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Research Article

Assessment of Sound Localization and Traffic Sign Recognition in Individuals with Hearing Impairment: Implications for Traffic Safety and Hearing Fitness Certification

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Abstract

Background: Drivers with hearing impairment rely on visual cues, which can lead to road accidents. Studies show mixed results on their driving safety. The current hearing fitness certification protocol is inadequate for assessing hearing ability in traffic conditions.

Method: The study involved 40 participants who were divided into two groups: a control group and a clinical group. The clinical group was further divided based on the severity of hearing loss, which was classified as mild, moderate to moderately severe, and severe. The study evaluated the ability of participants to locate sound and measured the degree of error. Additionally, the study assessed the participant's ability to recognize traffic signs by measuring their correct scores and average reaction time. The assessment was conducted in both unaided and aided conditions.

Results: The clinical group performed worse in locating sounds and recognizing traffic signs compared to the control group. Amplification didn't help much in locating sounds but aided the recognition of traffic signs. There was a correlation between the pure tone average and recognizing traffic signs. Regression analyses were performed to predict the degree of error, traffic sign cognitive correct scores, and the average reaction time from the pure tone average.

Conclusion: When issuing hearing fitness certificates to individuals with hearing impairment, it is recommended that they test their ability to locate sound and recognize traffic signs, in addition to the aided audiogram.

Keywords: Hearing Loss; Localization Ability; Traffic Sign Cognition

Introduction

Individuals with hearing impairment often face challenges related to road traffic safety due to difficulties in identifying potential hazards [1]. However, studies contradict and conclude that individuals with hearing impairment are safe drivers as they rely more on visual than hearing modality [2-5]. Sackey (2015) reported that deaf drivers performed better than their hearing counterparts, effectively utilizing rear mirrors and other senses to compensate for their hearing loss. Thus, providing driving licenses to individuals with hearing impairment holds equivocal results in the literature. Consequently, the issuance of driving licenses to individuals with hearing impairment remains a topic of debate in the literature.

In India, the Delhi High Court (2011) passed a law allowing those with hearing impairments to obtain a driving license, provided they pass a hearing test administered by a professional. However, there is currently no standardized test to evaluate hearing abilities in road traffic conditions for such individuals. Presently, an aided audiogram is conducted using warble tones (250 Hz to 4 kHz in octaves) at 0^0 azimuth in a sound field condition to assess hearing fitness for driving license applicants. Applicants with aided thresholds within the speech spectrum are issued a hearing fitness certificate.

Unfortunately, this test protocol does not adequately assess hearing abilities in realistic road traffic conditions, particularly the localization of sounds from the rear in noisy traffic environments. The study conducted by Thejeswini and Hemanth (2017) developed the test protocol to evaluate the hearing status of hearing impaired in simulated road traffic conditions focusing localization tasks. However, their protocol did not include cognitive assessment, which plays a crucial role in safe driving [6].

It is a well-established fact that hearing loss is strongly associated with cognition decline [7-12] and increased listening effort [13] during driving. Despite relying heavily on visual cues, hearing loss demands a lot of cognitive resources for driving, leaving only a small cognitive workspace to process the spontaneous dynamic event at the time of driving. Thus, localization and cognitive abilities should be assessed before issuing the hearing fitness certificate from a qualified audiologist. The study aims to assess sound localization and traffic sign recognition in a simulated road traffic environment. The study has three objectives: determining the differences in localization errors, cognitive scores for traffic sign recognition, and average reaction time between groups classified based on the degree of hearing loss and also between aided and unaided conditions. In addition, the relationship between pure tone average and each task administered in aided and unaided conditions was investigated. Furthermore, a regression model was developed to predict the audibility from each task in unaided and aided conditions.

Method

A standard group and comparative research designs were utilized to assess the localization ability in a cognitively enriched simulated traffic environment.

Participants

The study recruited 40 participants aged between 40 to 60 years. Out of these, 10 participants with normal hearing without neurological or otological conditions formed the control group. The clinical group included 30 participants who had bilateral symmetrical sensorineural hearing loss. Based on the severity of their hearing loss, the clinical group was further divided into three subgroups - Mild hearing loss (PTA: 26-40 dB HL), Moderate to Moderately severe hearing loss group (PTA: 41-70 dB HL), and Severe hearing loss group (PTA: 70-90 dB HL). Each clinical sub-group comprised 10 participants with no prior hearing aid experience. All study participants had normal middle ear status, normal cognitive score (> 24) in mini-mental state examination and no other otological complaints.

All participants in the clinical group were fitted with digital hearing aids. Aided thresholds were measured for each participant in the clinical group using the NAL-NL2 fitting formula. The directional microphone and noise reduction circuit were disabled for accuracy. The aided thresholds between 0.5 kHz and 4 kHz were found to be within the speech spectrum.

