IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Spatial Hearing Handicap Index (SHHI) - Development and Validation

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Abstract: Spatial hearing abilities are essential in everyday living situations losing which a sense of insecurity develops and also an individual may fall at risk becoming unaware of the signs of dangers. A questionnaire to tap on spatial hearing abilities (Spatial Hearing Handicap Index) was developed and validated in Tamil. A total of 119 normal hearing participants of age 11 to 70 years belonging to both gender groups were involved in the study. Comparisons were done between the age groups and gender groups. Although, differences were observed in the responses between gender groups and age groups, it was not statistically significant. This questionnaire can be used to identify and understand the areas where the patients have difficulty with respect to localisation, especially in case of hearing aid or amplificatory device users.

Key words: spatial hearing, localisation, questionnaire, Tamil.

I. INTRODUCTION

The visual and auditory senses extend beyond the boundaries of our bodies, and these senses serve different purposes. The visual sense gives us tremendous resolution over a small area, while hearing enables us to monitor what's going on in all directions and helps us decide where to direct visual attention.[1] Also, our awareness of the position and movement of sound sources is important in providing us with a sense of psychological comfort and security in a listening environment. Acoustic Localization abilities help one to locate the source of the sound heard. This ability is naturally present in all individual with ability to hear. Localization depends on factors such as presence or absence of hearing loss, amount of hearing loss, frequency or contour, monoaural vs binaural hearing[2], presence or absence of background noise, type and level of noise, age etc. There are three important cues that help in acoustic localization, namely, Interaural Time Difference (ITD), Interaural Level Difference (ILD) and Head Related Transfer Function (HRTF). These factors are accounted for head shadow effect and pinna shadow effect. It is important to note that these cues rely on the presence of a stored prototype, or template, of the sound,[3] so cognition is involved in the use of monaural cues. ITD helps in localization by differentiating low frequency and high frequency signal[4]. ILD helps in localization by differentiating the amount of loudness that is perceived by each ear.

The hearing loss is a crucial factor which affects localisation since if the sound is not heard, it cannot be located too. At the same time if the hearing loss is unequal in both ears and/or if the amplification device used does not equalise the hearing in both ears, again there will be difficulty in locating the sound source based on ILD. In terms of horizontal plane localization, the restoration of audibility can provide a listener with nearly normal skills, but, in some cases, hearing aids can impair horizontal localization.

It is a known fact that aging affects hearing and perception abilities and may result in presbycusis. It is also reported that the neural processing for localisation starts declining at 30s and hence, there might be difficulty or errors in localisation[5]. As age advances there is an increased error in front to back auditory spaces[6]. Evidence also suggest that the gender differences also affect the localization abilities. When there is a background noise, Signal to Noise Ratio (SNR) should be checked. The more positive the value of SNR, the easier it becomes to localize.

It becomes necessary to assess the ability to localize since it is skill that is helpful in everyday situations, like walking on the road or driving a vehicle, or to respond to someone calling to you, etc. Although these theories are conceptual and behaviourally measured, there are fewer studies on correlation between conceptual and perceptual facts (self-reports) on auditory localization abilities, which brings about the need for self-reporting questionnaire studies on auditory localization abilities to supplement the behavioural correlation[7]. There are fewer questionnaire-based studies on auditory localization. The widely used questionnaires include Spatial and Qualities of Hearing Scale (SSQ), developed by Gatehouse and Noble which contains 49 questions on speech perception in quiet conditions and special hearing abilities, along with localization tasks, and rating the quality of speech perceived on a scale of 0–10[8] and 'The Spatial Hearing Questionnaire' (SHQ), developed by Tyler et al., comprises 29 questions with similar domains of questions as in SSQ and has a rating scale from 0 to 100. Both these questionnaires focus on spatial hearing and speech perception in noise and quiet situations. Recently, in 2019, 'Localisation Handicap Index' (LHI) developed by Hemanth et al in Kannada was one questionnaire that related to Indian context[9].But there are no such questionnaires in Tamil, a language that has a statute of 'classic' and 'ancient'. Tamil is a language spoken in the state of Tamil Nadu, India. Thus, there is a need for the development and standardization of a questionnaire that will precisely focus on auditory localization abilities of an individual in the context of the community and culture of the state and Tamil speaking people. Thus, this study aims to develop a localization questionnaire in context to the state and people of Tamil Nadu.

