Assessment of Localization Ability – A Subjective Tool in Kannada Version

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Abstract

Introduction: Majority of the audiology clinics are not equipped to assess the localization ability due to the problem in availability of instrument, infrastructure and or cost involvement. Thus, questions from standardized tools sensitive to Indian scenario were selected to assess the localization ability. The objectives of the study were to a) develop Kannada localization questionnaire b) validate the developed questionnaire using degree of error (DOE) and c) investigate the relationship between localization ability from questionnaire and DOE from localization task. **Materials and Method:** Two experiments were carried out in this study. In Experiment -1 questionnaire was developed by translation, reverse translation and rated for goodness of questionnaire. The developed questionnaire was administered on 103 participants of different age groups from 11-70 years. In Experiment -2 using localization task an aggregated degree of error was measured for the target test stimuli (truck and automobile horns) in the presence of traffic noise at 65 dB SPL and 75 dB SPL. **Results:** On factor analysis a factorability of correlation suggested 14 of the 17 questions correlated well above 0.3. The questionnaire developed has Cronbach's alpha of 0.78 for 10 items and 0.53 for 4 items. In addition a significant reduction in localization ability on questionnaire and increased error on localization task were observed with advanced in age. Further a moderate negative correlation was noticed between localization ability scores and degree of error. **Conclusions:** The developed questionnaire can be effectively used in a clinic where there is an unavailability of localization experiment test setup.

Keywords: Degree of error, localization, questionnaire

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Introduction

Auditory localization is the ability to locate the distance and direction of the sound source.[1] It depends on three cues, namely interaural phase difference, interaural time difference (ITD), and interaural level difference (ILD). The head-related transfer function (HRTF) leads to differences in phase, time, and level between ears. HRTF is defined as sound arising from a particular location in space reaches two ears of the head at two different levels and at two different points of time. The extent to which each of these cues contributes to sound localization depends on the acoustical characteristic (frequency) of the signal. It has been reported that ITD helps in the localization of low-frequency sounds and high-frequency sounds.[1] A binaural hearing has been said to be associated with sound source localization.[2]

In advanced age, the accuracy of locating the sound source decreases irrespective of frequency bands.[3] It has been reported that the reduction in performance on localization starts with the third decade of life due to age-related decline in neural processing meant for localization.[3] Abel *et al*.[4] reported that in advanced age, an increased localization error was observed in front to back auditory space. The increased error in localization is due to a reduced contrast in ITD cues between ears.[5] Binaural segregation is equally essential in locating the sound source, especially in noise. The effect of noise on localization performance depends

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on the spectrum of signal and noise. If the frequency of noise and signal shares the same range of the spectrum, then the localization performance deteriorates because of the masking effect. Further, the accuracy of localization performance deteriorates with a decrement in signal-to-noise ratio (SNR).

There are different assessment tools to measure the localization ability. Localization questionnaire is a valuable tool to identify the localization difficulties in all age groups. Localization questionnaire is a self-assessment tool available in English as a part of Speech, Spatial and Qualities of Hearing Scale (SSQ) developed by Gatehouse and Noble,[6] Disability and Handicap Associated with Localization (DHAL) developed by Tyler *et al*.,[7] and Spatial Hearing Questionnaire (SHQ) developed by Gatehouse and Noble *et al*.[6] SSQ has been reported to have good reliability with a test–retest correlation of 0.83.[8] It has been found that SHQ is reliable when used in the individual with normal hearing and in individuals using cochlear implants.[9] However, in the Kannada language, there is no such questionnaire to assess localization ability. Development of questionnaire in the native language for Kannada-speaking individuals incorporating the localization questions from SSQ, DHAL, and SHQ would help to overcome the language barrier. Besides, validating the localization questionnaire with localization test in calculating the root mean square (rms) degree of error (DOE) would make the questionnaire more efficient to identify localization difficulty. If the scores obtained in the questionnaire correlate well with the localization scores, then it can be used as supplementary material or used alone to assess localization ability in the absence of localization test setup. Thus, it is hypothesized that the developed localization questionnaire identifies the localization difficulties.

