EFFECTIVENESS OF COMPUTERIZED AUDITORY TRAINING FOR KANNADA SPEAKING CHILDREN WITH HEARING IMPAIRMENT – A CROSS SECTIONAL STUDY"

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ABSTRACT

Listening training is one of the major aspects of rehabilitation in children with hearing impairment fitted with amplification devices. It provides children the opportunity to learn to listen and communicate. In the current scenario, this happens by one to one therapy provided by skilled and train clinicians at institute or clinic level. In order to move one step ahead and utilize the current technology, the present study aims to integrate both technology and human skill in teaching listening activities by a proper utilization of computer. This study aimed at developing software on auditory training for Kannada speaking children with hearing impairment. The software also consists of a database with details of the clients enrolled along with their test results. The study was divided into two phases- development of software and administration of the software. Twenty participants with hearing impairment in the age range of 2 to 7 years (3.8 years) were considered for the study. Out of them, ten were included in the experimental group while the other into the control group. The control group had children who attended regular listening training without software training. The second group attended regular listening training and also training with software which is the experimental group. Listening age was determined pre-therapy and also after one month of therapy (3 sessions of 45 min/week) for all the participants to determine the efficacy. The result showed significant improvement in the listening age of the experimental group. Also there was a positive feedback from the caregivers about the training provided by the software which added to the efficacy of the same.

INTRODUCTION

Hearing impairment (HI) is well known to cause breakdowns in communication. The existence of hearing loss has increased over time and reached alarming levels. As per World Health Organization (WHO), 2012, there are 360 million (5.3% of the world's population) people in the world with disabling hearing loss out of which 32 million (9%) are children. The report also suggests that the prevalence of disabling hearing loss in children is greatest in South Asia, Asia Pacific and Sub-Saharan Africa. These figures only direct us towards early identification, diagnosis and further build a more efficient rehabilitation program in order to allow effective communication for all. Rehabilitation of children with hearing impairment is considered of utmost importance to enable a child to be on par with peers in terms of communication. Following diagnosis and fitting of appropriate hearing device, the child must undergo auditory therapy alongside speech therapy (Bloom, 2004; Fu et al, 2005; Ross, 2005; Boothroyd, 2007; Fu & Galvin, 2007b; Martin, 2007; Sweetow & Sabes, 2007a, Sweetow & Sabes, 2007b; McCarthy & Schau, 2008; Sweetow, 2008; Boothroyd, 2010; Sweetow & Sabes, 2010; Pallarito, 2011; Abrams, 2013; Olson & Canada, 2013).

Rehabilitation after fitting of amplification device has evolved over the years from lip reading to methods such as, Auditory Verbal Therapy. It has been proven to be effective in the rehabilitation of hearing aid users (Seetow & Palmer, 2005; Sabes & Seetow, 2007; Wu, Yang, Lin & Fu, 2007). Typically, there are three ways of providing auditory training- individual, group and home/ computer-based training. Individual therapy is often inaccessible and demands a lot of resources like, an appropriate set up, clinical personnel, time consumption and non-reimbursement of these services (Fitzpatrick & Brewster, 2010 Bloom, 2004; Pallarito, 2011). This is a concern

especially in a country like India with less awareness and inaccessibility to the rural population. On the other hand, group therapy can be efficient in terms of both, time and cost (Hull, 2011). However, lack of individual attention and becomes a major concern.

With the advancement of technology, computer-based programs have gathered considerable attention amongst researchers to develop new programs that target development of listening skills (Jain, 2011; Bellman et al., 2011; Feijoo et al., 2012). Several computer based auditory training programs (CBATPs) for hearing loss have been designed and put forward in the market. The use of these CBATPs have been recommended for use as home-based training (Wu et al., 2007; Sabes & Seetow, 2007). However, only a handful of them have documented efficacy measures. Amongst those that are documented are mostly computer based auditory training programs (CBATP) for adults. Although there are several CBATPs for children with hearing impairment in the market, the efficacy of the same is not well documented. The literature reports of some objective evidence in support of CBATPs for adults (Fu et al, 2005; Martin, 2007; Stacey et al, 2010). However, Ross (2005) and Pallarito (2011) have pointed out that such research is limited, and the profession lacks clinical guidelines for the use of CBATPs (Pallarito, 2011).

In today's world, the use of technology and electronic gadgets is not limited only to adults. Children are adept in using gadgets especially for gaming and learning. The existence of several apps to teach phonetics, vocabulary, school based academic curriculum, etc are a sure indicator of their interest in using interactive computer programs for learning, in all age groups. A statement made by Gartner and Gartner, 2011 on their website reported that worldwide application store downloads had reached 17.7 billion downloads in 2011, which was a dramatic change (117 %) from an estimation of 8.2 billion downloads in 2010. With this advancement and the documented

evidence of using CBATPs in adults, there were several CBATPs for children in the market as well. However, there is little or no evidence of CBATPs for children with well documented efficacy.