II. METHODOLOGY

2.1 Objectives

1. To develop and validate a questionnaire for assessing localization abilities in Tamil.
2. To compare the localization abilities subjectively using this questionnaire between genders and across different age groups.

2.2 Questionnaire

A questionnaire was developed to assess the localisation abilities across age groups In Tamil
based on the 17 questions initially considered for Localisation Handicap Index, developed by Shetty et al, in Kannada which was taken from SSQ and SHQ. The questions were translated into Tamil and reverse translated by 6 individuals who were proficient in both Tamil and English to check the accuracy of the translation. The content validation was done by 35 audiologists who were proficient in Tamil and knew the localisation task to check if the questions are in context with both the Indian and Tamilian scenario. The questions were rated for relevancy, clarity and comprehensiveness using a 3-point rating scale with 3 being completely relevant, 2 being partially relevant and 1 being irrelevant.

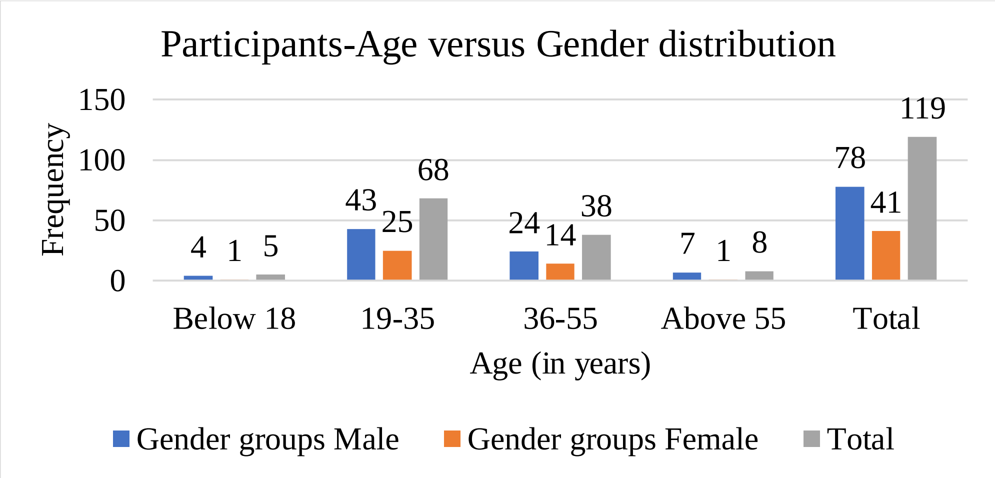
2.3 Study design

A cross sectional study design was opted for the research. Participants belonging to/residing in various regions of Tamil Nadu were considered for the study with slightly more focus on individuals from urban regions due to the nature of the questions.

2.4 Participants

A total of 119 participants (78 males and 41 females), who were proficient in both reading and writing Tamil were included in the study. The age range of participants was 11-70 years. The research purpose was explained to the participants and a consent was also received before involving them in the study as per the ethics of research. The inclusion criteria for the participants were that the individuals should have normal hearing (less than or equal to 15 dBHL) as per the Modified Goodman's classification and that their tympanometry findings should result in an 'A' type tympanogram indicating that there is no presence of middle ear pathology. Only participants who do not have any sensory-motor deficits were involved in the study. Patients with Central Auditory Processing Disorders and Auditory Neuropathy Spectrum Disorders were excluded from the study. The participants were divided into 2 groups based on their gender, as males and females and into 4 groups based on their age as adolescents (below 18 years), young adults, middle aged adults and geriatrics (Refer fig. 2.4.1).

Figure 2.4.1 showing age and gender wise distribution of participants included in the study.



2.5 Instrumentation

Pure tone audiometry was done using Cello Inventis with the use of TDH 39 circumaural headphones and B71w Bone Vibrator in a sound treated room with two room setups. The tympanogram was obtained using Flute Inventis.