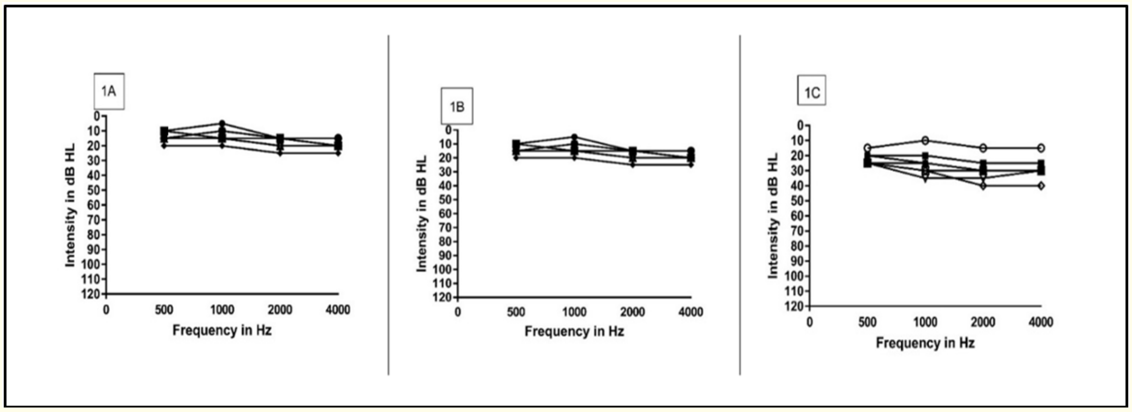

Figure 1: Aided audiogram of each participant in the clinical groups: 1A. Mild hearing loss group 1B. Moderate to Moderately severe hearing loss group and 1C. Severe hearing loss group.

Procedure

Localization ability assessment

The ability to localize sound was tested on the control and clinical group participants. The localization ability was tested in the clinical group under unaided and aided conditions. A target stimulus loaded in Cubase presentation software (Version 2.0.2.) (272 Hz truck horn) was played sequentially and randomly in five speakers at 90^0, 140^0, 180^0, 220^0, and 270^0 azimuth through Lynx aurora sound card. The five speakers are assigned a number from 1 to 5, respectively. In addition, traffic noise loaded in Cubase software was continuously played in four speakers positioned at 40^0, 120^0, 240^0, and 320^0 azimuth through Lynx aurora sound card. Figure 3.2 depicts the setup of the stimulus presentation.

A Bruel and Kjaer hand-held sound level meter (Model no. 2270) mounted on a tripod stand with a half-inch free field microphone (serial no: 02616511) was used to calibrate the target test stimulus (Truck horn) and traffic noise. The sound level meter (SLM) was located at the centre from 2-meter equidistance from each speaker assigned to deliver target test stimulus and noise. In SLM, the A-weighting network, automatic gain control, and fast time network were chosen to calibrate the target stimulus. The target stimulus 272 Hz horn was delivered through Cubase presentation software (Version 2.0.2) routed to the assigned speakers through Lynx aurora sound card. The target stimulus was calibrated at 100 dB SPL. The horn stimulus was calibrated in each speaker by adjusting the volume control in the Lynx mixer of Cubase software (Version 2.0.2) to ensure that the desired intensity was read in SLM. However, traffic noise was calibrated by presenting continuously through the loudspeakers assigned to it and calibrated at 65 dB SPL using a similar procedure. Unlike SLM setting for target signal, a slow weighting network was used in SLM to calibrate traffic noise.

