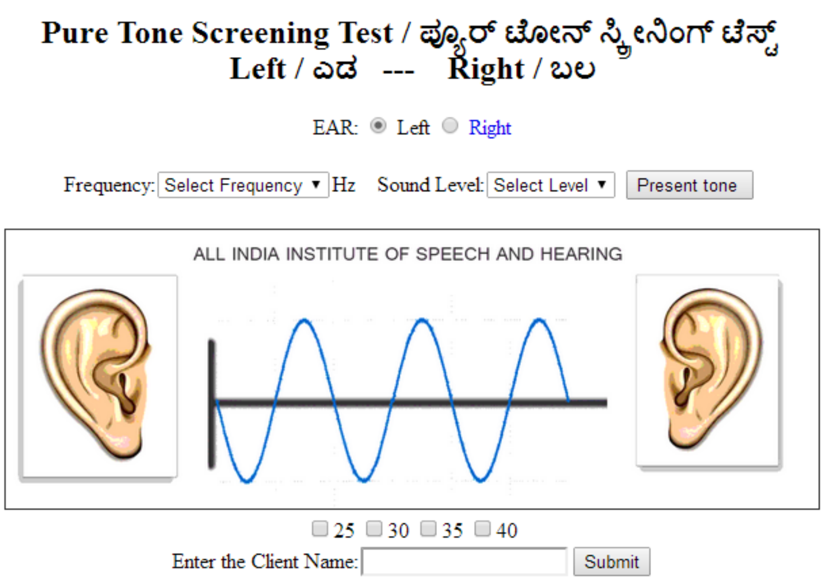
PROJECT REPORT

DEVELOPMENT OF ONLINE SYSTEM FOR HEARING SCREENING

AIISH Research Fund Project No. SH/CDN/ARF/4.63/2013-2014



All India Institute of Speech and Hearing

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DEVELOPMENT OF ONLINE SYSTEM FOR HEARING SCREENING

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Contents

CHAPTER 1

Introduction

India is the second most populous country in the world, with over 1.21 billion people and has a huge number of people with communication disability (Census, 2011) out of which 5 million are hearing impaired. The World Health Organization (WHO) describes hearing loss as an epidemic and states that hearing loss related disabilities can affect up to 16% of the population. There are 360 million persons in the world (5.3% of the world's population) with hearing loss (WHO, 2012).

The National Sample Survey Organization (NSSO, 2002) has reported that in India, there are 291 per 1, 00,000 of the population with hearing disability and in rural areas it is around 310 persons per 1,00,000 with hearing disabilities. Hearing loss can lead to communication disabilities, social withdrawal, confusion, depression, and deterioration in functional status. Hence, it becomes important to identify the individuals at risk for the hearing impairment and start the intervention at the earliest. One way to detect hearing impairment is through hearing screening, where the main objective is to identify individuals with possible hearing deficits at the earliest possible stage in order to refer for diagnosis and treatment, if required.

Screening school children for hearing loss has been recommended since 1963 (Hoenig & Leah, 1963). Adults are screened in their doctor's clinic, camps or institutes whereas preschoolers and children are screened in the schools periodically. Hearing screening programs have been conducted for many years and there are standard subjective and objective methods which are used for the same. Subjective methods used for hearing screening include pure tone hearing screening and administration of questionnaires. In pure tone hearing screening, thresholds are noted at 1000 Hz, 2000 Hz and 4000 Hz at 25 dB HL (ASHA, 1996) and it is the gold standard method for hearing screening since it gives frequency specific information. In questionnaires, there are set of questions related to the individual's state of hearing, handicap caused by hearing, social participation, quality of life etc.

Newborns are screened before they leave the hospital under the Newborn Hearing Screening Program. This is done with the help of the objective measures using Otoacoustic emissions (OAEs) and Automated Auditory Brainstem Responses (AABRs). The presence of evoked OAE responses indicates hearing sensitivity in the normal to near-normal range. OAEs are fast, efficient, and frequency-specific measurements of peripheral auditory sensitivity. However, the effectiveness of the test is reduced by contamination with low-frequency ambient noise in a busy nursery, vernix in the ear canal, or any middle ear pathology. AABR is an electrophysiological measurement that is used to assess auditory function from the eighth nerve through the auditory brainstem. It is mostly used to screen young infants. Thus, in the recent years, there has been a rapid evolution in the development of fast, easy and reliable techniques for hearing screening.

WHO (WHO, 2012) also reports that in India there are 10,65,462 inhabitants per audiologist compared to 19,603 inhabitants per audiologist in the USA. This reflects the acute shortage of trained manpower available in our country for early detection of hearing loss and intervention. However, there is increase in speech and hearing professionals with 51 training institutions generating manpower in the field of speech and hearing. But, the majority of the trained manpower either opt for higher studies in India or abroad or prefer to work in foreign nations due to better emoluments. Thus, persons with communication disorders do not have access to professionals owing to lack of a sufficient number of professionals, distance that they have to travel, and the number of days that they need to spend on rehabilitation. In India major population is in the villages and thus, the existing number of professionals in the field is insufficient to cater to the demand. Moreover, the speech and hearing professionals are mostly located in major cities and thus it is difficult to reach population in rural areas. Thus the village population is deprived of access to objective and subjective methods of hearing screening due to lack of manpower and non-availability of infrastructure.

National Program for Prevention and Control of Deafness (NPPCD) was initiated in 25 districts derived from 10 states and 1 union territory in the year 2008, by Government of India. The highlights of the major components of the program were to focus on prevention, early identification and manpower development for management of persons with hearing impairment. Since the program is also being implemented at the primary health care level, it envisages a reduction in the burden of deafness and prevention of future hearing loss in India. However, due to various reasons the program is not implemented successfully and the services have not reached the population in rural and semi urban areas. Hence there is a need to develop a hearing screening system for the country's rural masses.

There is a dearth of professionals in our country who can travel to the villages and serve individuals. This limited manpower makes it necessity to develop an alternate option to increase the access for rural patients. Long distance communication medium based assessment and rehabilitation can be considered as a suitable alternative to address the shortage of such manpower. Few examples of these include the use of Information and Communication Technology (ICT) tools such as videoconferencing system, websites, telephones etc.

Tele - assessment and rehabilitation of persons with speech and language disorders is being tried in India in the recent past, however related to hearing difficulties still research needs to be done. AYJNIHH, Mumbai started a tele-self assessment program on the web titled "Know your hearing through web" in the year, 2000 (www.ayjnihh.nic.in). The advantage of this program is that it is validated and person himself can assess his hearing difficulty. However, this program evaluates hearing through qualitative assessment using a questionnaire.