Data collection

The data was collected from 119 normally hearing participants through google forms and the links for the google form was shared via WhatsApp and e-mail. The google form consisted of Demographic data and the 17 questions to assess localisation abilities in Tamil. The participants were asked to respond to the questions by picking one out of the three options available as response for each question. The options available as responses were never/ occasionally/ always. The questions were asked both in positive and negative manner in order to avoid blind responses.

III RESULTS AND DISCUSSION

3.1 Data analyses

The data collected from the participants were analysed using SPSS (Statistical Software for Social Sciences) software (Version 26, IBM corporation, Chicago, USA).

3.2 Spatial Hearing Handicap Index (SHHI)

The 17 questions asked tapped on different listening situations such as in quiet and in noise, one to one or group, familiar and unfamiliar situations, etc. and different directional aspects such as above, below, right to left movement/ left to right movement, etc that constitutes to spatial hearing in a holistic way. India is a developing country and the road traffic and busy environment has become a part and parcel of the people living across the state of Tamil Nadu, especially in the towns and cities and so questions to check spatial hearing with respect to busy street/ roads and vehicle noise and movement were considered essential. More opportunities were given to male participants in the study, because of the fact that the self-driving is more frequent in males and also, compared to the females who self-drive, the duration, distance and frequency of driving and the different driving situations is more and demanding in males.

The question on localization with the sound of lawn mower was put to question for relevancy by few audiologists but it was well justified that it was relevant after validation by others who validated the question. The reason behind its relevancy as stated by the audiologists were, most of the people in villages and even those with gardens or who visit parks in the towns and cities would have come across the situation in their daily life and also, both the Central and the State Government had taken many initiatives to reinstate and convert free spaces to public parks, which now lead many people to spend their time in such places.

All the 17 questions were concluded and justified to be relevant and the questionnaire was then used for data collection from participants as per the criteria set.

To check the inter correlation of the questions, Pearson's correlation was done (Refer Table 3.2.1) and all questions were said to be correlating with each other contributing to the overall score. The internal consistency was checked using Cronbach's alpha and was found to be good (0.796).

The responses of the questions were scored based on a three-point rating scale in which the response 'never' was given a score of 0, the response 'occasionally' was given a score of 1 and the response 'always' was given a score of 2. Note that the questions 2, 4, 12 and 14 are asked negatively and hence requires the response as 'never' by an individual with good spatial hearing abilities. Hence, for those questions the option 'never' is given a score of 2, 'occasionally' is given a score of 1 and 'always' is given a score of 0. Therefore, the total score obtainable by an individual with good spatial hearing abilities is 34.
Based on the statistical analyses, the value of quartiles for SHHI scores were found to be 16, 19 and 22 respectively for 25^{th}, 50^{th} and 75^{th} quartiles. Since 16-19 has a very smaller interval, the scores were divided into three rather than four as below 16, 16-22 and above 22 and were rated as poor, fair and good respectively.

Table 3.2.1 showing Pearson's correlation for the 17 questions included in the questionnaire

Pearson's Correlations

	Q.1	Q.2	Q.3	Q.4	Q.5	Q.6	Q.7	Q.8	Q.9	Q.10	Q.11	Q.12	Q.13	Q.14	Q.15	Q.16	Q.17	Total
Q.1	1	.172	.254	.011	.175	.175	.111	.247	.336	.282	.430*	.033	.526**	.006	.242	.271	.282	.466**
Q.2	.172	1	.201	.619**	.046	-.177	.525**	.183	.234	.115	.280	.512**	.251	.285	.058	.245	.045	.634**
Q.3	.254	.201	1	.243	.156	.259	.174	-.165	-.097	.000	.349*	.106	.491**	.455**	.313	.091	.292	.504**
Q.4	.011	.619**	.243	1	.069	.069	.528**	.098	.195	.247	.196	.611**	.107	.487**	.243	.291	.173	.710**
Q.5	.175	.046	.156	.069	1	.059	-.045	.155	.230	-.104	-.027	.019	.092	.248	.323	.248	.274	.312
Q.6	.175	-.177	.259	.069	.059	1	-.226	.298	.104	.400*	.361*	.202	.208	.164	.208	.131	.148	.338
Q.7	.111	.525**	.174	.528**	-.045	-.226	1	.048	.085	.085	.130	.338	.194	.113	-.039	-.236	-.085	.405*
Q.8	.247	.183	-.165	.098	.155	.298	.048	1	.369*	.299	.351*	.431*	.191	-.126	.191	.227	.031	.401*