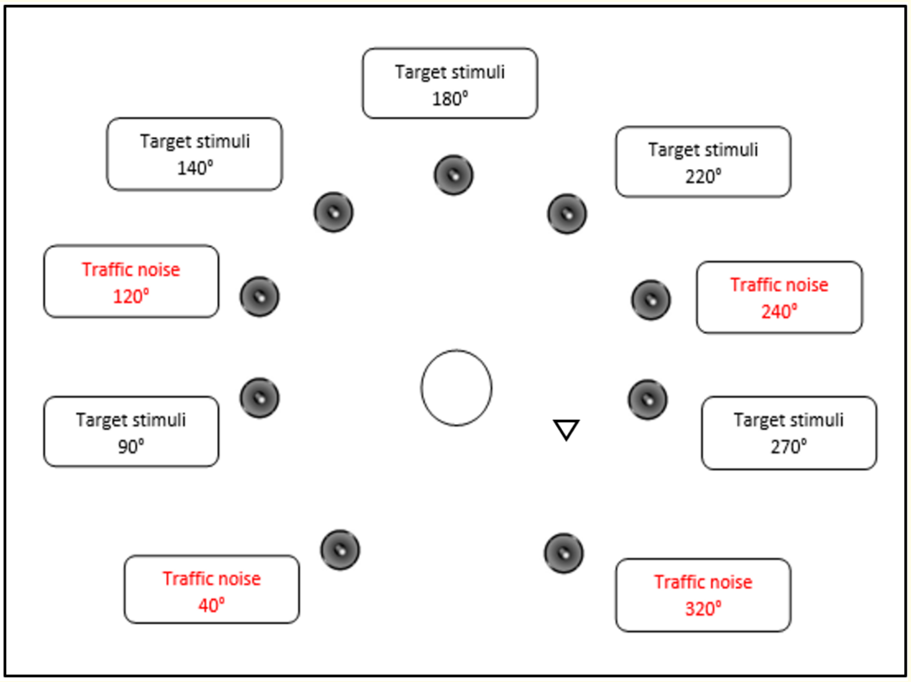

Figure 2: Localization test set-up: Location of the loudspeakers and stimuli assignment.

Each participant was seated at the center of the localization setup in the sound-treated room. The cone of each loudspeaker was positioned at the participant's ear level using the tripod's toggle button. Before the actual testing, a trial run was given to familiarize participants with the test procedure. Each participant received the following instructions: You will hear a horn sound that may come from any of the five speakers positioned at your rear and lateral sides. Your task is to locate the speaker from which the horn sound was delivered by either pointing or telling the number assigned to the speakers. The horn sound in the presence of continuous traffic noise will be delivered four times from each loudspeaker in a random order.

Analysis

The data regarding the loudspeaker number and the corresponding response from the participant for each trial is recorded in Table 1. This data is fed into a confusion matrix software (Version-1) to generate a stimulus-response matrix (Table 2). The degree of error is computed using an Excel-based degree of error application, represented in Table 3. The method of calculating average degree of error given by Ching, Van Wanrooy, Hill, & Dillon (2005) was adopted. The equation to calculate the average degree of error is given below.

$$DOE = \sqrt{(DOE1)2\ +\ (DOE2)2\ + \cdots \ldots \ldots . + (DOEn)2\ /\ N}$$

DOE_1: Degree of error in speaker no. 1

DOEn: Degree of error in the n^{th} number of speaker

RMS: Root Mean Square

N = Number of stimuli presented from each loudspeaker/ overall loudspeaker.

	Response				
Stimulus	**1**	**2**	**3**	**4**	**5**
1	2	0	1	1	0
2	0	4	0	0	0
3	1	0	3	0	0
4	0	1	0	3	0
5	0	1	0	1	2

Table 1: Stimulus and response matrix generated from confusion matrix software for each participant.

	Response				
Speaker number	**1**	**2**	**3**	**4**	**5**
1	0	45	90	135	180
2	-45	0	45	90	135
3	-90	-45	0	45	90
4	-135	-90	-45	0	45
5	-180	-135	-90	-45	0

Table 2: Ready reckoned degree of error.

Traffic sign cognitive abilities

Four different sets of stimuli were used to evaluate the cognitive ability using traffic signs. The cognition test software (Version-1) loaded in a personal computer was utilized to present these stimuli. Each set of stimuli was presented five times in a random order. The four sets of stimuli are given below.

- Target stimulus with distractor stimulus
- Target stimulus with direction congruency
- Target stimulus with colour congruency
- Target stimulus with a mathematical equation of the appropriate distance.

Each participant was seated in a localization set-up where traffic signs were displayed on the computer. At the beginning of each trial, a fixation point was displayed for approximately 1000 ms. The target stimulus was presented for 2000 ms. At the beginning of the experiment, the fixation point was displayed for about 1000 ms to seek the participants' attention, followed by the presentation of target stimulus with a rendering time of 2000 ms. It was done to prompt the subject to identify the target stimulus in a subsequent display. Traffic signs and distractions (other than target stimulus) were displayed for about 6000 ms. Participants were instructed to press either the right or left arrow key to the side where the target name was displayed. An inter-stimulus interval of 7000 ms was assigned before the next stimulus's arrival on the screen. It was ensured that an intra-stimulus interval of 1000 ms was given between the fixation point and target stimulus, as well as the target stimulus and distracting stimulus.

A similar procedure was utilized to deliver a second set of stimuli. The second set of stimuli involved displaying the target stimulus on either side, with the direction shown on the signboard being congruent to the direction of the road on one side and incongruent on the other. Participants were instructed to identify the target with direction congruency.