Smits, Kapteyn and Houtgast (2004) developed a computerized test which can be administered through telephones. This is a test of hearing screening measuring the speech reception thresholds in the presence of noise. The test is automated and uses digit triplets as the stimuli. They report that the telephone type and listening environment did not have any influence on the thresholds. Authors claim that the test has a sensitivity and specificity of 0.91 and 0.93 respectively. However, the availability of telephones in the rural setup is uncommon in India and hence restricts the usage of this method.

Tele-practice for clinical service delivery was also started by the Department of Speech, Language and Hearing Sciences at SRU, Chennai in 2011. Tele-ABRs were used for diagnostic confirmation of hearing loss after two levels of screening by community workers in 34 villages of Kanchipuram district in Tamil Nadu. ABRs have been obtained using satellite based mobile telemedicine van placed at an NGO in rural site using IP based systems. However, the outcome of this tele ABRs is still not validated.

However, there are few existing online hearing screening methods available in some of the hearing aid websites which include screening through questionnaires and tonal testing. Kam et al. (2013) have developed an automated pure tone hearing test system for screening school going children. The system uses a Tablet computer and a pair of noise cancelling headphones. Hearing screening is carried out in the form of an interactive listening game to sustain children's attention. But this system has low sensitivity and specificity. The hearing aid companies such as Phonak, Starkey also encompasses online hearing test where pure tone hearing screening is carried out. But the validation of these procedures is questionable. Thus till date, there is no program in India which enable us to do the hearing screening utilizing the Information and Communication Technology

A questionnaire is the main means of collecting quantitative primary data and it ensures standardization and comparability of the data across interviewers, increases speed and accuracy of recording, and facilitates data processing. The advantages of administering a questionnaire are:- it is practical, large amounts of information can be collected from a large number of people in a short period of time and in a relatively cost effective way. The results of the questionnaires can usually be quickly and easily quantified by either a researcher or through the use of a software package. It can be analyzed more 'scientifically' and objectively than other forms. Also, when data is quantified, it can be used to compare and contrast with other research and may be used to measure change.

There are few standardized screening questionnaires available to identify hearing impairment. Hearing Handicap Inventory for the elderly (HHIE) (Ventry & Weinstein, 1982) is a widely used questionnaire which has good internal consistency and content validity. It has ten items with three point rating scale. Screening version of the questionnaire has ten items which attempt to quantify the degree of impairment. However, this questionnaire might not be suitable for the Indian context, as the questions are framed according to the western life style.

Few questionnaires have been developed in Indian context which include self assessment of hearing handicap (Vanaja, 2000). It assesses self perceived hearing handicap in various situations such as familiar/unfamiliar, quiet/noisy, with/without visual clue. There are fifty items in the questionnaire and uses three point rating scale. Hence it takes more time to complete the questionnaire. The short form of this questionnaire is available which has only ten items with three point rating scale. However, this short form of the checklist doesn't cover all the listening situations usually encountered by a person, especially in the rural areas.

Check Your Hearing (AYJNIHH, Mumbai) is a screening checklist available online to self check the hearing. It has ten questions with only two point rating scale and hence it narrows down the responses of the person.

There are also few questionnaires developed by hearing aid companies like Phonak and Starkey which are self administered online. These questionnaires have very limited questions to illustrate a person's setback and standardization of these questionnaires is questionable. These questionnaires use two point rating scales which set confusion in a person's mind to report the extent of the problem. Thus a properly validated and effective questionnaire which can be used as a screening tool in Indian rural context is not available.

Need for the Study

Review of the past research, as summarized above, shows a need to develop a calibrated online shearing screening system with good sensitivity and specificity for use at Indian rural areas, overcoming the short comings of all the existing methods and technology. Considering all the limitations of the existing questionnaires, there is a need to also develop a questionnaire for hearing screening in the Indian rural context.

Aim of the Study

The aim of the present study was to develop an online system for hearing screening suitable for use at Indian rural areas, supplemented with a questionnaire based assessment.

Objectives of the Study

The main objectives of the study include:-

Phase I:

1. Developing a standardized questionnaire for hearing screening in Kannada.
2. Validation of the developed questionnaire

Phase II:

1. Developing a pure tone hearing screening software
2. Developing a stimulus delivery system
3. Objective calibration of the stimulus delivery system.
4. Validation of the developed hearing screening system.

Another objective of the study involved comparing test results/questionnaire outcomes administered by social worker and the professional.

CHAPTER 2

Method

The project was implemented in two phases. The first phase involved the development of a standardized questionnaire for hearing screening and the second phase involved the development of a calibrated online hearing screening system.

Phase I

Development and Standardization of questionnaire

a. Structure of the questionnaire

The questionnaire was developed initially in English language and to form the questions the following were considered:-

1. different listening situations (communication in quiet, communication in noise, listening over telephone) faced by normal hearing individual in Indian scenario.
2. few standardized screening checklists like Self Assessment of Hearing Handicap (Vanaja, 2000), Check Your Hearing (AYJNIHH, Mumbai).
3. appropriate suggestions from the experienced professionals (Audiologists and Speech language pathologists).

Based on the above, ten questions were framed with five point rating scale (0-4), wherein

0 - All the time- 100% of the time

1 - Most of the time -75% of the time

2 - Sometimes - 50% of the time

3 - Seldom - 25% of the time

4 - Never - 0% of the time

b. Standardization

These questions were given to five experienced audiologists and five laymen for finding out whether the questions were correctly comprehended or not. They were asked to rate/categorize the questions into 'meaningful and completely understood', 'ambiguous' and 'didn't understand'. The questions rated as ambiguous and didn't understand were modified based on their suggestions. Later the questionnaire was translated into Kannada. Reverse translation of the questionnaire in English was carried out by two native speakers of Kannada and necessary corrections were incorporated. Later the developed questionnaire (in Kannada) was given to five native speakers of Kannada (who were audiologists and speech language pathologists) for validation following the same procedure as mentioned before. Questionnaire in English and Kannada, used for the study are given in the Appendix 1 and 2 respectively.

Validation of the developed questionnaire

a. Participants

Five groups of participants were considered for the study. All the participants were native Kannada speakers will bilateral symmetric hearing loss. First group contained individuals with normal hearing sensitivity (N = 30). The other four groups contained individuals with hearing impairment with 30 participants in each group. Written consent was taken from all the participants for willingly participating in the study and the clearance was taken from AIISH ethics committee.

Group 1 included thirty participants aged above eighteen who are native Kannada speakers. All the participants had their pure tone air and bone conduction thresholds within 15 dBHL at octave frequencies from 250 Hz to 8000 Hz and from 250 Hz to 4000 Hz respectively. The speech recognition thresholds were within ± 12 dB of the Pure Tone Average (PTA) and speech identification scores were ≥ 90% in both the ears in quiet condition for all the participants. All the participants had normal middle ear functioning with bilateral 'A' type tympanogram with acoustic reflexes present in both the ears. No history of middle ear infections, speech and language disorder, neurologic disorder or any cognitive listening deficits were reported by participants. None of the participants complained of any illness at the time of testing.