The present study aimed to develop and validate a localization questionnaire in the Kannada language. The objectives of the present study include (a) to develop localization questionnaire in the Kannada language to subjectively assess the localization difficulties, (b) to assess the localization difficulties from rms DOE on study participants, and (c) to find the relation between the developed questionnaire and localization task.

Methods

The study included two experiments. Experiment 1 comprised two phases. In Phase 1, the questionnaire was developed to assess localization ability, and in Phase 2, developed questionnaires were administered to the participants of the study. In Experiment 2, the DOE was evaluated from the localization test.

Experiment 1

Phase 1: Development of the questionnaire

A total of 17 questions on localization were selected from three standardized questionnaires, i.e., SSQ, SHQ, and DHAL. The questions were translated into the Kannada language by a technical writer. The questionnaire was further subjected to do reverse translation by five individuals who were proficient in speaking and reading English and Kannada languages. For content validity concerning the Indian scenario, the questionnaire was given to 20 audiologists who were native Kannada speakers and knew the localization task. These participants were asked to rate each question for relevance, clarity, and simplicity on a 5-point rating scale, where 5 being very relevant/clear/simple and 0 being not at all relevant/clear/simple.

Phase 2: Administration of the questionnaire

A cross-sectional research design was used to conduct Experiment 1. A total of 103 participants were involved in the study. The participants were grouped based on their age. The age range and mean age in each group are as follows: Group 1 (n = 34): 11–20 years (mean age = 15.6); Group 2 (n = 21): 21–30 years (mean age = 24.7); Group 3 (n = 16): 31–40 years (mean age = 36.5); Group 4 (n = 16): 41–50 years (mean age = 46.1); Group 5 (n = 17): 51–60 years (mean age = 55.4); and Group 6 (n = 10): 61–70 years (mean age = 64.6). All the participants were native speakers of Kannada language and were proficient in reading and writing Kannada. All participants had normal hearing sensitivity (pure-tone average <15 dBHL) across the octave frequencies from 0.25 kHz to 8 kHz with normal middle ear function defined by "A-" type tympanogram.

To assess the localization difficulties, the developed questionnaire was administered to 103 normal hearing participants who were proficient in the Kannada language. Each participant was instructed to read the question and click on the appropriate options displayed on the computer, as given in Figure 1. Each question had three options, and each option was given a weightage of 7.14, 3.57, and 0, for never, occasionally, and always, respectively. The overall scores from 14 questions were calculated by considering the weightage mentioned above. The localization questionnaire score from each of the groups was then analyzed to check if the scores vary across age.

Experiment 2: Localization task

Participants

Ten participants were randomly selected using the lottery method from the participant list of each group of Experiment

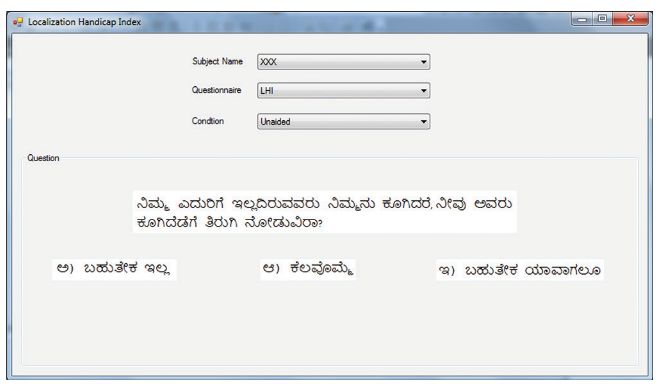

Figure 1: Illustration of software used for the administration of localization handicap index (LHI) questionnaire