NEED FOR THE STUDY

It has been established that CBATPs lead to enhanced speech perception in individuals with hearing impairment (Fu et al., 2005; Sweetow & Sabes, 2006; Burk & Humes, 2007). This improvement has been noted for speech perception in quiet, in the presence of noise and on hearing handicap inventories. Although there are commercially available CBATPs for children with HI, there is dire need for CBATPs that have appropriate outcome measures to rightly quantify its results. This gap in research is more in terms of availability of CBATPs in Indian languages. It is well known that auditory training in India is done in the native languages of the patients. While this is flexible in individualized auditory training, it is a challenge to advice for CBATPs for the same patient.

In literature, there have been reports of several CBATPs in English, especially for adults. These programs also have established efficacies. However, there is little evidence of CBATPs in Indian languages. While non speech stimuli can be used universally, the use of speech stimuli has been considered superior to that of non-speech stimuli (Ling, 1976). Due to the variability of languages across the country and dialects within each language, the task of developing a CBATP in Indian languages has not been done yet.

Auditory training moves in a hierarchy from easy non verbal sounds to perception of speech at sentence and paragraph levels. The loss of perception of vowels, consonants and other

spectral and temporal characteristics of a stimulus in individuals with HI is a well known fact (Kiang, Moxon & Levine, 1970; Glasberg & Moore, 1986). This calls for the need to include a variety of stimuli in CBATPs too for children with HI. The stimuli should be able to address aspects related to duration, frequency and intensity as well.

Hence, there is dire need for the development of CBATPs in Indian languages with a variety of stimuli and activities. The study must also have appropriate outcome measures to rightly quantify its results. These CBATPs will enable children and caregivers to provide supplementary training through the software. This in turn will aid the ongoing auditory training and facilitate faster learning. Thus, the objectives of the present study were:

- To develop language specific computer based auditory training software focusing on Kannada speaking children with hearing impairment.
- Develop database management system for client records to capture and analyze the data.
- To determine if there is any improvement in listening with and without the developed software in selected groups of Kannada speaking children with hearing impairment which would be determined based on pre and post therapy changes in the listening age.

REVIEW OF LITERATURE

Hearing impairment, as we all know is much more than simple loss of audibility. HI also causes disruption in the way a signal is processed and enhanced, therefore, affecting its processing at the end level. This leads to a communication breakdown and ultimately a decline in the quality of their lives. This called for auditory training, following diagnosis and fitting of appropriate listening device. This will enable one to learn and develop auditory behaviors like in a normally developing peer. Auditory training (AT) is a term used to describe a prescribed regimen of listening exercises designed to improve an individual's ability to perceive speech sounds. Different views exist as to what AT should consist of (Sweetow & Palmer, 2005) but at the center of all approaches is the aim to enhance a patient's communication skills.

Advent of CBATPs

Auditory training has come a long way from using hearing tubes in 19th century to using computers today, in the 21st century. Kricos and McCarthy (2007) give a comprehensive idea of the way auditory training has evolved. The use of computers for speech perception began towards the end of 20th century. The first few mentions of CBATPs were that of dynamic audio video interactive device (DAVID; Cronin et al., 1979), computer-assisted speech perception evaluation and training (CASPER; Boothroyd, 1987), and computer assisted tracking simulation (CATS; Dempay et al., 1992). These programs made use of CD-ROMs through which they were played. The main focus of these programs was sentence level speech perception training. Although these programs addressed the issues of cost effectiveness, ease of administration, ease of access to and availability of resources like clinics and clinicians, they gained little popularity in their period. They gained more interest only in the 21st century, also partly owing to the advent of a tech-savvy

world. The gap in the demand and availability of clinicians and resources also prompted people to depend more on home based CBATPs.

Listening and Communication Enhancement (LACE; NeuroTone, Inc., Redwood City, CA; Sweetow & Sabes, 2004) was one of the early CBATPs introduced. This was primarily released to improve speech perception in noise in adults through activities like, perception of speech in babble, time-compressed speech, competing speakers, a short-term memory task, identification of missing words in sentences, and interactive communication strategies. Cochlear Corporation (2006) released a program by the name 'The Sound and Beyond'. This was designed for individuals with cochlear implants. It had modules progressing from perception of pure tones to word discrimination. Sensimetrics, 2006 introduced a program during the same period called 'Seeing and Hearing'. This was designed for both auditory and visual speech perception training. 'Conversation Made Easy' was a program by Tye –Murray, 2002. It is a program that offers structured auditory and visual speech perception training, as well as exercises in conversational strategies.

The beginning of 21st century saw the evolution of several other CBATPs. This period gave scope for the development of many CBATPs. Ross (2005) also suggested the use of these types of programs at home alongside regular therapy in order to achieve more benefit.

CBATPs for children with HI reported in literature

There is a huge research gap in terms of reporting CBATPs for children with HI. There are consistent reports and reviews of similar programs for adults. However, there have been very few studies documenting CBATPs for children with HI.