Pearson's Correlations

	Q.1	Q.2	Q.3	Q.4	Q.5	Q.6	Q.7	Q.8	Q.9	Q.10	Q.11	Q.12	Q.13	Q.14	Q.15	Q.16	Q.17	Total
Q.9	.336	.234	-.097	.195	.230	.104	.085	.369*	1	.299	.107	.268	-.121	.302	-.013	.149	.299	.421*
Q.10	.282	.115	.000	.247	-.104	.400*	.085	.299	.299	1	.378*	.333	.121	.093	.121	.181	.174	.444**
Q.11	.430*	.280	.349*	.196	-.027	.361*	.130	.351*	.107	.378*	1	-.003	.449**	.024	.338	.272	.136	.521**
Q.12	.033	.512**	.106	.611**	.019	.202	.338	.431*	.268	.333	-.003	1	.077	.327	.234	.287	.076	.636**
Q.13	.526**	.251	.491**	.107	.092	.208	.194	.191	-.121	.121	.449**	.077	1	.094	.202	.244	.121	.477**
Q.14	.006	.285	.455**	.487**	.248	.164	.113	-.126	.302	.093	.024	.327	.094	1	.239	.229	.093	.541**
Q.15	.242	.058	.313	.243	.323	.208	-.039	.191	-.013	.121	.338	.234	.202	.239	1	.648**	.338	.522**
Q.16	.271	.245	.091	.291	.248	.131	-.236	.227	.149	.181	.272	.287	.244	.229	.648**	1	.401*	.529**
Q.17	.282	.045	.292	.173	.274	.148	-.085	.031	.299	.174	.136	.076	.121	.093	.338	.401*	1	.408*
Total	.466**	.634**	.504**	.710**	.312	.338	.405*	.401*	.421*	.444**	.521**	.636**	.477**	.541**	.522**	.529**	.408*	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

3.3 Spatial hearing and Gender:

There are evidences from the literature that there is difference between the genders in terms of spatial orientations. Andrea Bosco in 2004, reported that the visual spatial memory is more in males[10]. Researches reveal that men and women utilize different strategies for processing spatial information. In a study by Lynn Simon et al in 2009, it was concluded that males responded more accurately than females to targets in attended locations and that the sexes exhibited different Event Related Potential (ERP) patterns during test performance which were consistent with existing predictions of female top-down and male bottom-up strategies in spatial processing[11].

Yoko K. Naylor and Michael McBeath in 2008 reported that women exhibited more bias in the absence of auditory information and more improvement was observed when auditory information was added during a body tilting task that was performed with and without auditory and visual cues[12]. Another article by John G Neuhoff, Rianna Planisek and Erich Seifritz in 2009 reported that sex differences were observed in estimating time-to-arrival of full cue looming sound and in estimating the distance of a moving object that approached them but stopped[13].

Thus, this study compared the spatial hearing in males and females through SHHI.

Table 3.3.1 showing the frequency of responses received by both gender groups for the questions in SHHI.

SHHI									
Questions	**Never**			**Occasionally**			**Always**		
	M	F	T	M	F	T	M	F	T
Localization at home	2	4	6	36	16	52	40	21	61
Response to call	40	12	52	32	20	52	6	9	15
Lawn mower	10	4	14	38	23	61	30	14	44
Meeting	28	23	51	36	13	49	14	5	19
Door bang	5	3	8	33	20	53	40	18	58
Apartment floor	8	3	11	33	20	53	37	18	55
Direction- car horn	36	12	48	23	20	43	19	9	28
Dog bark	8	1	9	32	19	51	38	21	59
Direction of bus	11	7	18	32	21	53	35	13	48
Distance of bus/ truck	15	9	24	47	20	67	16	12	28
Distance with voice	9	7	16	47	20	67	22	14	36
Person from above	34	13	47	36	21	57	8	7	15
Moving around helps	6	1	7	40	19	59	32	21	53
Airplane	19	16	35	46	16	62	13	9	22
Bus- R-L/L-R	10	9	19	31	19	50	37	13	50
Voice or footsteps	11	4	15	43	18	61	24	19	43
Judgement accuracy	6	4	10	46	22	68	26	15	41