In the third set of stimuli, the target name and direction were displayed on either side. However, the color of the direction and target name could be either the same or incongruent. Participants were asked to identify the side where both the direction and target name had congruent colors.

In the fourth set of stimuli, a mathematical operation with respect to the distance of the target place was displayed. Participants were instructed to select the signboard where the mathematical equation was appropriate.

Analyses

Correct response and its reaction time (four sets - presented five times) were considered to assess traffic sign cognitive ability. Each correct response was awarded a score of one, and the incorrect response was assigned a score of zero. Cognition test software (Version-1) computes the correct response from the scores obtained from four sets of traffic signs. A maximum score of 20 was assigned for traffic sign cognitive task. In addition, cognition test software (Version-1) software automatically computes the average reaction time from the correct response.

The tasks, i.e., the localization task and the traffic sign cognition task, were presented in a pseudo-randomized order. The presentation of stimuli was organised so that the traffic horn precedes every presentation of stimuli corresponding to the traffic sign cognitive task.

Statistical analyses

The collected data was analyzed using the SPSS (Statistical Package for Social Science) software version 21. The study conducted a detailed descriptive statistics analysis including mean, standard deviation, cognitive score reaction time, and degree of error in both aided and unaided conditions. The effect of hearing loss on the cognitive score, degree of error, and average reaction time was studied using a MANOVA for unaided and aided conditions. Additionally, a Post Hoc Duncan test was performed to compare the performance of groups on each task in both conditions. The unaided and aided performance on various measures was compared using a paired sample t-test. A Karl Pearson correlation was conducted to establish the relationship between pure tone average and cognitive scores. Finally, a regression model was used to estimate performance based on the pure tone average.

Results

The current study examined hearing-impaired individuals' localization abilities and cognition in simulated traffic. Data were collected from both clinical and control groups in aided and unaided conditions, and statistical analyses were conducted using SPSS version 21.0.

Localization and traffic sign cognitive abilities in unaided and aided conditions

Descriptive statistical analysis was conducted to document the impact of hearing loss on the degree of errors, correct scores, and reaction time in both aided and unaided conditions. Table 3 represents the same descriptives in aided and unaided conditions. The results indicated that hearing loss was directly proportional to increased errors in localization tasks, reduced cognitive scores, and longer reaction time in both aided and unaided conditions. Individuals with hearing impairment made more errors than those without in unaided conditions. Moreover, the hearing-impaired individuals demonstrated lower cognitive scores and longer reaction times than individuals with normal hearing. The same results were observed when each group of hearing-impaired individuals was compared with normal-hearing individuals in unaided condition.

A MANOVA was conducted to compare the Control and Clinical groups. The study revealed significant differences between the groups (4 groups in unaided and 3 groups in aided condition): errors made during a localization task, cognitive scores for identifying traffic signs, and reaction times in unaided and aided conditions. The degree of error in the localization task increased with hearing loss. Similarly, increasing degrees of hearing loss also affected traffic sign cognitive scores and reaction times. The results were the same in both the aided and unaided conditions.

A post hoc analysis revealed significant differences between the control group and each clinical group regarding the degree of error in unaided conditions. There was also a significant difference in the degree of error between the mild and severe hearing loss group and between the moderate to moderately severe hearing loss and severe hearing loss group in both aided and unaided conditions. However, there was no significant difference between the mild and moderate to moderately severe hearing loss groups.

The Duncan test showed that participants with mild hearing loss performed significantly better ($p < 0.05$) on cognitive traffic sign scores than the other groups. There was no significant difference between the moderate to moderately severe and severe hearing loss groups. Additionally, individuals with mild hearing loss took significantly less time ($p < 0.05$) to perform the traffic signs cognitive task than those with moderate to severe hearing loss. The post hoc analysis results also remained the same in both aided and unaided conditions.

Table 3: Mean and Standard deviation of the degree of error, correct scores, and average reaction time obtained from the clinical group in the unaided and aided conditions.

	Unaided condition			**Aided condition**		
	Mean ± SD			**Mean ± SD**		
	Degree of error	**Correct scores**	**Average reaction time (ms)**	**Degree of error**	**Correct scores**	**Average reaction time (ms)**
Normal	7.92 ± 4.36	17.5 ± 1.27	2287.35 ± 498.7			
Mild	24.48± 9.72	14.70 ± 2.71	2986.30 ± 751.65	23.30 ± 8.80	16.50 **± 2.71**	2381.57 ± 1119.28
Moderate to Moderately severe	27.35 ± 10.51	12.50 ± 2.91	3626.00 ± 566.16	28.68± 11.45	13.40 **± 2.63**	3005.45 ± 782.58
Severe	42.42 ± 6.08	11.0 ± 1.49	3967.00 ±449.63	40.90± 9.17	11.80 **± 1.32**	3703.90 ± 611.09

Comparing aided and unaided conditions for localization error, traffic sign cognitive score, and reaction time in each group.