Glyde, Cameron, Dillon and Hickson (2014) examined the use of a program called LiSN & Learn which was directed to improve spatial processing. The study consisted of two groups with HI- children (6-11 years) and adults (60-74 years) and their respective control groups. The training program lasted for 60 sessions (15 min per day, 5 days per week). Outcome measures were used before and after the training programs to compare results. The outcome measure used were- LiSN-S test (Cameron and Dillon, 2009); Speech, Spatial and Qualities of Hearing Scale (SSQ; Gatehouse and Noble, 2004); Listening Inventory for Education: Student Appraisal of Listening Difficulty (LIFE; Anderson & Smaldino, 1998); and Bamford-Kowal-Bench (BKB) sentences (Bench et al, 1979). The authors found no significant improvement in spatial processing in both groups. This result was attributed to the presence of hearing impairment. Since the spatial processing deficits in hearing impaired arise from peripheral changes (interaural time and level differences are usually distorted before they leave cochlea), rather than from higher order deficits (Cameron & Dillon, 2011), the study hypothesized that training would not bring about a significant difference in their spatial processing. This hypothesis was proved right with the help of parametric statistics. The study also noticed no significant difference between the two groups. The reason for the same was stated unclearly.

Silva, Comerlatto Junior, Balen and Bevilacqua (2012) conducted a study to evaluate the applicability of Software Auxiliar na Reabilitação de Distúrbios Auditivos – SARDA (Auxiliary Software for the Rehabilitation of Hearing Disorders) in the rehabilitation of children with hearing impairment. Two groups- ten children with CI, seven children with hearing impairment were taken. Pre and post HINT scores were calculated as the only outcome measure. Results noted a longer time for children with CI to finish the strategies. There was a significant improvement in

HINT score post training. However, there was no effect of age or type of device used on their performance. The authors also noticed that children found non verbal stimulus to be more difficult as compared to verbal and attributed this to more familiarity of verbal in one's daily life. This observation was however, tested with any statistical measure.

SARDA was based on the American software Fast ForWord Language. It consisted of 6 strategies that cover a variety of stimulus ranging from non verbal to verbal (CV combinations, words and sentences). Concepts such as recognition, discrimination and memory are focused on. These strategies have further phases and difficulty levels. The training was given in 30 minute sessions twice a week, until the child finished the modules. These results however, could be influenced by lack of sufficient outcome measures.

Prawin (2011) developed a Computer-Assisted Listening Training (CALT) in Indian English. There were 31 participants with hearing aids in the study. As outcome measures, six different speech perception tests were administered before and after training. The study had 4 evaluations- pre, mid, post therapy and follow up. The program was divided into four sections- detection, duration discrimination, identification and comprehension with a variety of activities in a hierarchy from easy to difficult. The results of the study concluded with a positive outcome with the use of CALT. There was an absence of effect of age on the outcome measures as all participants had a minimum language age of 6 years. Degree of hearing impairment was a factor that influenced the results. On the other hand, duration of hearing use also did not influence the results.

Therefore, the CBATPs for children with HI reported in literature with the use of outcome measures are very limited. There is scope for further research in this area.

CBATPs for children with HI in the commercial market

The lack of well documented CBATPs for children with HI in literature is evident as against the amount of research done on CBATPs for adults. However, there are many commercially available CBATPs designed for children with HI. These programs, however, do not have literature supporting their efficacy. The following is a review of such programs.

Angel sound training

Angel Sound Training is a product developed by TigerSpeech Technology and distributed by Emily Shannon Fu Foundation. It is a PC based interactive auditory training and hearing assessment program that is a potential self administrable auditory rehabilitation program. It has 9 modules the covers a wide range of stimuli and activities ranging from non verbal to syllables, words, sentences in both quiet and in noise. It also has music and cognition based activities. It involves levels of difficulties within each in a hierarchy.

It is the most comprehensible program reviewed by the current authors and is widespread in terms of the concepts covered. It is a freely downloadable software and available on the internet.

Otto's World of Sounds

Otto's World of Sounds is a multimedia auditory training tool from Oticon. It was based on the French training software entitled "La Souris Bleue" (The Blue Mouse), developed in 1999 by the French audiologist Alain Vinet and the computer scientist Denis Barbier. It is available free of cost along with hearing aids purchased from Oticon for children below 8 years of age.

Otto's world is designed to help hearing impaired children in the age range of 2-1/2 to 8 years to improve their auditory skills by detecting, discriminating, and identifying sounds. This program runs through a CD-ROM. It has interactive activities that also require the caretaker's participation in terms of assisting the child. It provides the child with 10 different auditory environments, each focusing on 10 different sounds. It includes activities for sound detection, discrimination, and identification, using sounds from the child's everyday environment. Within each of these environments, there are activities for discovery, memory, and recognition, which go in a hierarchy. The concept of building vocabulary is also addressed.

Programs offered by Advanced Bionics

Advanced Bionics, a cochlear implant company has many rehabilitation based programs for children and adult. The programs for children are- AB Listening Adventures and VocAB Scenes.

AB Listening Adventures- it is best suited for children aged between 4 and 10 years. The program is designed to guide development of listening and language skills using six different story-based games which focus on listening for multiple elements, plurals, pronouns or minimal pairs. It focuses on listening for words in sentences.