Group 2, 3, 4 and 5 were comprised of 30 individuals each having minimal, mild, moderate and moderately severe degree of Sensori Neural hearing loss, respectively. Pure tone average for the minimal, mild, moderate and moderately severe degree of hearing loss ranged from 16- 25 dB HL, 26 – 40 dB HL, 41 – 55 dB HL and 56 – 70 dB HL respectively. Speech recognition thresholds were found to be within ± 12 dB of PTA. None of the participants complained of active middle ear infection. Immittance tympanometry or reflexometry was done, to rule out middle ear dysfunction.

Procedure

All the participants were informed about the study and written consent was taken. Demographic data of all the participants were collected and a hearing screening questionnaire was administered to all the participants prior to the online hearing testing. All the selected participants were explained about the need and objectives of the study before the questionnaire was administered. Each question was read out (explained when necessary) to each participant by the researcher. Then they were asked to rate their problem among one of the five scales mentioned earlier. Scoring was done and total score (out of 40) was obtained for each participant.

Phase II

Development of the Online system for Hearing screening

The development of the online hearing screening system involved three steps. In step 1, a software for pure tone hearing screening was developed, step 2 involved development of stimulus delivery system at the receiver end (laptop in the field) and linking it with the control station at the source end (AIISH, Mysuru). Step 3 involved calibration of the stimulus delivery system and in step 4 validation of the developed system was done by administering the screening test on selected population.

Step I - Developing software for pure tone hearing screening

Software for pure tone hearing screening was developed at the All India Institute of Speech and Hearing, Mysuru. The program for the hearing screening software was written in MATLAB. In the study, hearing screening was administered using a laptop with the accessories such as headphones (GSI TDH 39) and a data card (MTS M blaze) for wireless internet connection. Four pure tone frequencies (500, 1000, 2000 & 4000 Hz) were generated as recommended by ASHA guidelines (2005) at different intensity levels using Matlab code.

The screen shot of the home page of the screening software is shown in the appendix 3. The home page of the screening software has an option to either login or retrieve the old reports or the contact details. The login page of the software requires to enter the login ID and password which would lead to the patient's details screen. The screen shots of login and patient's details page are shown in the appendix 3. The patient's details page allows to enter the demographic details of the patient, otological and medical history and details about earlier evaluations.

After filling the patient's details in the software, it leads to the screen where either hearing screening questionnaire or pure tone screening test can be selected. Selecting the option of the questionnaire would allow the examiner to administer the hearing screening questionnaire on the client.

The total score for a particular client will be displayed at the end of the test. Selecting the option of hearing screening would allow the examiner to test the hearing threshold at the four frequencies mentioned above. This screen provides the examiner to select the testing ear, testing frequency, testing level and to save the result (appendix 3). The software also has an option to view the results of each patient by selecting the 'reports' icon on the home screen (appendix 3).

Step II - Development of a stimulus delivery system

Step II involved the development of a stimulus delivery system (Figure 1), which would be placed at the receiver end located at the targeted site (semi urban and rural areas). The software developed at step I is loaded to a laptop with headphones (Figure 1). The portable hardware interface (for keeping the stimulus calibrated) between the laptop and the headphones was also developed. This stimulus delivery system was linked with the central station located at AIISH, Mysuru through a wireless internet connection (Figure 1). The entire stimulus delivery system is battery operated so that the power interruptions in rural areas will not affect the screening.

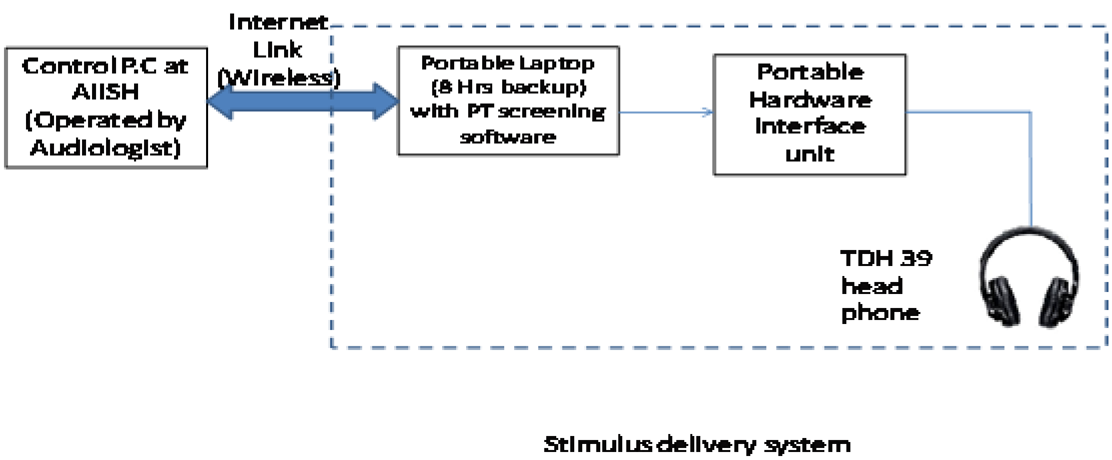

Figure 1: Functional Block Diagram of the Developed Online System for Hearing Screening

Step III - Calibration of stimulus delivery system

The accuracy of the generated pure tone for frequency and intensity was checked for. The stimulus was played from the laptop where the software was installed and was recorded using the SLM (B & K). The recorded file was transferred to the system using the software (BZ 5503) and later, this file was analyzed using the Pratt software. The total harmonic distortion of the frequency of the test signal was within the permissible limits which is <2% (ANSI S3.22-2003).

