $P < 0.001$). Therefore, factor analysis was suitable for the data, and the variables were correlated and consequently appropriate for structure detection. Based on factor analysis, the items of the scale were loaded on three factors. The categories of "understanding speech in public situations," "watching TV or listening to the radio," and "participating in conversation" categories loaded on the first factor. The "sound localization" category, in addition to item 3 and item 14 (that are related to sound discrimination skills) loaded on the second factor. The categories of "distinguishing between different voices/speakers," and "talking on the phone" loaded on the third factor. Except for item 4 and item 6, all P-HISQUI19 items were loaded on a similar factor with their group. The three factors could explain 73.85% of the total variance.

Total score calculation

. The mean P-HISQUI$_{19}$ total score was 78.2 ± 21.7, indicating a moderate subjective auditory benefit in the patient's daily listening condition (Table 5). According to the global rating scale, of 70 patients, 13 subjects (18.58%) reported poor auditory benefits (30–59 points), and 35 subjects (50.0%) reported "moderate" auditory benefits (60–89 points). Furthermore, 18 patients (25.71%) showed good auditory benefits (90–109 points), and 4 patients (5.71%) showed very good auditory benefits (110–133 points). However, none of the patients indicated very poor auditory benefit (lower than 30 points).

Spearman's rho test results did not show a significant correlation between the P-HISQUI19 total score and age at implantation (r = -0.164, P=0.893). Furthermore, the total score of P-HISQUI$_{19}$ and the duration of deafness showed no significant correlation (r = 0.263, P = 0.561).

Our findings demonstrated that patients <40 years at CI surgery had slightly, but not significantly, better P-HISQUI$_{19}$ total scores (average score: 79.23 ± 22.56) than those > 40 years at surgery (average score: 75.85 ± 19.01) (Mann–Whitney U test, P = 0.491). Furthermore, the difference in sound quality perception between individuals who had a shorter length of deafness (≤20 years, average score: 79.36 ± 21.30) and with a longer deafness length (>20 years, average score: 72.66 ± 22.38) was not significant (Mann–Whitney U test, P = 0.494). In our study, the comparison of the mean P-HISQUI$_{19}$ scores between the females and males was not significant (Mann– Whitney U test, P = 0.51).

The self-perceived auditory benefits between MED-EL CONCERTO Mi1000 and SONATA Ti100 users indicated no significant difference (Mann–Whitney U test, U = 95, P = 0.632; d = 0.27). Our analyses also showed that the side of implantation did not affect the patient-reported level of sound quality (Mann–Whitney U test, P = 0.375).

DISCUSSION

Standardized self-rating measures are very common clinical tools to diagnose or discriminate against patients and help to quantify patients' deterioration or improvement over time. In the current study, the psychometric properties of the P-HISQUI$_{19}$ and the impacts of demographic parameters were evaluated among adult cochlear implanted users. Our results demonstrated that the P-HISQUI$_{19}$ has acceptable reliability and validity.

Reliability is an important psychometric property of outcome measures that assists the medical team to make decisions regarding measures providing the highest level of measurement consistency. The presence of internal