VocAB Scenes- it is best suited for children aged between 4 and 10 years. It is a scene based vocabulary building app that utilizes everyday scenes from the child's environment to introduce new vocabulary. It has three different games for each scene.

Programs offered by MED-EL

MED-EL is another cochlear implant company that has rehabilitation programs for children and adult. One of them is called SoundScape. These programs are freely downloadable from the company's website. It has 8 modules within, out of which only the first six are for children. The modules are designed in hierarchy for different age groups. They are as follows,

- Starting out- 0-2 years
- Ms. MacDonald's Shed- 2+ years
- Old MacDonald's Farm- 2+ years
- Let's go Shopping- 6+ years
- Telling Tales- 10+ years
- Continents and Oceans- teens

These modules cover age appropriate stimuli ranging from words and phrases to sentences and paragraphs using different activities that have varying levels of difficulties. They have sub levels within them.

Programs offered by Cochlear

Cochlear is also a cochlear implant company that provides users with rehabilitation programs for all ages. The programs for children are- HOPE words and Kaci's games.

HOPE words- it is a preliminary app that focuses on phonetics and basic vocabulary building through alphabet based activities.

Kaci's games- This is about remembering matching objects. The cards have animal pictures that present with their corresponding sounds.

It is clear that there exist several CBATPs in the market which address many important concepts of auditory training through a wide range of stimuli in different child- friendly activities. However, evidence reporting their efficacies would have added value to these programs.

Stimulus considerations for CBATPs

There is considerable review done for the CBATPs used for adults (Henshaw & Ferguson, 2013; Zhang, Miller & Campbell, 2014). These auditory programs, however, cannot be used for children because of factors like stimulus, interface, etc. Yue and Zin (2013) suggest that even in children, pre lingual and post lingual hearing loss will require different stimulus approaches.

A program called Otto's world of Sounds suggests that CBATPs with visual representations of sounds of animals, places, things with environment pictures, broad types of sound effects are help children with HI to improve their access to sounds. Sirichokswad et al., (2006) throws light on the careful selection and processing of non-verbal everyday sounds that are important for the initial stages of auditory training. They selected 50 common sounds. After seeking approval of sound quality normal hearing individuals, they were analyzed by power spectral density (PSD) and separated them into three groups based on their frequencies. These sounds were suggested for further use as the discrimination and identification becomes easier with classification. Studies in the area of stimulus for auditory training have been plenty for all types of stimulus- verbal (Manoharan & Yathiraj, 2007-2008; Humes, Burk, Strauser & Kinney, 2009), non-verbal (Rochette & Bigand, 2009; Gil & Iorio, 2010). Further, studies for use of non sense

syllables, isolated words and sentences have also been done (Humes et al., 2009). However, these studies assume the presentation of stimulus for auditory training given in person. There have been very few or no studies reporting the guidelines to develop stimuli for CBATPs. Nevertheless, it is safe to assume that the rules for stimulus selection in individualized auditory training can also be applicable to choosing stimulus for CBATPs as long as precautions are taken to conserve the quality of stimulus. Thus, literature reports of many CBATPs developed for adults and children with (C) APD as well as structured reviews that comment on these programs. This approach, however, has not been noticed for children. There is a huge gap in literature in terms of development of CBATPs for children with HI and documenting their efficacies. Stimulus considerations while developing a CBATP may also be taken as the focus of further studies.

In addition, there is limited literature on development and validation of these CBATPs in Indian scenario. India being a multilingual country, there is greater need to develop CBATPs for children with HI including stimulus in their respective languages. Although it is difficult to include stimulus in all the languages, however, there is a need to initiate it in at least one language. Thus, the present study attempts to initiate the development and validation of CBATPs in Indian Scenario. Kannada being the language of current interest based on the regional requirement.

METHOD

This study aimed at developing software on auditory training for Kannada speaking children with hearing impairment. The software also consisted of a database with details of the clients enrolled along with their test results. The study was divided into two phases- development of software and administration of the software.

I. DEVELOPMENT OF SOFTWARE

The front end of the software was developed using JAVA script and PHP. The database for client records was developed by using MSQL. The software consisted of the following, in brief:

- Home page
- Modules
- Results

Home page:

The home page had a brief introduction to the contents and purpose of the software. Figure 1 displays the screenshot taken from the software displaying the home page. Following this, the patient was led to the log in page. The log in page required the user to enter the following demographic and case details,

- Name
- Password
- Case number
- Age/ gender
- Education
- Mother tongue
- Other languages known
- E-mail id
- Address
- Provisional diagnosis- right ear/ left ear
- Hearing device in use- right ear/ left ear

- Choice to upload case file

Upon uploading these details, the user is registered and saved in the database.

Figure 1

Screenshot of the home page of the software.