These pure tones were calibrated at different levels viz. 25, 30, 35 and 40 dB HL from the laptop through the headphones for three seconds (Kam et.al., 2013) and the inter stimulus interval ranged from 4-6 seconds. The output of the headphones was measured with the Artificial Ear (Larsen & Davis AEC 101) connected to a Sound Level Meter (Larsen & Davis 824) which measured the output of the system via the headphones. The output for the right and left headphones were measured separately. At each frequency, the signal amplitude was adjusted till the values shown in the SLM matches with the target RETSPL values. The attenuation characteristics of the headphones used (TDH 39) are given below in Table 2.1:-

f(Hz)	125Hz	250Hz	500Hz	1 kHz	1.6kHz	2kHz	3.15kHz	4kHz	6.3kHz	8kHz
Mean (dB)	5.1	2.8	6.1	12.9	18.7	22.4	27.9	28.3	24.5	24.5
s.d. (dB)	6.8	4.6	5.5	4.8	3.5	4.6	5.3	5.2	8.6	7.5

Table 2.1: Mean and Standard Deviation for the sound attenuation of TDH 39 headphones

Step IV- Validation of the developed system

Step III involved the validation of the developed system through field testing. A total of two hundred seventy participants aged 18 years and above participated in the study. All of them were from the nearby villages (approximate distance of 25 km from the central station) of

Mysore district in Karnataka, India. All the participants voluntarily participated in the study and were not paid for it. All the participants completed both hearing screening through the developed system and using manual pure tone audiometry through portable audiometer. The hearing screening was done at four test frequencies (500, 1000, 2000 & 4000 Hz) and at four different intensity levels (25, 30, 35 & 40 dB HL). 25 dB was included as per ASHA guidelines, 30 dB was included as it was used in some of the earlier studies, 35 dB & 40 dB was used as an extended range as it gives supplementary information. Duration of the pure tones was 3 seconds (Kam et.al., 2013) and the inter stimulus interval ranged from 4-6 seconds. The test was carried out in a lesser noisy area where the noise levels ranged between 70-75 dB A, which was measured prior to the testing session. The hearing screening started with right ear at 500 Hz and 25 dB HL. The participants were instructed to indicate when he/she hears the tone. If there was a positive response test was repeated at the next frequency. If the participants did not hear the tone, the tone level was increased up to 40 dB HL in 5dB steps till a positive response was obtained. The same procedure was followed for other frequencies and for the other ear. Tones were presented three times and the response which was repeated 2 times was considered.

The participants who had hearing thresholds as 25 dB HL at all the frequencies and in both the ears were considered passed. The participants who failed to respond at 25dBHL even at single frequency were referred for the complete diagnostic evaluation.

The manual hearing screening test was carried out using a portable audiometer (Proton Dx) with Telephonics TDH-39 supra-aural headphones on all the participants. The equipment was calibrated according to ANSI S3.6-2010. The test was performed in the same environment as the hearing screening was done through the developed system. Air conduction thresholds at 500, 1000, 2000 and 4000 Hz were estimated using the bracketing method.

All the procedures which were mentioned in both phase I and II were also investigated by a social worker upon training from the research officer. The social worker observed the operation of the system for one full day along with the experienced professional. Training was also given on how to prepare the client to start the test and how to organize the system for the test. Fifteen participants who were selected in a village were tested by both research officers and the social worker.

CHAPTER 3

Results

Software for pure tone hearing screening was developed with the front end code on PHP and back end code in Java script. The code for generating pure tones in four frequencies (500, 1000, 2000 & 4000 Hz) was written in MATLAB. The facility for saving the calibration values were also incorporated in MATLAB. After filling the patient's details in the login page of the software, either hearing screening questionnaire or pure tone screening test was selected. After selecting the appropriate option, the client was tested either using the questionnaire or the hearing screening test. The control of the software was done through Desktop sharing mechanism (AMMYY admin / team viewer) using wireless internet link. The total score for a particular client is displayed at the end of the test. The results obtained during phase 1 & 2 of the development of the Online system for hearing screening are summarized below:-

Phase I

In this phase, the focus was on developing a questionnaire and administering it on individuals with normal hearing sensitivity and clinical group. The questionnaire was administered on 30 individuals with normal hearing and on 120 individuals with different degrees of hearing loss. The median of the scores obtained for each question in different groups is tabulated in Table 3.1.

Table 3.1: Median scores for each question in different groups.

Qn. No.	Groups				
	Normal	**Minimal**	**Mild**	**Moderate**	**Moderately Severe**
Q1	4.00	3.00	3.00	2.00	0.00
Q2	4.00	3.00	3.00	2.00	1.00
Q3	4.00	4.00	4.00	2.00	1.50
Q4	4.00	2.00	2.00	1.50	1.00
Q5	4.00	2.00	3.00	2.00	1.00
Q6	4.00	4.00	4.00	3.00	2.00
Q7	4.00	4.00	3.50	2.00	1.00
Q8	4.00	3.00	2.00	2.00	1.00
Q9	4.00	4.00	4.00	2.00	2.00
Q10	4.00	4.00	4.00	3.00	2.50
Median of Total score	40.00	32.50	31.50	21.00	12.50
Range	37-40	23-36	17-33	14-32	04-19

As seen in Table 3.1, the median score obtained for individuals with normal hearing is 4 for all the questions. But for individuals with minimal hearing loss and mild hearing loss, it ranged from 4 to 2. Persons with moderate and moderately severe hearing loss achieved a median range of 3 to 1.5 and 2 to 1 respectively.

The Kruskal Wallis test was administered to examine whether there is any significant differences in scores between the groups for each question. The test results revealed that there is a significant difference in scores between the groups for all the questions which is depicted in the Table 3.2 ($p<0.001$).

Table 3.2: Chi-Square values of group comparison for each question

	Chi-Square	**P value**
Q1	109.635	0.000
Q2	106.666	0.000
Q3	111.287	0.000
Q4	96.307	0.000
Q5	76.914	0.000
Q6	92.642	0.000
Q7	110.868	0.000
Q8	112.627	0.000
Q9	95.868	0.000
Q10	110.529	0.000
Total	121.790	0.000

Later, the Man Whitney U test was administered to assess significant differences between each group and 10 comparisons were made between the groups for each question. The results of the test are tabulated in Table 3.3. Test results revealed that all the group comparisons except the comparison between minimal and mild group showed a significant difference. Group comparisons between minimal and mild hearing loss participants [p = 0.083] showed no significant differences.

Table 3.3: Significance level obtained for paired group comparisons

Group Comparisons	**Significance level (p)**
Normal and Minimal	0.000
Normal and Mild	0.000
Normal and Moderate	0.000
Normal and Moderately Severe	0.000
Minimal and Mild	**0.083**
Minimal and Moderate	0.000
Minimal and Moderately Severe	0.000
Mild and Moderate	0.000
Mild and Moderately Severe	0.000
Moderate and Moderately Severe	0.000

Phase II

The developed online hearing screening system uses a menu driven computer-based system with the test procedures made automatic and standardized, thus requiring minimal expertise to conduct the test. It also has the facility for digital storage of data for offline review.

The online hearing system has a stimulus delivery system, implemented on a laptop with head phones which is placed at the receiver end located in the targeted site (semi urban and rural areas). The hardware interface between the laptop and the earphone was also developed. The stimulus delivery system is linked to the central station, which is located at the All India Institute of Speech and Hearing, Mysuru through a wireless internet connectivity. The entire system is battery operated with a back up of 3 hrs.