consistency (Cronbach's α = 0.96) and acceptable test–retest reliability (ICC = 0.91) of P-HISQUI$_{19}$ in the present study confirm similar research performed in German[10] (Cronbach's α = 0.95, ICC = 0.94), Spanish[9] (Cronbach's α = 0.93, ICC = 0.91), Dutch[8] (Cronbach's α = 0.93), and Turkish[12] (Cronbach's α = 0.94, ICC = 0.91) languages. In addition, a high degree of internal consistency reveals that the P-HISQUI19 is a reliable tool to determine the benefit of cochlear implantation.
Validity is also an important psychometric property of a scientific test tool. It refers to the degree of accuracy and effectiveness of a scale, that is, the degree to which it can precisely measure what it is intended to measure. The presented study demonstrated that P-HISQUI19 has excellent content and construct validity to evaluate Persian-speaking CI recipients' sound quality in common everyday listening conditions. In this regard, Amann and Anderson,[10] and Calvino *et al*.[9] also indicated that HISQUI$_{19}$ is a valid tool to represent the everyday listening challenges of adult CI recipients in German and Spanish languages, respectively. Similar to the original version of HISQUI$_{19}$ [10] no ceiling or floor effects were found for the P-HISQUI$_{19}$. Therefore, it is applicable as a valid measurement tool for outcomes reported by the patient.
The mean total score of P-HISQUI$_{19}$ was 78.2, which corresponds to overall moderate self-perceived sound quality. Our result is rather similar to the Calvino *et al*.'s [9] study that reported a mean total score of 79.9 points. However, Amann and Anderson [10] (mean score: 75.7 points) and Mertens *et al*. [8] (mean score: 64.9 points) reported a smaller total score of the HISQUI19 for the implanted adults in their daily life. It is noteworthy that although CI devices can improve sound quality in hearing-impaired patients, the sound quality in implanted users is poorer than in normal-hearing individuals due to the degradation of multiple auditory fine structures.[4]
Despite technological advances in surgical methods, sound processors, electrode designs, and programming approaches, the ability to perceive speech and music sounds remains limited for many CI users. It seems that the spectral (frequency) aspect of sound is highly influenced by electrical stimulation in CI users. Frequency resolution is important for the perception of complex types of acoustical stimuli such as music or speech prosody. Restrictions in CI-mediated frequency perception could be manifested as reduced pitch change direction detection, decreased harmony/timbre perception, and reduced perception of cues and pitch-driven voice emotion [15-17]. This degraded pitch quality may seriously affect the sound quality and speech intelligibility of CI users in everyday listening situations.
Roy et al. [18] indicated that CI users (average age: 51.8 years, n = 11) exhibited more difficulties than listeners with normal hearing ability (average age: 30.5 years, n = 10) in recognizing sound quality differences among high pass filter (HPF) musical stimuli with cutoff frequencies of 200 Hz to 1000 Hz. Their results demonstrated that implanted patients were not able to recognize sound quality differences among musical stimuli missing up to 400 Hz of bass frequency information. The decreased ability of CI recipients to detect variations in sound quality among low-frequency HPF cutoff frequencies (200 Hz and 400 Hz) represents the deterioration of bass frequency perception that contributes to reduced sound quality perception while listening to a piece of music. Information with low frequency is especially crucial in the processing of complex sounds, like music. Caldwell et al. [4] suggested that presenting low-frequency stimuli to users of CI is possibly an effective procedure to enhance sound quality. This improvement in low-frequency perception could be achieved through deeper electrode insertion, electric-acoustic stimulation of low-frequency areas, or bass-enhancing modified processing strategies.
Our results also indicated that younger adults had greater subjective functioning, although no significant difference was detected in the P-HISQUI$_{19}$ scores of adults younger than 40 years at the time of CI surgery and those older than 40 years at CI surgery. This finding supports previous results regarding the validation of Spanish [9] and German-HISQUI$_{19}$ [10]. Contrary to our findings, Mertens et al. [8] demonstrated that the age of the implantation is moderately correlated with the mean HISQUI$_{19}$ score. We also found that patients with shorter length of hearing loss reported slightly but not significantly better hearing benefits in daily life compared to patients with longer length of hearing loss. Amann and Anderson [10] and Calvino *et al*. [9] reported that length of hearing impairment has no significant impact on the self-perceived auditory benefits in daily life.
Gender had no effect on the sound quality, which confirms the results of Caporali et al. [11], Amann and Anderson [10], and Calvino et al. [9] All subjects who participated in this study were provided with a multi-channel MED-EL system. However, Caporali et al. [11] indicated that the type of CI prosthesis had no significant effect on the sound quality experienced by the CI users.
According to our results, the implantation side showed no significant influence on the self-perceived auditory benefits. This finding is in line with the results reported by Amann and Anderson [10] and Calvino et al. [9] who

also indicated that the side of implantation in post-lingual adult users did not affect the sound quality. Furthermore, our findings suggested that the type of audio processor (CONCERTO Mi1000 vs. SONATA Ti100) did not influence sound quality. Caporali et al. [11] also showed that the type of CI prosthesis (MED-EL, Advanced Bionics, or Cochlear) has no statistically significant impact on sound quality experienced by the CI users.

The present study has its own limitations, including 1) since study participation was contingent on returning their $HISQUI_{19}$ questionnaire, a self-selection bias might be observed. Patients who are satisfied with the benefit of their devices are often more motivated to participate in a study than those less satisfied, 2) all included CI users underwent unilateral implantation; then, the sound localization and speech perception abilities may negatively affected in noisy and quiet listening situations, 3) the etiology of deafness may also contribute to the association of subjective assessments with speech perception performances; this could not be analyzed in the current study because too many patients had an unknown etiology.