Modules:

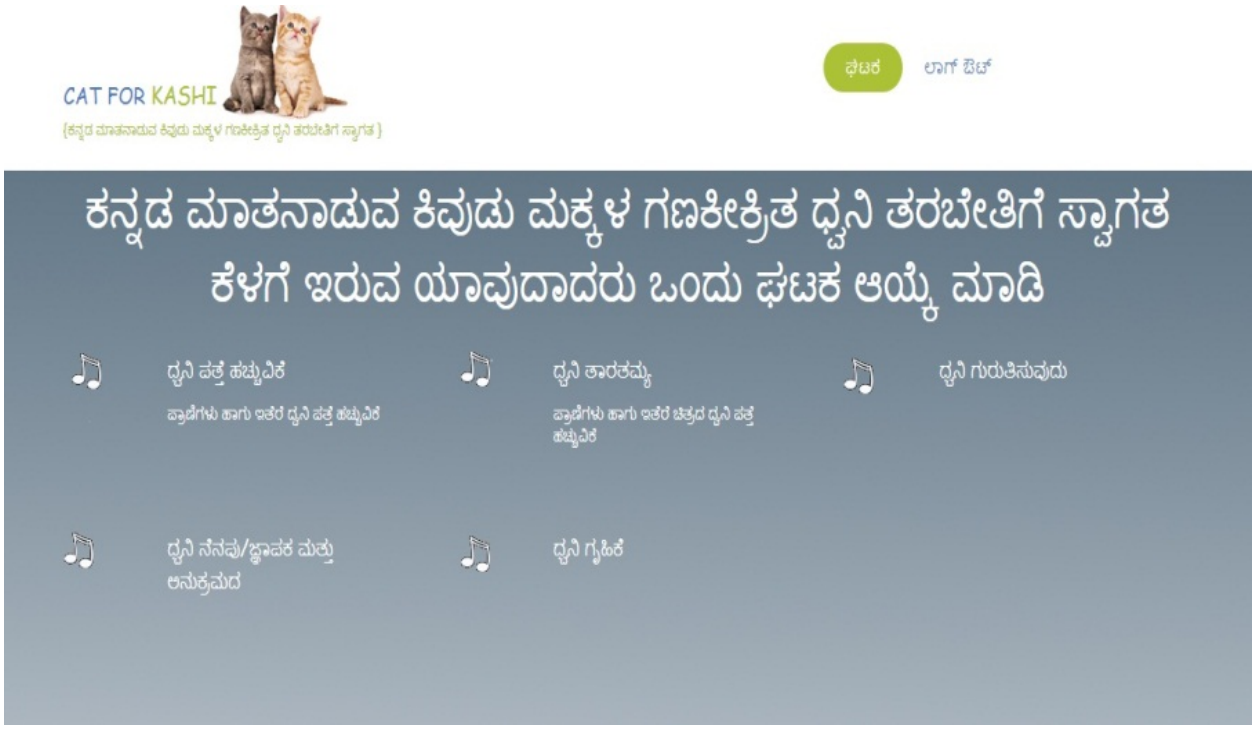
The software consisted of five modules and the Figure 2 depicts the screenshot of the various modules displayed on the computer screen.

- Awareness
- Discrimination

- Identification
- Memory and sequencing
- Comprehension

Figure 2

Screenshot of the various modules displayed on the computer screen



Each of these modules has training and test phase. Following a brief regarding the meaning, importance and application of that module, the parent was led to the page with training phase first and then test phase. In every module and level, a pass criterion of 70% was set, after which the child was moved to the next level. The modules are explained in detail below. Detailed description of stimuli used in the software is provided in Appendix 1. Screenshots of the startup pages of each of the module is displayed from Figure 3, Figure 4, Figure 5, Figure 6 and Figure

7 for awareness, identification, discrimination, memory and sequencing and comprehension respectively.

1. Awareness

This module focused on the child responding to the presence or absence of sound. The stimuli in both training and test phases were divided into four categories, namely- animals, vehicles, other common sounds and Ling sounds. Each of the sound files was analyzed for their frequency composition using Praat software v 4.4.31. Accordingly, they were classified into low (below 1000 Hz), mid (1000 to 4000 Hz) or high frequency (above 4000 Hz) according to their peak frequency composition.

Training phase:

Upon choosing a category to train in, the clinician was prompted to click on the screen for the sound to begin. Five seconds after the auditory stimulus ended, the corresponding picture/ animation was introduced, in which time the child was made to focus on the stimulus and hence be aware of it. The clinician was provided with buttons to replay, adjust volume, and go to the previous or next stimulus throughout all modules in the software. Once the picture appeared, clinician/ parent helped the child associate the sound with its corresponding picture/ animation. This was done by encouraging the child to link between the sound presented and the picture displayed. Since the picture followed the auditory stimulus each time, the child was expected to associate both. Since there were multiple such trials, the child was encouraged to learn to associate the auditory stimulus with the picture displayed. Similarly, the child was introduced to all the categories. There was no feedback given in this phase because the aim was just to encourage the child to learn association and no judgement was made whether the responses were right or wrong. Also, every auditory stimulus was followed by the correct display picture.