1 (Phase 2). A total of 32 participants gave their consent to be the part of Experiment 2. The age range and mean age in each group are as follows: Group 1 (n = 5): 11–20 years (mean age = 14.5); Group 2 (n = 10): 21–30 years (mean age = 25.2); Group 3 (n = 6): 31–40 years (mean age = 35.3); Group 4 (n = 4): 41–50 years (mean age = 47.6); Group 5 (n = 3): 51–60 years (mean age = 54.5); and Group 6 (n = 4): 61–70 years (mean age = 63.7). The study is approved from the AIISH Institutional Review Board (SH/CDN/ARF-36/2015-16). Informed consent was obtained from each participant.

Stimuli

The noise was recorded in an average road traffic condition using the sound level meter (SLM). Automatic gain control and "A" weighted network were selected in the SLM. A half-inch free-field microphone (serial no: 02616511) connected to a SLM mounted on a tripod was positioned to record the noise. The truck horn and automobile horn were downloaded from the internet. The sampling frequency of each horn was downsampled to 22,000 with 16-bit resolution. The centroid frequency of truck horn and automobile horn was 150 Hz and 350 Hz, respectively. Low-frequency horn is common in road traffic because of its high energy. Thus, the test stimuli which had the energy at low frequency were selected. Truck horns had the center frequency of around 150 Hz and automobile horn with the center frequency of approximately 350 Hz.

Loudspeaker locations

A localization task was administered on 32 participants with normal hearing. A total of nine speakers (Genelec 8020B) were used to present stimuli (target and noise) covering 0°–360° azimuths. Truck horn had the center frequency of around 150 Hz at 110 dB sound pressure level (SPL), and automobile horn with the center frequency of around 350 Hz at 100 dB SPL was used as the target stimuli. The target stimuli were presented in random order through five loudspeakers at 90°,130°, 180°, 220°, and 270° azimuths. The recorded traffic noise at 65 dB SPL (average traffic noise) and 75 dB SPL (peak-hour traffic noise)[10] was utilized as background noise which is used to simulate traffic condition in a more realistic manner. A traffic noise was continuously presented through four speakers through 40°, 120°, 230°, and 320° azimuths. All these loudspeakers were positioned at 2 m away from the reference-test position where a participant seats in an actual testing condition.

Calibration

A half-inch free-field microphone (serial no: 02616511) connected to a SLM mounted on a tripod was positioned at reference-test position. Automatic gain control and "Á" weighted network were selected in the SLM. The Cubase 6 software (Steinberg; Yamaha Corporation; Hamburg; German) loaded in a personal computer was connected to the Lynx Aurora signal router to deliver the truck horn stimulus at 110 dB SPL to the assigned speaker. If the intensity of the stimulus was not read the specified value in the SLM, then the equalizer in Cubase 6 software was toggled up and down to increase or decrease the level. It was ensured that the level in the SLM reads the intensity of 110 dB SPL for the truck horn. A similar calibration procedure was performed for each of the speakers for automobile horn at 100 dB SPL. Whereas speakers assigned to deliver noise was calibrated by changing the toggle option in the equalizer till the SPL read 65 dB SPL in the SLM. Similarly, it was performed for the noise delivered at 75 dB SPL. The test setup is shown in Figure 2.

Procedure

Before the testing, each participant was instructed about the task and provided a trial just to get familiarized with the test condition. In a trial, a target stimulus was presented through the loudspeaker which was assigned with a number. Each participant was instructed to locate the loudspeaker through which the target stimulus was delivered either by telling the assigned number of the loudspeaker or showing the hand where the sound delivered from. In actual testing, each target stimulus at each noise level was presented ten times through each loudspeaker. The two target stimuli (automobile horn – 100 dB SPL and truck horn – 110 dB SPL) presented in noise at two levels (65 dB SPL and 75 dB SPL) through different loudspeakers were pseudo-randomized and counterbalanced across study participants. Each participant was made to sit in the reference-test position and instructed to locate the loudspeaker through which the target stimulus was delivered.