A paired sample t-test was conducted to determine whether there was a significant difference between aided and unaided conditions for each clinical group task.

The degree of error in the aided and unaided conditions was compared. Although the degree of error was higher in the unaided condition than the aided condition, the mean difference did not reach significance for the mild hearing loss group [t (9) = 0.276, p = 0.789], the moderate to moderately severe hearing loss group [t (9) = -0.473, p = 0.648], and the severe hearing loss group [t (9) = 0.740, p = 0.478].

Furthermore, the traffic sign cognitive correct scores were compared in the aided and unaided conditions. The mean traffic sign cognition score was higher in the aided condition than in the unaided condition. This difference was significant and was observed in the mild hearing loss group [t (9) = -3.674, p = 0.005], the moderate to moderately severe hearing loss group [t (9) = -2.586, p = 0.029], and the severe hearing loss group [t (9) = -2.753, p = 0.022].

Lastly, the average reaction time was compared in the aided and unaided conditions. The mean traffic sign cognitive reaction time was significantly longer in the unaided condition than in the aided condition. This difference was observed in the mild hearing loss group [t (9) = 2.541, p = 0.0320], the moderate to moderately severe hearing loss group [t (9) = 4.863, p = 0.001], and the severe hearing loss group [t (9) = 3.362, p = 0.008].

Relation between pure tone average and each task in the unaided condition

Pure tone average (PTA) was measured in four groups (N = 40) of participants and correlated with the degree of error in a localization task, cognitive scores for traffic signs, and average reaction time using Karl Pearson's correlation. Linear regression was also used to predict the degree of error, cognitive scores, and average reaction time from PTA. Figure 4 illustrates the linear regression drawn with measured data and the mean of the predicted data for each measure and PTA on a scatter plot in unaided condition.

The results of the correlation analysis showed a strong positive correlation between PTA and degree of error, indicating that degree of error increased with an increase in hearing impairment (N = 40, r = 0.816, p = 0.000). A linear regression analysis revealed a significant model (R2 = 0.666, F(1,38) = 75.70, p = 0.000), with the equation y = a(x) (a = 5.995; b = 0.465), predicting the degree of error from PTA. This suggests that individuals with a PTA of 0 dB HL have a degree of error of 5.995, and a 1 dB increase in PTA would result in a 6.46 degree of error.

The correlation analysis also showed a strong negative correlation between PTA and traffic sign cognitive correct scores, indicating that cognitive scores decreased as hearing loss increased (N = 40, r = 0.714, p = 0.000). The linear regression analysis revealed a significant model (R2 = 0.510, F(1,38) = 39.516, p = 0.000), with the equation y = a(x) (a = 17.741; b = -0.091), predicting traffic sign cognitive correct scores from PTA. This suggests that individuals with a PTA of 0 dB HL have a traffic sign cognitive correct score of 17.74, and a 1 dB HL increase in PTA would reduce traffic sign cognitive score by 0.091.

Finally, the correlation analysis showed a strong positive correlation between average reaction time and PTA, indicating that average reaction time increased as hearing loss increased (N = 40, r = 0.710, p = 0.000). The linear regression analysis revealed a significant model (R2 = 0.505, F(1,38) = 38.734, p = 0.000), with the equation y = a(x) (a = 2222.071; b = 23.66), predicting the average reaction time from PTA. This suggests that individuals with a PTA of 0 dB HL have an average reaction time of 2222.07 ms, and a 1 dB HL increase in PTA would result in an average reaction time of 2244.73 ms.

Relation between pure tone average and each task in aided condition

The study investigated the relationship between pure tone average (PTA) and performance in cognitive and localization tasks in aided conditions among three groups of 30 participants. The study used Pearson's correlation to evaluate the correlation between PTA, degree of error, correct response, and average reaction time. They also employed linear regression to predict the degree of error, accurate response, and average reaction time based on pure tone average. Figure 5 illustrates the linear regression drawn with measured data and the mean of the predicted data for each measure and PTA on a scatter plot.