Test phase:

The test was given category wise. The stimuli were randomly chosen from the category each time a test was taken. Each test consisted of ten trials. When the user started the test, a sound was played. If the child gave a behavioral response to the sound, the parent was advised to click on 'correct'. Else, click on 'incorrect'. Behavioral responses like head turn, eye blinks, eye widening, lateralization, smiling, cessation of activity, pointing etc. were considered. Appropriate immediate feedback is given through a picture/ animation with an aim to reinforce the child and motivated him/her to get correct responses. Following the test, the parent is guided to the results section.

Figure 3

Screenshot of the startup page for the "Awareness" module of the software

2. ***Discrimination***

This module focused on developing the child's ability to differentiate between two similar sounding stimuli. This concept was taught for both non verbal and verbal stimulus in terms of

gross and fine discrimination. The aspects covered were- frequency, intensity and duration. Only the frequency component had two activities- same/ different and odd one out.

Training phase:

- Frequency: the stimulus consisted of sounds from different frequency groups- low, mid, high. Here, the pictures corresponding to the sound were given along with similar/ differently coloured boxes. The child was expected to match the picture of the stimulus to two similarly coloured boxes if they were similar and differently coloured boxes if they were different. Likewise, in odd one out, the child was to match the picture of the dissimilar stimulus to the differently coloured box. In fine discrimination, the task is tougher as the stimuli are taken from the same frequency groups.
- Intensity: Pictures of two loudspeakers, one representing a loud sound and another representing a soft sound were seen. The child was expected to identify the sound clip with higher intensity. Gross discrimination had a difference of 30 dB HL while fine discrimination had intensity difference of 5 dB HL.
- Duration: Presentation of stimulus is associated with an animation following the same. That is a long sound is depicted through lengthier image and a short sound through a short length image. Hence, the association of the length of the stimulus is established. The child is prompted to choose the stimulus with longer duration. Both gross (larger difference) and fine discrimination tasks (smaller difference) were used.

Test phase:

The activity remains the same. However, the actual pictures are removed and only the numbered boxes are seen, ensuring that child responds to auditory stimulus only. The child was expected to choose an option appropriate to the auditory stimulus presented. Accordingly, the child

received a positive reinforcement or an encouraging phrase like ‘try again’ with an animation. Here, the primary reinforcer was an animation considering the level of the child but with an aim to have a natural way of communication, verbal feedback was also included to enhance future learning. Correct responses are awarded a score of one each. After ten trials, the score of the test phase is displayed.

Figure 4

Screenshot of the startup page for the “Discrimination” module of the software

3. <u>Identification</u>

This level was made to enable the child to recognize the sound, understand it and associate it to its source. This module introduced both verbal and non verbal stimulus. The non verbal stimuli used in this module were the same as that in awareness. The verbal stimuli included six other

categories. The names of the items in these categories were recorded from a female native Kannada speaker. Following are the various categories used.

- Non verbal
    - Animals
    - Vehicles
    - Others
    - Ling sounds
- Verbal
    - Family members
    - Body parts
    - Fruits
    - Vegetables
    - Colours
    - Opposites

Training phase:

The training was specific to categories. In this phase, the sound and picture/animation were presented together in order to enable association of the two. The name of the stimulus item was also given in text below the picture/ animation.

Test phase:

This module had four test levels with each test consisting of 10 trials. All the trials had immediate feedback according to the response entered- correct or incorrect. Every correct entry was scored one. The following were the levels in this module.

- Level 1- within category test

There are four trials in this level, one for each category. This level has two items as options (2 alternate forced choice method - 2AFC). The child is expected to match the auditory stimulus to the correct animation.

- Level 2- within category test with 4AFC method
- Level 3- across category test with 4AFC method
- Level 4- (for non verbal stimuli only) Scene based test. A scene with stimuli from various categories will be presented. These scenes are selected from Karnataka state board primary school text books. According to the stimulus presented, the child will be expected to click on the respective object. For example, scene- a baby playing with a toy car in the kitchen with mother cooking in the background.

  Possible stimuli- baby crying, car, cooker whistle, mother coughing, phone ringing.

The verbal stimulus has six categories as mentioned above. Each category has two blocks one for training and the other for testing. Under training, stimulus will be played first and then followed with the respective image and the child is encouraged to learn the same. Later in the test phase, the trial has two images and the child will hear a target sound and then the child is expected to select the correct option. Appropriate visual reinforcements are provided.

Figure 5

Screenshot of the startup page for the "Identification" module of the software

4. <u>Memory and sequencing</u>

This module focused on enabling the child to listen, interpret and retain information in the sequence in which it was presented. The module was divided into words and phrases with two levels in each. In 'words', both the levels in words had two components each- memory; memory and sequencing. In the former, the child was expected to only memorize the stimulus and reproduce the same in any order. The later also included reproducing it in the same sequence. This was also done in gradation with 3 words as stimulus first and then 4 words. The stimuli for level 1 of 'words' was a context based closed set task. The contexts presented words from the same lexical category. The level 2 of 'words' had stimuli from the lexical categories that were familiarized during the identification stage. Lexical categories included were, body parts, fruits, vegetables, animals, colors and vehicles.