To validate the system, hearing screening was performed on a total of two hundred and seventy ears using both online hearing screening software and portable audiometer. All the participants could complete the test successfully. The average time required for testing through software was around three to five minutes, including the time for administration.

The referral rates were calculated for two different referral criteria. Table 3.4 shows the number of participants referred with different methods and different criterion levels. When the referral was made with the criteria set to 25 dB, that is when the participants was not able to hear at that level for any one frequency and in any one ear the referral rate of the screening test through the software was 58.14% (157/270). When the referral criteria were set for 30 dBHL, the referral rate reduced to 43.33% (117/270). The data of number of participants referred using two different methods and two different criterion levels is given in Table 3.4.

Table 3.4: Number of participants referred using two different methods and two different criterion levels.

a. For 25dB criteria

	Portable Audiometer		
Screening Software	**Pass**	**Refer**	**Total**
	105	8	113
	25	132	157
	130	140	270

b. For 30 dB criteria

	Portable Audiometer		
Screening Software	**Pass**	**Refer**	**Total**
	147	6	153
	5	112	117
	152	118	270

The sensitivity and specificity of the developed online hearing screening test was calculated by comparing with the test results obtained through portable audiometer which was considered as the gold standard. When the referral criterion was set to 25 dB HL, the overall sensitivity and specificity of the screening software were found to be 94.29% and 80.77% respectively. The positive predictive value and negative predictive value for 25 dBHL criterion level was 84.08% and 92.92% respectively. When a higher criterion level of 30 dBHL was considered, it showed a sensitivity of 94.92%, specificity of 96.71%, positive predictive value of 95.73 % and negative predictive value of 96.08%.

The sensitivity and specificity of the screening software were also calculated for different test frequencies (500 Hz, 1000 Hz, 2000 Hz & 4000 Hz) at two referral criterion levels. These results are tabulated in Table 3.5. It can be noted from the Table 3.5 that the specificity at 500 Hz was lesser at both the referral criterion levels compared to other higher frequencies.

Table 3.5: Sensitivity and Specificity for different frequencies and at two criterion levels.

Frequency	**500 Hz**		**1000 Hz**		**2000 Hz**		**4000 Hz**	
Criterion	25	30	25	30	25	30	25	30
Sensitivity (%)	94.69	96.59	96.30	96.84	95.37	97.85	95.76	96.15
Specificity (%)	82.8	94.51	93.83	97.71	93.83	96.05	88.16	95.18

The agreement between the thresholds obtained trough screening software and portable audiometer was evaluated using kappa coefficient. The results showed that there is an almost very good agreement between both at all frequencies and at both criterion levels as shown in the Table 3.6. (p <0.001).

Table 3.6: Agreement between the thresholds obtained trough screening software and portable audiometer evaluated through Kappa coefficient

	25 dBHL Criterion Level		**30 dBHL Criterion Level**	
Frequency	Kappa	P value	Kappa	P value
500 Hz	0.755	0.000	0.893	0.000
1000 Hz	0.893	0.000	0.943	0.000
2000 Hz	0.885	0.000	0.927	0.000
4000 Hz	0.829	0.000	0.907	0.000
Overall	0.75	0.000	0.917	0.000

Another objective of the present study was to compare the results of the online hearing screening software when the tester was an audiologist and when the tester is a social worker. For this purpose 15 participants from a village who were randomly selected were tested both by the researcher audiologist and by the social worker. The results were compared using Pearson's Chi-square test and is represented in the Table 3.7. The comparison between the two testers were done in four domains, i.e. screening with a criterion of 25dBHL, screening with a criterion of 30dBHL, questionnaire scores at the cutoff 75% and questionnaire scores at the cutoff 90%. Results showed that there were no significant differences between the results when the administration of the software was done with two testers. Thus, it can be inferred that a social worker can effectively conduct online hearing screening.

Table 3.7: Chi-Square values of comparison between the tests obtained by a researcher and social worker

Domains	**Researcher**		**Social worker**		**Chi Square**	**P value**
	Pass	**Refer**	**Pass**	**Refer**		
Screening with a criterion of 25dBHL	3	12	2	13	0.240	0.624
Screening with a criterion of 30dBHL	10	5	9	6	0.144	0.705
Questionnaire scores at the cutoff 75%	10	5	11	4	0.159	0.690
Questionnaire scores at the cutoff 90%	8	7	10	5	0.556	0.456

CHAPTER 4

Discussion

The objective of the project was to develop an online hearing screening system supplemented with a questionnaire which was executed in two phases.

Phase I

In this phase, the objective was to develop a questionnaire and distinguish individuals with different degrees of hearing impairment based on the questionnaire scores.

The groups taken for comparison were normal hearing individuals, individuals with hearing impairment individuals with minimal, mild, moderate and moderately severe degree of hearing loss. The results demonstrated a significant difference between all the groups except between minimal and mild group. The probable reason for overlapping of scores in these groups could be that the difference in the degree of hearing impairment between the minimal and mild degree of hearing loss may be very subtle. It can even be interpreted that the present questionnaire is unable to tap the subtle hearing handicap disparities between these two groups.

There are screening tools which declare a correlation between the self perceived hearing handicap and pure tone thresholds. Vanaja (2000) reports a significant relation between the self reported hearing handicap and pure tone thresholds. The results of the present study (mean and standard deviation) showed that all the groups in comparison can be distinguished into normal or different degree of hearing impairment based on the questionnaire scores except for the groups; individuals with minimal and mild degree of hearing impairment.

The normal hearing group obtained a median score of 40 where the scores ranged from 37 to 40. This result lead us to state that any individual getting a score within the range of 37 – 40 can be considered as having normal hearing sensitivity. On the contrary, it means that individuals scoring lesser than 37 are at the risk of hearing impairment and should be referred for detailed evaluation. Furthermore this questionnaire can be used not only as a screening tool, but also to monitor the benefits of intervention.

Phase II

In this phase the online screening system with the calibrated stimulus delivery system was developed and has been evaluated for its sensitivity and specificity. Hearing screening was conducted over participants using both online screening system and portable audiometer at two criterion levels. The referral rate dropped to 43.33% from 58.14% when the criterion level was set to 30 dBHL instead of 25 dBHL.