In the present study, only MED-EL implants were utilized. Then, using different established CI instruments for evaluating the criterion/convergent validity of the $HISQUI_{19}$ scale is highly recommended.

CONCLUSION

The $HISQUI_{19}$ questionnaire is a reliable and valid measure for detecting Persian-speaking CI recipients' self-perceived sound quality in everyday listening situations. The good internal consistency and ease of scoring of this scale suggest that it is a beneficial tool for assessing the subjective outcomes of hearing implants.

Compliance with ethical guidelines

This study was approved by the local Ethics Committee (registration number: IR.AJUMS.REC.1395.433). Written informed consent forms were signed by all the participants.

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Conflicts of interest

No potential conflict of interest was reported by the authors.

Authors' contribution

HB: Study design, interpretation of the results, and drafting the manuscript; NS: Study design, interpretation of the results and drafting the manuscript; AS: Statistical analysis, and drafting the manuscript; AB: Study design, acquisition of data, interpretation of the results, and drafting the manuscript;

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Table 1: Demographic and clinical characteristics of cochlear implanted patients

Parameter	*n*=70, *n* (%)
Age at the time of implantation (years)	
Mean±SD of all subjects	33.87±11.49
Mean±SD of 30 subjects	35.13±12.57
Duration of deafness (years)	
<=20	41 (58.57)
>20	29 (41.43)
Months of CI use, mean±SD	15.18±10.48
Implant side of all subjects	
Left	25 (35.7)
Right	45 (64.3)
Implant side of 30 subjects	
Left	9 (30)
Right	21 (70)
Implant type	
CONCERTO Mi1000	44 (62.86)
SONATA Ti100	36 (37.14)
Gender of all subjects	
Female	34 (48.6)
Male	36 (51.4)
Gender of 30 subjects	
Female	18 (60.0)
Male	12 (40.0)
Etiology of hearing loss	
Unknown	32 (45.71)
Middle ear disorders (e.g., otosclerosis)	14 (20.0)
Ototoxicity	5 (7.14)
Head trauma	2 (2.85)
Sudden hearing loss	3 (4.29)
Autoimmune disorder	1 (1.43)
Meniere's disease	2 (2.85)
Hereditary	11 (15.71)

SD: Standard deviation, CI: Cochlear implant

Table 2: Reliability analysis of the hearing implant sound quality index questionnaire items

Item number	Corrected correlation	Cronbach's alpha if item deleted
1	0.725	0.958
2	0.745	0.958
3	0.625	0.959
4	0.713	0.958
5	0.727	0.958
6	0.752	0.958
7	0.808	0.957
8	0.722	0.958
9	0.726	0.958
10	0.807	0.957
11	0.721	0.958
12	0.671	0.959
13	0.677	0.959
14	0.775	0.957
15	0.823	0.957
16	0.689	0.959
17	0.788	0.957
18	0.781	0.957
19	0.643	0.959

Table 3: Content validity of the hearing implant sound quality index questionnaire items

Item number	CVR	CVI		
		Relevancy	Clarity	Simplicity
1	1	1	1	1
2	1	1	0.9	1
3	0.8	0.9	0.9	0.9
4	1	1	1	1
5	1	1	1	1
6	0.8	1	0.8	0.8
7	0.8	1	1	0.9
8	1	1	0.8	0.9
9	1	1	1	1
10	1	1	1	1
11	1	1	1	1
12	1	1	1	1
13	1	1	1	1
14	1	1	1	1
15	1	1	1	1
16	1	0.9	1	0.9
17	1	1	1	1
18	1	1	1	1
19	1	1	1	1

CVR: Content validity ratio, CVI: Content validity index

Table 4: Factor pattern matrix of the hearing implant sound quality index questionnaireitems