In 'phrases', level 1 had 2-3 word phrases as stimuli. These phrases were pictorially represented. In a 3AFC method, the child was expected to choose the picture corresponding to the phrase

presented as stimulus. Level 2, on the other hand, had 2 step commands as stimulus in four different commonly encountered contexts. They are,

- Daily activities
- In a classroom
- Making lime juice
- In a playground

Training

The training phase had the software prompting the correct pictures as options for the auditory stimulus presented.

- Words- level 1 and 2- in the context based picture that was displayed, the correct words to be chosen were highlighted when the auditory stimulus was played. The child was expected to click on the same.
- Phrases- level 1- for every sentence that was played, there were 3 pictorial options out of which the correct one was highlighted. The child was expected to click on the same.

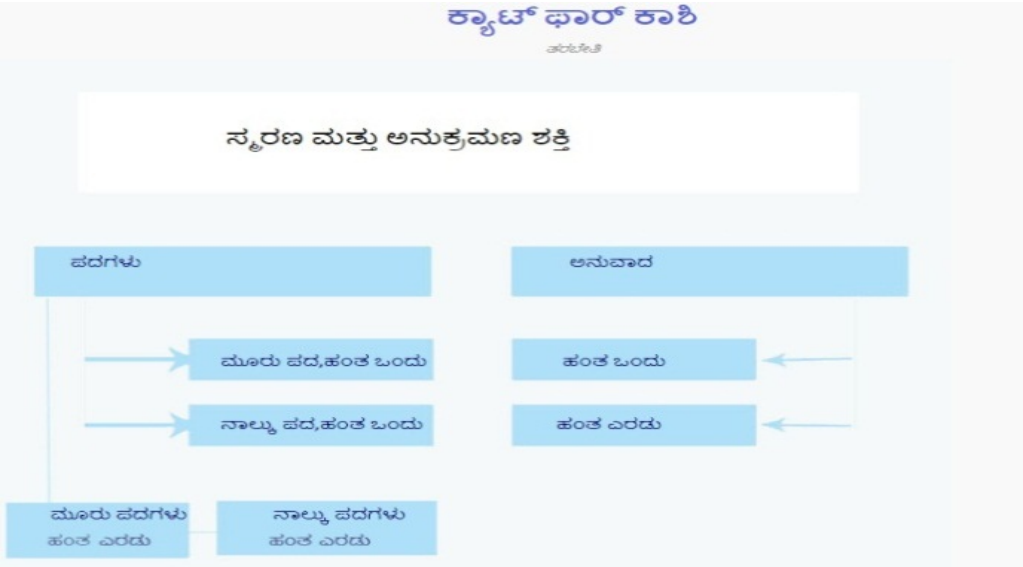
Level 2- the ten commands were in a sequence. The commands were played one after the other in a sequence. These commands were pictorially represented and the child was given time to comprehend the concept.

Test phase

The test phase was similar to that of training with the only difference being that there were two commands said and the child was expected to point out to the two commands told from the three pictures displayed on the screen. Each correct response was scored one and the total correct responses were finally calculated.

Figure 6

Screenshot of the startup page for the "Memory and Sequencing" module of the software



5. <u>Comprehension</u>

In this module, the aim was to go a step ahead of being able to listen and remember a string of words to understanding it as a whole. This concept was taught in two stages- sentences and paragraphs. The sentences were further divided into two kinds of activities- concatenated sentences (has 2 levels within); public places. On the other hand, paragraphs were taught using stories with a hierarchy of responses from closed to open set questions.

Concatenated sentences were given in the form of subject-object-verb and subject-number--object-verb in a hierarchy. Out of a table consisting of words under each column, the child is expected to drag and drop the words in the auditory stimulus to form a sentence. In level 2, public places were described in 4-5 sentences. Upon comprehending the same, in the test phase, the child was expected to identify the public place being described in 2-3 sentences and click on its picture.

The stories portion has five moral stories being narrated along with a video. Following this, there were two levels to test the comprehension of the stories- closed set and open set questions.

Training

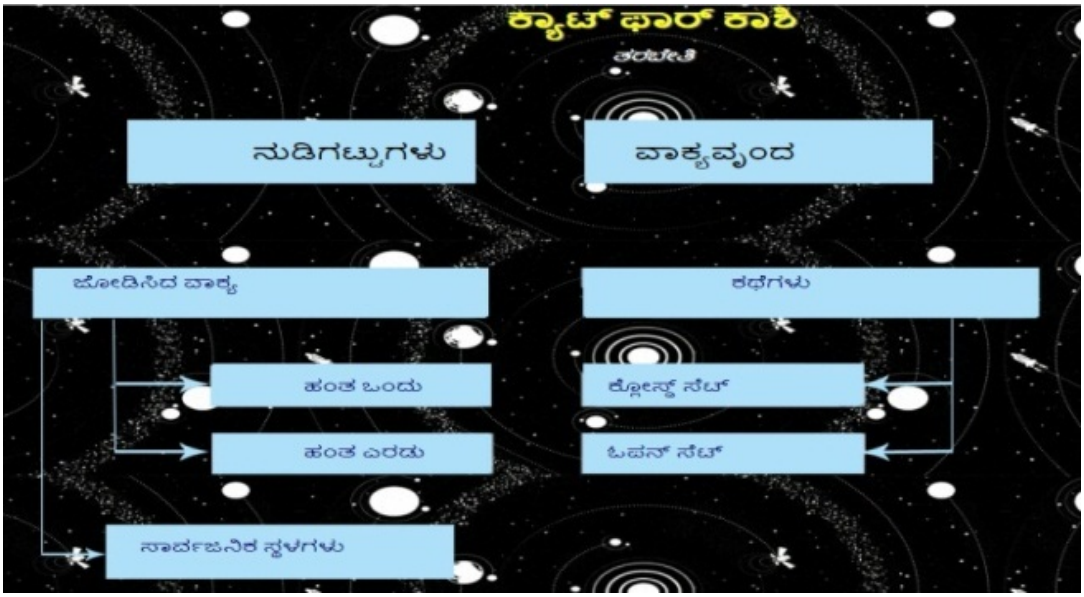
Similar to the previous module, the training phase has surplus cues along with auditory stimulus in order to help the child connect auditory, visual stimuli, concept and the activity.