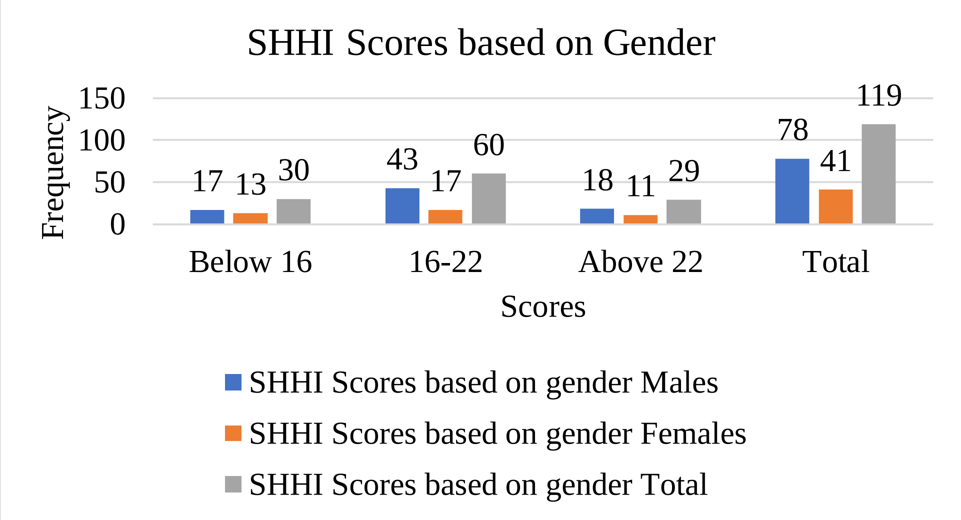
9.8% of the females reported that they could never perform the task given in the questions 1, 3 and 16 appropriately. 2.4% females responded with 'never' to questions 8 and 13; 7.3% of females reported clear difficulty in performing the tasks given in questions 5 and 6. 17.1% of females faced difficulty in localization tasks with respect to questions 9 and 11 and 22.0% of females reported that they will never be able to accurately localize with respect to tasks given in questions 10 and 15.

Similarly, In males, 2.6%, 12.8%, 6.4%, 10.3%, 10.3%, 14.1%, 19.2%, 11.5% and 7.7% of participants responded that they will never be able to accurately locate the sound source or be able appropriately perform the tasks related to spatial hearing abilities mentioned in the questions1,3,5,6,8,9,10,11,13,15 and 16 respectively.

Maximum frequency with respect to the response 'never' were recorded for the questions 2 and 7 in both the gender groups (29.3% of females and 51.3% and 46.2% of males respectively). 12.2%, 17.1% and 22.0% of females and 17.9%, 10.3% and 16.7% of the males reported that they always had difficulty with spatial hearing tasks mentioned in questions 4, 12 and 14. 9.8% of females and 7.7% of males reported that their judgements with respect to identifying the sound source were never accurate (Refer Table 3.3.1).

When compared the frequency percentage (within gender groups) of the responses between males and females, females dominated in tasks such as identifying the speaker in a group discussion or meeting, locating the dog with its bark without visual cues, estimating the distance with the sound of vehicles or a person's voice, locating an airplane with its noise, identifying the direction of movement with a person's voice or footsteps. More females than males have reported that moving around helps when there is a difficulty in localisation and also that their impression of sounds are exactly where they expect them to be.

Figure 3.3.1 showing frequency of gender wise SHHI scores



The results of the comparison of SHHI scores between the gender groups shows that out of the 30 participants who scored less than 16, 17 were males and 13 were females. 43 males and 17 females scored between 16-22 and 18 males and 11 females scored above 22. When compared in terms of percentage within the groups, percentage of females who scored above 22 is more than males (Refer fig. 3.3.1).

Table 3.3.2 showing the results of ‘t’ test done on the SHHI scores to compare between the gender groups.