The screening test has been carried out at different frequencies and the sensitivity and specificity at these frequencies are compared. It is found that the sensitivity and specificity of the developed screening system at 500 Hz is reduced compared to other frequencies. This could be because of the presence of noise, which was measured to be around 70-75 dBA. As testing at 500 Hz gets affected by the presence of noise, more false positive responses have been obtained at this frequency (Leventhall, 2004). This may also be the reason for a lesser agreement between the thresholds obtained trough screening software and portable audiometer when compared with other frequencies. All the other frequencies showed an almost perfect agreement between the tests at both criterion levels. The overall sensitivity and specificity of the developed online system at 25 dBHL and 30 dBHL is 94.29% and 80.77% and 94.92% and 96.71% respectively. There is a substantial agreement at 25 dBHL and almost perfect agreement at 30 dBHL overall between the two tests. The system also has a good positive and negative predictive factor at both the criterion levels. This suggests that the conventional screening through the portable audiometer can be replaced by the developed online system. This in turn reduces the time, increases efficiency since an audiologist is performing the screening. The major advantage of this developed online system is that the screening can be carried out in any distant places provided with the internet connection (wired or wireless). Offline analysis of the data can be useful in statistics and initiates further research.

Good correlation shown in the comparison of test results obtained from research officer and social worker clearly suggests that a social worker can administer the online hearing screening software if properly trained. This helps to overcome the shortage of the professional in the rural areas. Thus the hearing screening services can be provided even in the absence of professional and the services of the professional can be utilized at the supervisory level. As the entire test procedure can be monitored by the professional sitting at the central station, chances of manipulation is also reduced.

Chapter 5

Summary and Conclusion

The aim of the present study was to develop an objectively calibrated hearing screening system which can be specifically used in Indian rural areas. The study also aimed to develop a hearing screening questionnaire in Kannada. To accomplish this aim, the study was conducted in two phases. The first phase included the development and validation of the hearing screening questionnaire in Kannada. The second phase involved the development of online hearing screening software which was developed at AIISH, Mysuru according to ASHA guidelines 2005. In phase I, a hearing screening questionnaire was developed in English and then translated to Kannada. It consisted of 10 questions with a 5 point rating scale. For validation of the screening questionnaire, it was administered on normal individuals and clinical group with different degrees of hearing impairment (ranging from minimal to severe). Results indicated significant differences between each question and the groups except between the minimal and mild group. In phase II, an online hearing screening system was developed which does the hearing screening at four pure tone frequencies (500 Hz, 1000Hz, 2000 Hz & 4000 Hz) and at four intensity levels (25, 30, 35 & 40 dBHL). A calibrated stimulus delivery system was developed which is interfaced with the output of the laptop containing screening software. To validate the developed system, the hearing screening was done on 270 ears in different villages around Mysuru district of Karnataka state. The overall sensitivity and specificity was noted to be above 90% for all the frequencies as compared with the portable audiometer. In addition, the whole procedure (administration of pure tone screening and questionnaire) was carried out by a social worker to a small group of population. Results showed that a professional can be replaced by a trained social worker to carry out the hearing screening procedure.

It can be concluded that the developed online hearing screening software can replace a standard portable audiometer especially in rural areas where access to the hearing health care is limited. Further, it addresses the problem of lack of professionals as the test can be executed by a trained social worker. All the trained social workers can be monitored from a central station by a professional.

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Appendix 1

Online Hearing Screening Questionnaire

Please read all the following questions carefully and select any one of the option to indicate your answer:

1. Do you feel that your hearing has changed over years?
   a. All the time b. Most of the times c. Sometimes d. Seldom e. Never

2. When someone is talking to you, do you ask them to repeat many times?
   a. All the time b. Most of the times c. Sometimes d. Seldom e. Never

3. When someone is speaking to you over the telephone, do you have difficulty in understanding?
   a. All the time b. Most of the times c. Sometimes d. Seldom e. Never

4. Do you have difficulty in understanding conversations in a noisy background?
   a. All the time b. Most of the times c. Sometimes d. Seldom e. Never

5. Do you have difficulty in conversing when several people are speaking at the same time?
   a. All the time b. Most of the times c. Sometimes d. Seldom e. Never

6. Do you have difficulty in identifying from where the person is speaking?
   a. All the time b. Most of the times c. Sometimes d. Seldom e. Never

7. Do you have problem in understanding if someone speaks from other room?
   a. All the time b. Most of the times c. Sometimes d. Seldom e. Never

8. Do you have difficulty in understanding when someone speaks in a whisper?
   a. All the time b. Most of the times c. Sometimes d. Seldom e. Never

9. Does your family tell you that you increase the volume of TV or radio frequently?
   a. All the time b. Most of the times c. Sometimes d. Seldom e. Never

10. Do you have difficulty in hearing sounds like door bell/ phone ring?
    a. All the time b. Most of the times c. Sometimes d. Seldom e. Never

Appendix 2

ಪ್ರಶ್ನಾವಳಿ

ಕೆಳಕಂಡ ಪ್ರಶ್ನೆಗಳನ್ನು ಎಚ್ಚರಿಕೆಯಿಂದ ಓದಿ ಹಾಗು ನಿಮ್ಮ ಉತ್ತರವನ್ನು ಯಾವುದಾದರೊಂದು ಆಯ್ಕೆಯಿಂದ ಸೂಚಿಸಿ.

೧. ನಿಮ್ಮ ಕೇಳುವಿಕೆ/ಶ್ರವಣ ಶಕ್ತಿ ವರ್ಷಗಳಿಂದ ಬದಲಾಗಿದೆ ಎಂದು ನಿಮಗೆ ಅನ್ನಿಸುತ್ತಿದೆಯೇ?

ಅ. ಎಲ್ಲಾ ಸಮಯದಲ್ಲೂ ಆ. ತುಂಬಾ/ಹೆಚ್ಚು ಸಮಯದಲ್ಲಿ ಇ. ಕೆಲವೊಮ್ಮೆ ಈ. ವಿರಳವಾಗಿ ಉ. ಎಂದೂ ಇಲ್ಲ

೨. ಯಾರಾದರು ನಿಮ್ಮೊಡನೆ ಮಾತನಾಡುತಿರುವಾಗ, ನೀವು ಅನೇಕ ಬಾರಿ ಪುನರಾವರ್ತಿಸಲು ಹೇಳುತ್ತೀರಾ?

ಅ. ಎಲ್ಲಾ ಸಮಯದಲ್ಲೂ ಆ. ತುಂಬಾ/ಹೆಚ್ಚು ಸಮಯದಲ್ಲಿ ಇ. ಕೆಲವೊಮ್ಮೆ ಈ. ವಿರಳವಾಗಿ ಉ. ಎಂದೂ ಇಲ್ಲ

೩. ನೀವು ಯಾರೊಡನೆಯಾದರೂ ದೂರವಾಣಿಯ ಮೂಲಕ ಮಾತನಾಡುವಾಗ, ಮಾತುಗಳನ್ನು ಅರ್ಥ ಮಾಡಿಕೊಳ್ಳಲು ಕಷ್ಟವಾಗುತ್ತದೆಯೇ?