Analysis

The responses were noted down in the response sheet for further investigation of the DOE. DOE is calculated by considering the difference in the degree of azimuth between the speaker from which the stimulus was presented and the speaker in which participant located it. The root mean square DOE developed by Ching *et al.*[11] was adopted to compute the cumulative DOE. This was performed for each participant, and the obtained rms DOE was subjected to statistical analysis to show localization difficulty as a function of age.

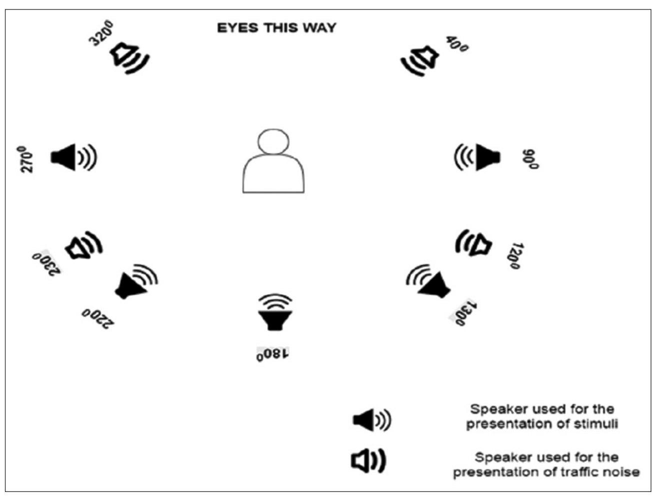

Figure 2: Test setup used for localization task

$$\text{rms DOE}\sqrt{\frac{(\text{DOE})1^2+(\text{DOE})2^2+\ \ldots\ldots\ldots\ +(\text{DOE})n^2}{n}}$$

Results

A factor analysis was performed on the selected questions of localization which were sensitive to the Indian scenario. The data on localization questionnaire and rms DOE obtained from participants of different age groups were subjected to statistical analyses using SPSS (Statistical Package for Social Sciences) software (version 17, IBM Corporation; Chicago; USA). Before conducting an appropriate statistical analysis of the data collected, the normality and homogeneity tests were administered. The Shapiro–Wilk test for normality was performed, and the results revealed that the data did not follow the normal distribution ($P > 0.05$) for each of the parameters assessed (questionnaire and rms DOE). A Levene's test indicated ($P < 0.05$) a nonhomogeneous between groups on collected data. Hence, a nonparametric test was used for the data collected under each objective.

Localization questionnaire to the Indian context

To create the construct for factor analysis, the 17 questions on localization were examined. A factorability of correlation was used and it suggested 14 of the 17 questions correlated well above 0.3. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.63, which is above the suggested value of 0.6, and Bartlett's test of sphericity was significant ($P < 0.05$). Principal component analysis was performed to identify the questions that are sensitive to the Indian context. In commonality, the sum of the squared factor loading for all the three factors for a given localization question is the variance in that variable accounted for by all factors and which is not due to measurement error. Only the first two factors have eigenvalues over 1.00, and together, these explain over 92% of the total variability in the data. An oblimin rotation provided the best-defined factor structure. The rotated oblimin factor loadings are presented in Table 1. The Factor 1 (strongly relevant questions) is loaded with high and moderatepositive values and in Factor 2 (moderately relevant questions), high positive values are loaded with one moderate value.

Internal consistency for each of the factors was examined using the Cronbach's alpha. The alpha value was strong 0. 78 for the 10 questions and moderate 0.53 for 4 questions which assess localization ability. The skewness of 0.48 and 0.36 and kurtosis of 0.34 and 0.41 for strongly and moderately relevant questionnaire, respectively, which were well within a normal distribution.

Overall, 3 of the 17 items were eliminated. From the remaining items, two factors were formulated. Strongly relevant questions factored ten items which had strong alpha. Moderately relevant questions factored another 4 items which had the moderate alpha value. On remaining, 14 questions on localization are administered to the study participants to investigate their ability on localization.