The results indicated a significant moderate positive correlation between pure tone average and degree of error (r = 0.589, p = 0.001), indicating that as hearing loss increases, the degree of error also increases. The regression model was significant [R^2 = 0.347, F (1, 28) = 14.908, p = 0.001] and predicted the degree of error in aid condition based on PTA. The study result infers the degree of

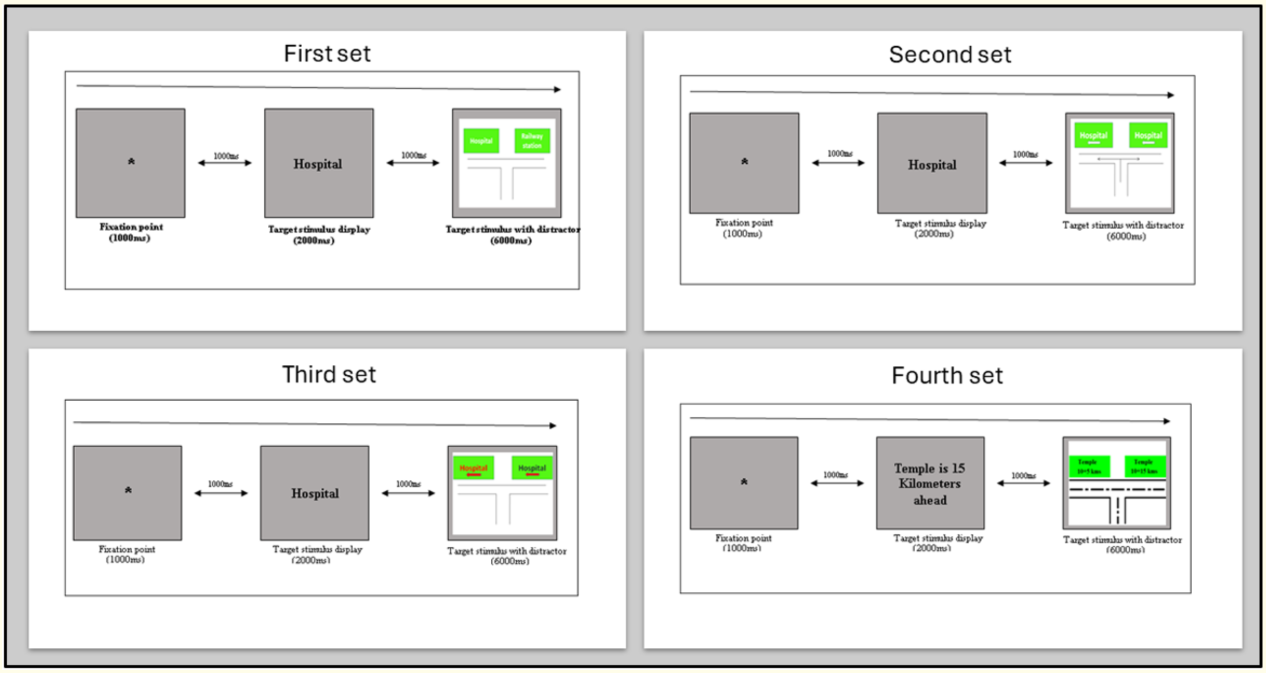

Figure 3: Four sets of stimuli used in traffic sign cognitive task.

error was found to be 12.67 if the individuals have their pure tone average of 0 dB HL based on the obtained equation (y = a +b(x) (a = 12.671; b = 0.348). Further, a 1 dB change in pure tone average would result in 13.01 degrees of error.

The study also revealed a moderate negative correlation between traffic sign cognitive correct scores and pure tone average (r = -0.591, p = 0.001), indicating that as hearing loss increases, cognitive scores decrease. The regression model was significant [R^2 = 0.349, F (1, 28) = 38.734, p = 0.001], and it predicted the traffic sign cognitive correct score in aided condition based on PTA. Based on the equation y = a +b(x) (a = 18.415; b = -0.086) that was obtained, the study infers that the traffic sign cognitive score was found to be 18.41 if their pure tone average is 0 dB HL. Further, a 1 dB HL increase in pure tone average would result in a traffic sign cognitive score of 18.32.

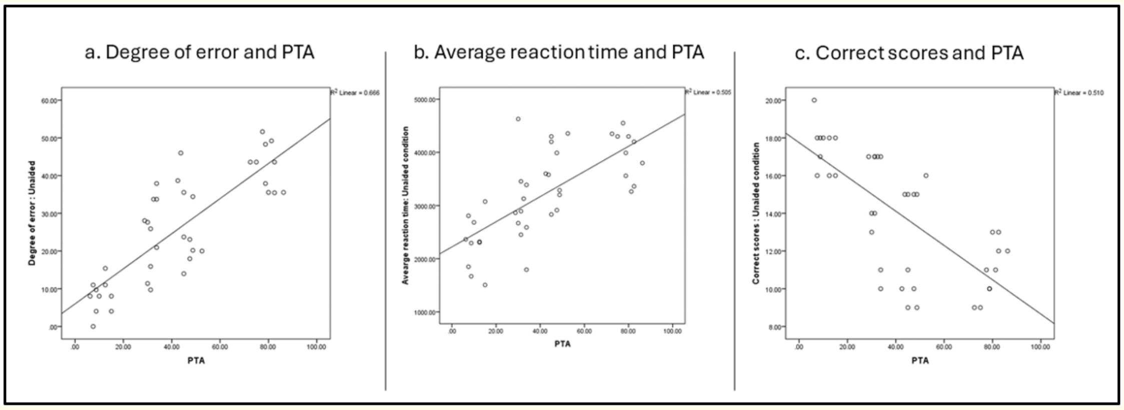

Figure 4: Linear regression drawn with measured data and mean of the predicted data on a scatter plot in unaided condition.