ಅ. ಎಲ್ಲಾ ಸಮಯದಲ್ಲೂ ಆ. ತುಂಬಾ/ಹೆಚ್ಚು ಸಮಯದಲ್ಲಿ ಇ . ಕೆಲವೊಮ್ಮೆ ಈ. ವಿರಳವಾಗಿ ಉ. ಎಂದೂ ಇಲ್ಲ

೪. ನಿಮಗೆ ಗದ್ದಲದ ಹಿನ್ನೆಲೆಯಲ್ಲಿ ಮಾತುಗಳನ್ನು ಅರ್ಥ ಮಾಡಿಕೊಳ್ಳಲು ಕಷ್ಟವಾಗುತ್ತದೆಯೇ?

ಅ. ಎಲ್ಲಾ ಸಮಯದಲ್ಲೂ ಆ. ತುಂಬಾ/ಹೆಚ್ಚು ಸಮಯದಲ್ಲಿ ಇ. ಕೆಲವೊಮ್ಮೆ ಈ. ವಿರಳವಾಗಿ ಉ. ಎಂದೂ ಇಲ್ಲ

೫. ಅನೇಕ ಜನರು ಒಂದೇ ಸಮಯದಲ್ಲಿ ಮಾತನಾಡುವಾಗ, ಮಾತುಗಳನ್ನು ಅರ್ಥ ಮಾಡಿಕೊಳ್ಳಲು ಕಷ್ಟವಾಗುತ್ತದೆಯೇ?

ಅ. ಎಲ್ಲಾ ಸಮಯದಲ್ಲೂ ಆ. ತುಂಬಾ/ಹೆಚ್ಚು ಸಮಯದಲ್ಲಿ ಇ. ಕೆಲವೊಮ್ಮೆ ಈ. ವಿರಳವಾಗಿ ಉ. ಎಂದೂ ಇಲ್ಲ

೬. ನಿಮಗೆ ವ್ಯಕ್ತಿ ಯಾವ ಕಡೆಯಿಂದ ಮಾತನಾಡುತ್ತಿದ್ದಾನೆ ಎಂದು ಗುರುತಿಸುವಲ್ಲಿ ಕಷ್ಟವಿದೆಯೇ?

ಅ. ಎಲ್ಲಾ ಸಮಯದಲ್ಲೂ ಆ. ತುಂಬಾ/ಹೆಚ್ಚು ಸಮಯದಲ್ಲಿ ಇ. ಕೆಲವೊಮ್ಮೆ ಈ. ವಿರಳವಾಗಿ ಉ. ಎಂದೂ ಇಲ್ಲ

೭. ನಿಮಗೆ ಯಾರಾದರು ಬೇರೆ ಕೊಠಡಿಯಿಂದ ಮಾತನಾಡಿದಾಗ, ಅರ್ಥ ಮಾಡಿಕೊಳ್ಳಲು ಕಷ್ಟವಾಗುತ್ತದೆಯೇ?

ಅ. ಎಲ್ಲಾ ಸಮಯದಲ್ಲೂ ಆ. ತುಂಬಾ/ಹೆಚ್ಚು ಸಮಯದಲ್ಲಿ ಇ. ಕೆಲವೊಮ್ಮೆ ಈ. ವಿರಳವಾಗಿ ಉ. ಎಂದೂ ಇಲ್ಲ

೮. ನಿಮಗೆ ಪಿಸುಮಾತುಗಳನ್ನು ಅರ್ಥ ಮಾಡಿಕೊಳ್ಳಲು ಕಷ್ಟವಾಗುತ್ತದೆಯೇ?

ಅ. ಎಲ್ಲಾ ಸಮಯದಲ್ಲೂ ಆ. ತುಂಬಾ/ಹೆಚ್ಚು ಸಮಯದಲ್ಲಿ ಇ. ಕೆಲವೊಮ್ಮೆ ಈ. ವಿರಳವಾಗಿ ಉ. ಎಂದೂ ಇಲ್ಲ

೯. ನೀವು ಆಗ್ಗಾಗ್ಗೆ/ಪದೇ ಪದೇ ಟಿವಿ/ರೇಡಿಯೋನ ಶಬ್ದ/ಧ್ವನಿಯನ್ನು ಹೆಚ್ಚಿಸುತ್ತೀರೆಂದು ನಿಮ್ಮ ಕುಟುಂಬದವರು ಹೇಳಿದ್ದಾರೆಯೇ?

ಅ. ಎಲ್ಲಾ ಸಮಯದಲ್ಲೂ ಆ. ತುಂಬಾ/ಹೆಚ್ಚು ಸಮಯದಲ್ಲಿ ಇ. ಕೆಲವೊಮ್ಮೆ ಈ. ವಿರಳವಾಗಿ ಉ. ಎಂದೂ ಇಲ್ಲ

೧೦. ನಿಮಗೆ ಬಾಗಿಲ ಘಂಟೆ/ದೂರವಾಣಿ ಕರೆ ಅಂತಹ ಶಬ್ದಗಳನ್ನು ಕೇಳಿಸಿಕೊಳ್ಳಲು ಕಷ್ಟವಾಗುತ್ತದೆಯೇ?

ಅ. ಎಲ್ಲಾ ಸಮಯದಲ್ಲೂ ಆ. ತುಂಬಾ/ಹೆಚ್ಚು ಸಮಯದಲ್ಲಿ ಇ. ಕೆಲವೊಮ್ಮೆ ಈ. ವಿರಳವಾಗಿ ಉ. ಎಂದೂ ಇಲ್ಲ

Appendix 3

Figure 2: Screenshot of home page of the online hearing screening software.