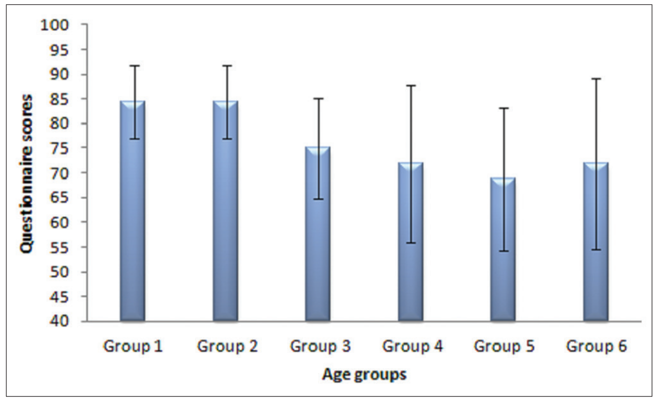

Figure 3: Median and standard deviation of localization questionnaire score in each age group

Localization ability as a function of age questionnaire

The localization scores obtained through questionnaire from the six age groups were represented in the median, and its standard deviation is shown in Figure 3. From Figure 3, it is indicated that as the age increases, there is a deterioration in the localization ability scores. The Kruskal–Wallis test was performed on localization questionnaire obtained from different age groups. The results revealed a significant reduction in localization ability as a function of age (χ^2 (5) = 33.325, $P < 0.001$).

Further, to investigate which groups have caused a significant reduction in localization ability, a pair-wise comparison between groups was performed using the Mann–Whitney U-test. From Table 2, it can be inferred that the localization ability scores obtained from (a) Group 1 were significantly better in localization abilities than all other age groups, except Group 2; (b) Group 2 were significantly better than all other age groups, except Group 1; and (c) Group 3 were significantly poorer than Groups 1 and 2. In addition, Groups 4–5 and 6 were not significantly different from each other on localization ability scores.

The degree of Error$_{rms}$ on localization as a function of age

The rms DOE on localization was computed for each individual. A median and standard deviation of the errors for each age group are shown in Figure 4. It is observed that the DOE on localization increases with an advance in age.

The Kruskal–Wallis test was performed to see if there any significant difference between groups on localization error. The results revealed a significant increase in localization error with the increase in age (χ^2 (5) = 26.469, $P < 0.001$). Further, a pair-wise comparison of groups as a *post hoc* analysis was carried out using the Mann–Whitney U-test to investigate which group has caused a significant difference on localization error. The result of Mann–Whitney is shown in Table 3. The localization error scores obtained from Group 1 was significantly lesser in localization error than all other age groups, except Group 2. The participants of Group 2 and

Table 1: Factor loadings and communalities based on a principal component analysis with oblimin rotation for 17 items (n=20)