Furthermore, the study found a moderate positive correlation between average reaction time and pure tone average (r = 0.543, p = 0.002), indicating that as hearing loss increases, reaction time also increases. The regression model was significant [R^2 = 0.295, F (1, 28) = 11.715, p = 0.001]. Equation y = b + a (x) (a = 1601.924; b = 26.765) was obtained to predict the average reaction time from PTA. It infers that the average reaction time was found to be 1601.924 ms if their pure tone average is 0 dB HL. Further, a 1 dB HL increase in pure tone average would result in an average reaction time of 1628.69 ms.

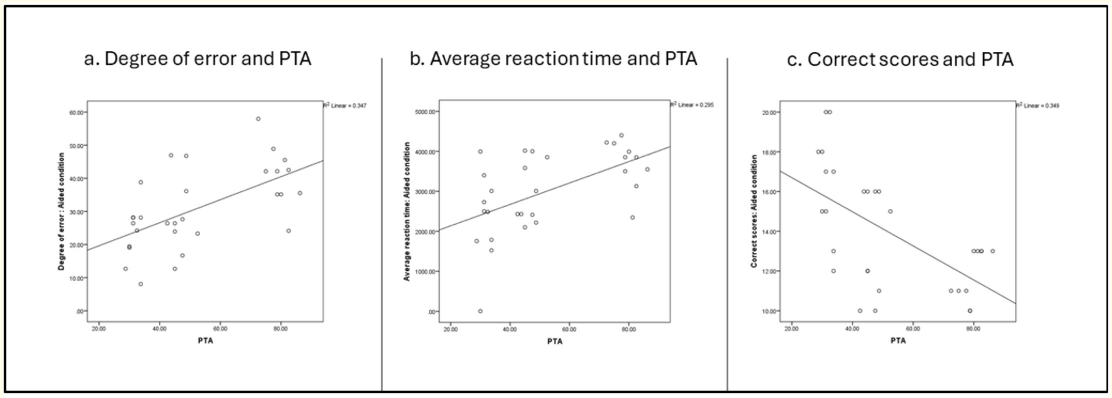

Figure 5: Linear regression drawn with measured data and mean of the predicted data on a scatter plot in aided condition.

In summary, the study found that as hearing loss increased, there was a significant decline in cognitive correct scores and an increase in both degree of error and average reaction time when identifying traffic signs. Additionally, the degree of error, correct scores, and average reaction time were found to have a significant correlation with the level of hearing loss. Using a linear regression model, the study also predicted each task's degree of error, cognitive correct responses, and average reaction time under unaided and aided conditions based on the pure tone average.

Discussion

Participants performed localization in cognitively loaded traffic sign tasks presented pseudo-randomized to simulate the road traffic environment. The clinical subgroups exhibited significantly increased error in localization, reduced scores, and increased reaction time in the traffic sign task compared to the control group, with these differences further pronounced within the clinical group as the degree of impairment increased.

In a localization task, the low-frequency horn was used. Detecting the source of incident sound energy requires the cues of interaural time difference [14], which affect individuals with hearing loss [15]. Specifically, individuals with moderate to moderately severe and severe hearing loss made significantly more errors than the group with mild hearing loss. This can be explained with the help of the travelling wave propagation mechanism. The basilar membrane is stiffer at the base and relatively flaccid at the apical end. A travelling wave usually propagates from the base to the apex. It takes at least 5 to 9 ms for the travelling wave to reach the point of maximum amplitude along the basilar membrane in response to low-frequency stimuli. The normal travelling wave propagation mechanism mainly depends on the nonlinear mechanics of the cochlea, where sharp frequency tuning is mediated by healthy functioning outer hair cells. Damage to the outer hair cell causes a disturbance in the nonlinear mechanics of the cochlea, which in turn affects the traveling wave propagation mechanism. When the traveling wave propagation is affected, ITD (interaural time difference) cues are not efficiently coded, leading to errors in locating the low-frequency sounds [16-18]. The extent of damage to the cochlea increases with the degree of hearing loss. It causes a failure in retrieving the ITD cues [19], reflected in a positive correlation between the degree of error and hearing loss.