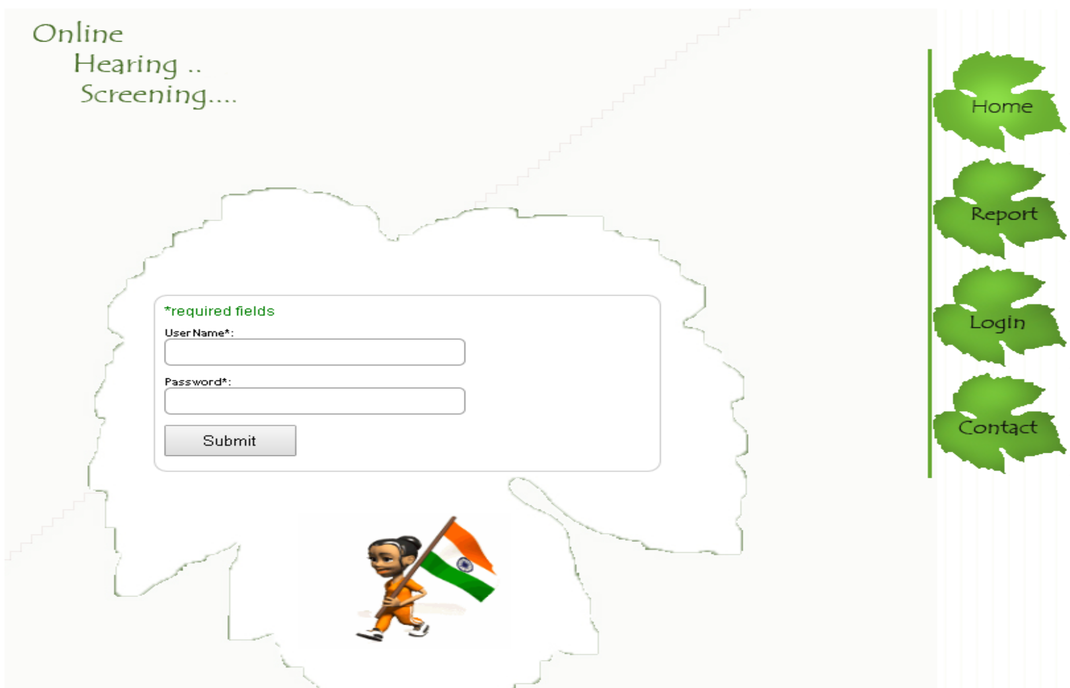

Figure 3: Screenshot of the login page

Effective Communication By One & All

All India Institute of Speech and Hearing

Logout

NAME

AGE

SEX

NUMBER

DOB

ADDRESS

STATE Select state

DISTRICT

LANGUAGE

EDUCATION

OCCUPATION

OTOLOGICAL

a) EAR DISCHARGE Yes No

b) EAR PAIN Yes No

c) TINNITUS Yes No

d) BLOCKING SENSATION Yes No

e) FULLNESS IN THE EAR Yes No

MEDICAL

a) ANY SURGERY UNDERGONE Yes No

b) UNDER MEDICATION Yes No

c) OTHER

EARLIER EVALUATION

Submit

Figure 4: Screen shot of the patient's details form

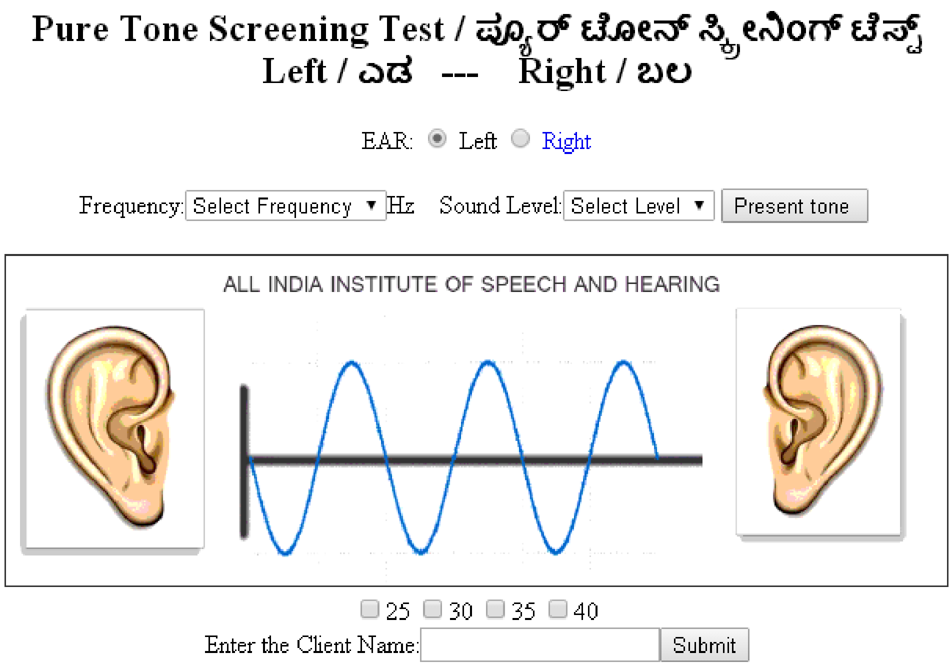

Figure 5: Screenshot of the Puretone testing window

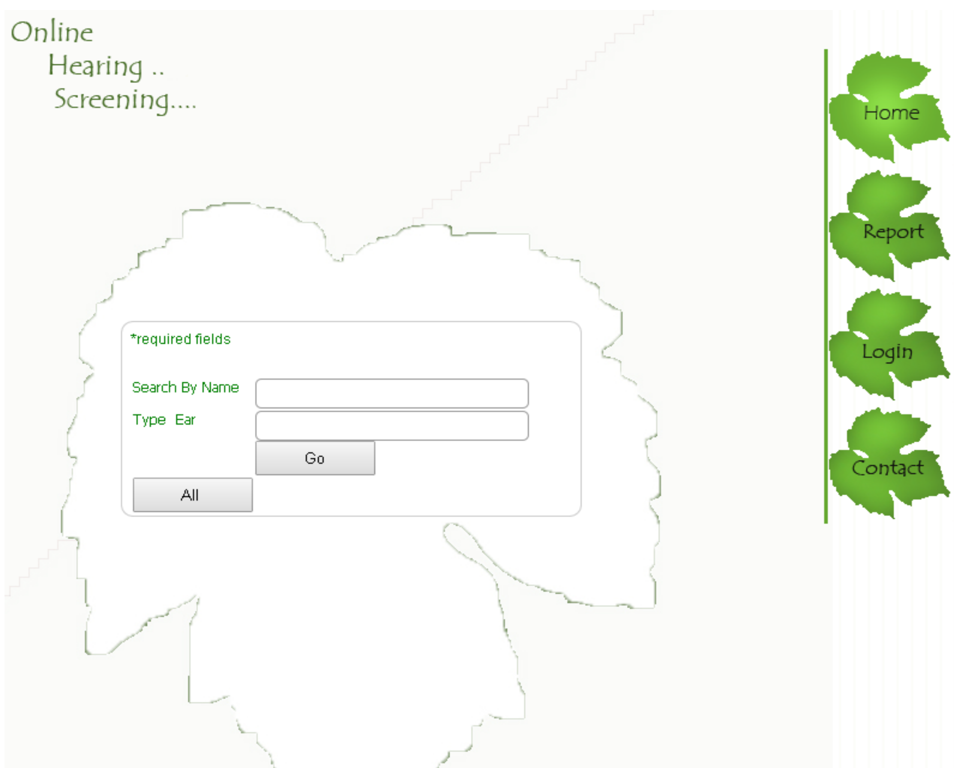

Figure 6: Screenshot representing the page for retrieving patient details