Questions number	Questions	Strongly relevant	Moderately relevant	Irrelevant	Communality
1	You are at home in a quiet room. There are other people in the house (friends or family). They are talking in another room and you can hear them. Can you tell which part of the house those people are in?	0.74			0.55
2	Do you turn the wrong way when someone that you cannot see calls out to you?	0.69			0.48
3	You are outdoors in an unfamiliar place. You can hear the sound of someone mowing a lawn. You cannot see where they are. Do you know where the sound is coming from?	0.63			0.39
4	You are sitting around a table or at a meeting with several people. There is some background noise. You cannot see everyone. Do you find it hard to know which person is speaking?	0.58			0.45
5	You are in an unfamiliar house. It is quiet. You hear a door slam. Can you tell right away where that sound came from?	0.57			0.33
6	You are in a high-rise apartment or office building. You can hear sound from another floor. Can you tell whether the sound is coming from above or below you?	0.54			0.39
7	You are standing on the footpath of a busy street. A car horn sounds. Do you have difficulty telling which direction it came from?	0.53			0.33
8	You are outside. A dog barks loudly. Can you tell immediately where it is, without having to look?	0.52			0.62
9	You are standing on the footpath of a busy street. Can you hear right away which direction a bus or truck is coming from before you see it?	0.51			0.62
10	You are standing on the footpath of a busy street. Can you tell, just from the sound, roughly how far away a bus or truck is?	0.42			0.59
11	You are standing on the road and someone is calling at a distance. Can you tell from how far away voice is coming?		0.76		0.34
12	You are outdoors in an unfamiliar place. Someone calls out from somewhere above you (such as a balcony or bridge). Do you find it hard to tell where the voice is coming from?		0.74		0.66
13	If you have a problem telling where something is coming from, does it help if you move around to try to locate the sound?		0.72		0.55
14	You are outside. You can hear an airplane. Do you find it hard to tell where the plane is in the sky, by the sound alone?		0.54		0.34
15	Can you tell from the sound which direction a bus or truck is moving, for example, from your left to your right or right to left?			-	0.82
16	Can you tell from the sound of their voice or footsteps which direction a person is moving, for example, from your left to your right or right to left?			-	0.87
17	Do you have the impression of sounds being exactly where you would expect them to be?			-	0.32

Factor loadings <0.3 are suppressed

Table 2: Z values of Mann-Whitney U-test obtained from groups on the localization scores in questionnaire

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Group 1						
Group 2	0.131					
Group 3	2.433*	3.007**				
Group 4	2.277*	3.082**	0.788			
Group 5	3.278**	4.336**	1.179	0.508		
Group 6	3.131**	3.892**	1.106	0.820	0.331	

*P<0.05, **P<0.005

Group 3 had significantly lesser localization error than other age groups. Although the localization error was increased with advanced in age (Group 4, Group 5, and Group 6), this difference was failed to reach significant between groups [Table 3].

The relationship between localization questionnaire score and degree of error on localization

The individuals for whom the questionnaire was administered and the localization task was performed were selected for the correlation analysis. The results of Spearman's correlation revealed that there was a significant moderate negative correlation (ρ = −0.583, n = 32, P < 0.001), as shown in Figure 5. It infers that as the score increases in localization ability in the questionnaire, the DOE in localization task decreases.

Discussion

Audiologist judgment regarding relevant or irrelevant questions on localization to the Indian context was assessed by factor analysis. It was found that factor loading >0.3 was observed for 14 questions over 17 questions. The three

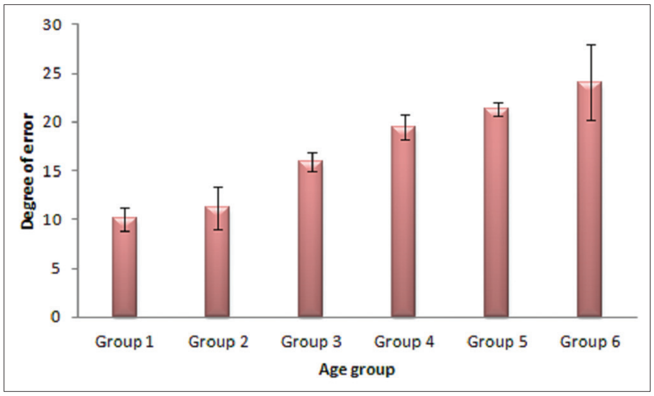

Figure 4: Median and standard deviation of degree of error scores in each age group