SHHI Scores- ‘t’ test				
Gender	Frequency	Mean	‘t’ value	‘p’ value
Male	78	19.29		
Female	41	19.59	0.309	0.758

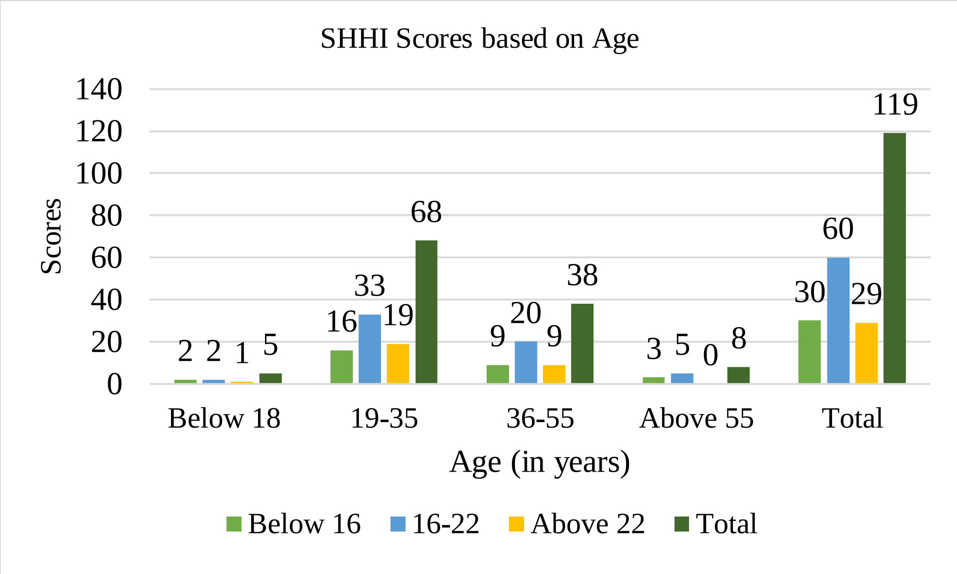
Though there are differences observed in the frequency and percentage of responses obtained between both the gender groups, when compared the overall scores between the two groups statistically using the ‘t’ test, it revealed that there was no significant difference (p value is > 0.05) between them.

3.4 Spatial hearing and age:

Literature provides evidence that as age increases localization abilities especially in terms of accuracy deteriorates. Marina S. Dobreva, William E. O’Neill, and Gary D. Paige (2011) reported in their study, that when compared to young adults, middle aged and elderly listeners showed significant difficulty in horizontal localisation for narrowband stimuli within the range of 1250Hz to 1575Hz[14]. Freigang et al (2014), reported that the accuracy declined by 23% from younger to older adults for the low frequency noise band across all the literalities[15].

To check the difference between the age groups with respect to spatial hearing, the responses and scores obtained through SHHI were compared.

Figure 3.4.1 showing the SHHI scores obtained by different age groups



The SHHI scores, when compared between the age groups, shows that out of the 30 participants who scored below 16, two were below 18 years, sixteen were of 19-35 years, nine were of 36-35 years and three were of age above 55 years. Out of the 5 participants who were below 18 years of age, 1 participant has scored above 22. Out of 68 young adults and 38 middle-aged adults, nineteen and nine participants have scored above 22 respectively. No elderly participant has scored above 22 (Refer fig. 3.4.1).

Table 3.4.1 showing One-way ANOVA test results of SHHI scores for age wise comparison

ANOVA					
Spatial Hearing Handicap Index (SHHI) -Scores					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	62.906	3	20.969	.885	.451
Within Groups	2725.530	115	23.700		
Total	2788.437	118			

To compare the scores statistically, One-way ANOVA (Refer Table 3.4.1) was used which revealed that the differences between the age groups were insignificant ('p' value > 0.05).

IV Conclusion

The SHHI can be used as a subjective tool to tap spatial hearing individuals in Tamil speaking individuals subjectively. Though there are differences observed in the responses between the gender groups and age groups they were statistically insignificant due to unequal distribution within the two groups. The questionnaire can also be used in cases of individuals with hearing loss, hearing aid or any other amplificatory device users in order to understand their difficulty and aid them accordingly, for example, enhancing the device's SNR properties like noise cancellation, suggesting binaural amplification in cases of monoaural users, etc.

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