Item number	Item description	Factor 1	Factor 2	Factor 3
	Distinguishing between different voices/speakers			
1	Can you effortlessly distinguish between a male and a female voice?			0.629
10	Can you effortlessly distinguish between a female voice and a child's voice (6–10 years of age)?			0.703
14	You are listening to friends or family members talking to each other in quiet surroundings. Can you effortlessly identify the talker?		0.752	
	Identifying music sound			
3	When listening to music, can you effortlessly distinguish whether one or multiple instruments are being played simultaneously?		0.478	
6	Can you effortlessly distinguish single instruments in a familiar piece of music?	0.534		
	Sound localization			
5	Can you effortlessly hear noises such as falling keys, the beeping of the microwave, or the purring of a cat?		0.752	
13	Can you effortlessly hear the ringing of the phone?		0.885	
16	Can you effortlessly allocate background noise to a specific sound source (e.g. toilet flushing or vacuum cleaner) using acoustic help only?		0.818	
	Talking on the phone			
2	When talking on the phone, can you effortlessly understand the voices of familiar people?			0.827
8	When talking on the phone, can you effortlessly understand the voices of unfamiliar people?			0.775
	Watching TV, listening to the radio (speech in noise)			
7	You are watching a movie on TV and music is playing in the background. Provided that the volume of the TV is loud enough, can you effortlessly understand the movie's text?	0.691		
11	At home when other family members are having a conversation and you are listening to the news on the radio, can you effortlessly understand the news?	0.812		
	Understanding speech in public situations (speech in noise)			
9	Can you effortlessly understand a speech/lecture in a hall (e.g. lecture hall, church)?	0.711		
12	Can you effortlessly understand the announcement in a bus terminal, a train station or an airport?	0.781		
15	You are seated on the back seat of a car and the driver in the front is talking to you. Can you effortlessly understand the driver?	0.594		
	Participating in conversations (speech in noise)			
4	When background noise is present, can you effortlessly participate in a conversation with friends or family members (e.g. at a party/in a restaurant)?			0.549
17	When other people in your close surrounding are having a conversation (e.g. talking to a salesperson, a bank clerk at the counter or a waiter in a busy restaurant), can you effortlessly talk to another person?	0.599		
18	When background noise is present (e.g. in the office, printer, copier, air conditioning, fan, traffic noise, in busy restaurants, at parties, noisy children), can you effortlessly participate in a conversation with multiple people?	0.797		
19	When multiple people are talking simultaneously, can you effortlessly follow discussions of friends and family members?	0.738		

Table 5: Descriptive statistics of hearing implant sound quality index questionnaire items

Item number	Item description	Mean±SD
1	Can you effortlessly distinguish between a male and a female voice?	4.6±1.5
2	When talking on the phone, can you effortlessly understand the voices of familiar people?	3.9±1.5
3	When listening to music, can you effortlessly distinguish whether one or multiple instruments are being played simultaneously?	3.9±1.4
4	When background noise is present, can you effortlessly participate in a conversation with friends or family members (e.g., at a party/in a restaurant)?	3.9±1.2
5	Can you effortlessly hear noises such as falling keys, the beeping of the microwave, or the purring of a cat?	5.0±1.4
6	Can you effortlessly distinguish single instruments in a familiar piece of music?	4.0±1.4
7	You are watching a movie on TV and music is playing in the background. Provided that the volume of the TV is loud enough, can you effortlessly understand the movie's text?	3.5±1.4
8	When talking on the phone, can you effortlessly understand the voices of unfamiliar people?	3.5±1.5
9	Can you effortlessly understand a speech/lecture in a hall (e.g., lecture hall, church)?	3.4±1.4
10	Can you effortlessly distinguish between a female voice and a child's voice (6–10 years of age)?	4.5±1.4
11	At home when other family members are having a conversation and you are listening to the news on the radio, can you effortlessly understand the news?	3.4±1.4
12	Can you effortlessly understand the announcement in a bus terminal, a train station or an airport?	3.6±1.5
13	Can you effortlessly hear the ringing of the phone?	5.2±1.4
14	You are listening to friends or family members talking to each other in quiet surroundings. Can you effortlessly identify the talker?	4.2±1.4
15	You are seated on the back seat of a car and the driver in the front is talking to you. Can you effortlessly understand the driver?	3.9±1.5
16	Can you effortlessly allocate background noise to a specific sound source (e.g., toilet flushing or vacuum cleaner) using acoustic help only?	4.8±1.5
17	When other people in your close surrounding are having a conversation (e.g., talking to a salesperson, a bank clerk at the counter or a waiter in a busy restaurant), can you effortlessly talk to another person?	4.1±1.5
18	When background noise is present (e.g., in the office, printer, copier, air conditioning, fan, traffic noise, in busy restaurants, at parties, noisy children), can you effortlessly participate in a conversation with multiple people?	4.0±1.5
19	When multiple people are talking simultaneously, can you effortlessly follow discussions of friends and family members?	4.0±1.5
Total		78.22±21.4