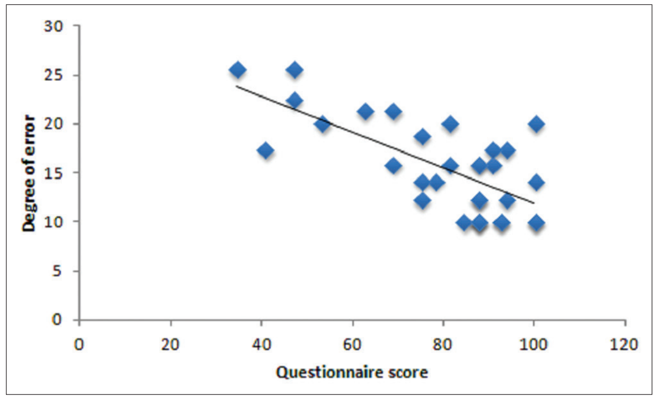

Figure 5: Scatter plot showing scores obtained in the questionnaire and degree of error in localization task

Table 3: *Z* values of Mann-Whitney U-test obtained from groups for the localization degree of error

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Group 1						
Group 2	0.739					
Group 3	2.837**	2.918**				
Group 4	2.513*	2.903**	2.546*			
Group 5	2.320*	2.626**	2.438*	1.852		
Group 6	2.513*	2.903**	2.546*	1.323	1.080	

*P<0.05, **P<0.005

questions failed to reach factor value >0.3 are because of commonality in the questions. In an informal interview, an about 14/20 audiologists reported question numbers 15 and 16 were almost similar to that of question number 7. The content of question numbers 15, 16, and 7 was virtually the same, where they tend to assess the direction in which a sound is coming from. Thus, in commonality, the factor was found to be strong 0.82 and 0.87 for question numbers 15 and 16, respectively. In addition, the question number 7 is not specific to direction, whereas question numbers 15 and 16 are specific to either right or left directions. Thus, audiologists might have responded as "irrelevant" to the question numbers 15 and 16. Further, the first ten questions come under the primary factor as strongly relevant. Remaining four questions were factored into moderately relevant question. In total, 14 questions on localization were selected under two factors.

A significant aging effect was observed in the DOE and reduced localization ability in the questionnaire. Worsening in localization scores with aging agreed with studies reported in the literature.[3,4,12] They attributed that decrement in localization ability is due to a reduction in temporal processing efficiency associated with the aging phenomenon.[13] The lowfrequency horn stimuli was used to assess the localization objectively. Inter-aural time difference induced by head related transfer function provided a cue to locate the low frequency horn stimuli. To capture this subtle cue between ears, an efficient binaural interaction processing, comparing timing cues between ears, execution, and decision-making were necessary skills one should have. However, with the advance in aging, the neural correlate of temporal processing skills deteriorates,[3] which in turn has a debilitating effect on interaction processing results in difficult to locate the sound source.[13] Although the horn presented was at positive SNRs, older adults find it challenging to capture the horn sound in noise due to a lesser efficiency of binaural segregation than younger participants of the study.

Further, the spectrum of horn falls within frequencies of traffic noise. The above-explained reasons might have caused the older adults to find it difficult to locate the sound source.

As expected, errors in localization increase with reduced localization ability. Empirically, this was studied by correlating the localization ability from questions with assessing errors in localization task. A moderate significant negative correlation was observed between the localization ability from questions and error in the localization task.

Ideally, both localization ability measured from questionnaire and DOE from localization experiment are required to have an extensive evaluation of localization capabilities in individuals of any age groups. Unfortunately, the majority of the audiological setups do not have the facilities to assess localization ability due to several reasons including space limitation, expertise in carrying out the task, and necessary infrastructure. In such circumstances, the clinician can least use the developed questionnaire to judge the client's localization ability.

Our results in this study indicate the close relationship between localization questionnaire and DOE in localization experiment. Hence, assessing the localization ability through the questionnaire will surely identify the localization difficulties, especially in clinics where no localization setup installed.

Conclusion

Increase in DOE in localization task and reduction in localization abilities were observed with aging. The study found that there is a negative correlation between the DOE from localization task and localization abilities measured from the questionnaire. The results of the study suggest that the questionnaire can be used as the potential tool to assess localization abilities in different age groups.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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