Furthermore, precision in phase locking affects individuals with cochlear hearing loss, leading to impaired ITD discrimination [20,21]. In addition, the dual-task paradigm taxes both auditory and cognitive systems. The effort invested by the auditory system to perform the localization task is relatively more significant with an increased degree of hearing loss, leaving a small resource available to do the cognitive task. Thus, in the present study, the cognitive correct score was reduced, and their reaction increased with the degree of hearing loss. The result of the study is in line with the reports of Lin, Yaffe [8], Lindenberger and Baltes [9], Baltes and Lindenberger [10], Uhlmann, Larson [11], Tay, Wang [12], Lin, Ferrucci [22] who have reported that hearing loss and cognition are associated, and with increased hearing impairment, more effort is required to perform the task, eventually leading to errors.

It was observed that there was no significant change in the degree of error between unaided and aided conditions for individuals with hearing impairment. Although hearing aids can restore audibility, they cannot overcome the impaired physiological mechanism observed in SNHL [23,24]. Restoring audibility might not necessarily improve the ability to locate the source of a sound, as the distortion in the auditory system due to physiological impairment persists. Therefore, merely restoring audibility with a hearing aid cannot improve localization ability. Furthermore, the additional delay induced by the hearing aid's signal processing strategies might distort the original ITD cues of the incoming signal [25,26].

Individuals with hearing impairment who have been deprived of auditory stimulation may have developed alternative compensatory strategies (e.g., head and body movements, visual searching) to locate sound sources [27]. Furthermore, the brain exhibits malleability in interpreting the newly amplified signal until it retrains and integrates it into auditory memory. In the current study, novice hearing aid users exposed to novel sounds did not show an improvement in their ability to localize sounds with aided conditions compared to unaided conditions. The microphone location effect might contribute to the poorer localization performance observed during the study [28,29]. Localization performance with hearing aids was assessed using a behind-the-ear (BTE) hearing aid. Typically, microphones in BTE hearing aids are positioned away from the eardrum, which affects the original interaural time difference (ITD) cues. Front microphone placement distorts ITD information at −90° and +90°, potentially affecting localization performance [30]. However, the clinical group participants showed significantly better performance in traffic sign cognitive abilities in the aided condition compared to the unaided condition. Individuals took less time to complete the cognitive task and scored higher than in the unaided condition, which was significant. This improvement could be attributed to hearing aids reallocating resources for both localization and cognitive tasks. Despite observing localization errors in the aided condition, fewer resources were needed for the localization task, allowing more cognitive resources to be available for increased correct scores and reduced reaction times in the cognitive sign task, contrasting with the unaided condition.

Individuals in India applying for a hearing certificate for a driving license must meet aided thresholds within the speech spectrum, traditionally being used to assess hearing ability in road traffic conditions. Research findings indicate that even if aided thresholds fall within the speech spectrum, individuals may still struggle to locate sounds during cognitively demanding traffic sign tasks. Accurate sound localization in noisy traffic conditions is vital for safe driving. Therefore, it is essential to incorporate localization tasks with cognitive loads simulating real road traffic situations into the hearing ability assessment protocol for individuals with hearing impairment seeking a hearing fitness certificate. A regression model has been devised to predict the extent of error, traffic sign cognitive scores, and average reaction time based on an individual's pure tone average. This model offers more precise predictions of localization errors and cognitive scores, surpassing the reliance solely on an aided audiogram to determine hearing fitness.

Conclusion

The study examined localization tasks combined with cognitive traffic signs in a simulated road traffic setting among individuals with hearing impairment. Findings indicated that, despite appropriate gain adjustments, there was no significant improvement in localization ability. The localization error rate heightened with the severity of hearing loss, accompanied by a notable decrease in cognitive scores and increased reaction time. As a result, it is recommended that localization skills be evaluated through cognitively demanding tasks rather than relying solely on the aided audiogram to certify the hearing status of driving license applicants.

Implications of the Study

The study findings suggest incorporating localization tasks combined with cognitive challenges to evaluate hearing ability in road traffic conditions, particularly for individuals seeking a hearing status certificate for a driving license. This approach offers a more thorough assessment of an individual's hearing capabilities, contributing to the safe operation of a motor vehicle.

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Data Availability Statement

Data will be made available upon request.

Ethics Approval

The protocol was approved by the Institutional Ethics Committee at JSS Medical College, Mysuru (JSSMC/IEC/110523/14 NCT/2023-24).

Conflict of Interest Statement

No potential conflict of interest was reported by the author(s).

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