Test phase

This phase has alternate forced choice method activities to ensure the child responds to the auditory stimuli which are verified through the options chosen. The closed set task was scored one for each correct response. The only open ended task is the last level in ‘paragraphs’. Here, the parents/ caregivers/ clinicians are asked to keep track of their response and give a subjective score.

Figure 7

Screenshot of the startup page for the “Comprehension” module of the software



II. ADMINISTRATION OF THE SOFTWARE

This was done in the following stages,

- Selection of participants
- Pre therapy evaluation
- Administration of therapy
- Post therapy evaluation

Participants

Twenty participants with hearing impairment in the age range of 2 to 7 years (mean age of 3.8 years) were considered for the study. Out of them, ten were included in the experimental group while their age and listening age matched counterparts were taken in the control group. Children from both the control and experimental groups attended the standard listening therapy at the Listening Training Unit, AIISH and the home training by the parents. The goals taken were according to the listening age of the child. The children in the experimental group only, received the computerized therapy using the current software. Thus, care was taken none of the children were deprived of the listening therapy. The following criteria was used for subject selection,

- Had pre-lingually acquired sensorineural hearing loss greater than or equal to moderately severe hearing loss.
- Regular bilateral users of amplification devices prescribed by experienced audiologists
- Aided audiogram is within speech spectrum (Byrne et al., 1994) at least up to 4 kHz in one or both ears
- Had normal IQ based on psychological evaluation.
- Were native speakers of Kannada

The experimental subjects for each module were age and listening age matched, apart from satisfying the above criteria. The demographic details of the participants are given in table 1 and table 2.

Table 1

Demographic details of the participants of the experimental group

Sl no.	**Age (years)/ Gender**	**Degree of hearing loss**	Years of therapy taken	Listening level
1	2.1/Male	Severe to profound hearing loss	1 months	Awareness
2	3.6/Female	Severe to profound hearing loss	2 months	Awareness
3	2.6/Male	Severe to profound hearing loss	4 months	Discrimination
4	4.6/Male	Severe to profound hearing loss	5 months	Discrimination
5	4.2/Male	Severe to profound hearing loss	8 months	Identification
6	4/Female	Severe to profound hearing loss	9 months	Identification
7	4/Female	R: Moderately severe hearing loss	1.5 years	Memory and sequencing

		Lt: Severe to profound hearing loss		
8	4.2/Female	Severe to profound hearing loss	2 years	Memory and sequencing
9	4.11/Male	Severe to profound hearing loss	2.5 years	Comprehension
10	5.5/Female	R: Moderately severe hearing loss Lt: Severe to profound hearing loss	3 years	Comprehension

Table 2

Demographic details of the participants of the control group

Sl no.	**Age (years)/ Gender**	**Degree of hearing loss**	Years of therapy taken	Listening level
1	1.6/Female	Severe to profound hearing loss	15 days	Awareness
2	3.6/Male	Severe to profound hearing loss	2 months	Awareness
3	3/Male	Severe to profound hearing loss	3 months	Discrimination
4	5/Male	Severe to profound hearing loss	5 months	Discrimination

5	3.5/Female	Severe to profound hearing loss	7 months	Identification
6	3/Male	Severe to profound hearing loss	10 months	Identification
7	3.10/Male	Severe to profound hearing loss	1.8 years	Memory and sequencing
8	7/Male	Severe to profound hearing loss	1.5 years	Memory and sequencing
9	4.2/Female	Severe to profound hearing loss	3 years	Comprehension
10	5.4/Male	Severe to profound hearing loss	3.2 years	Comprehension

Instrumentation

The following instruments were used in the study,

- Motu MicroBook II instrument connected with AHUJA AUD- 101XLR dynamic unidirectional microphone was used to record the stimulus.
- Loudpeakers connected to a Dell Inspiron 14R laptop (Realtek sound card) was used to present the stimulus/ administer the software.
- Praat software v 4.4.31 for frequency analysis of the sound files.

Environment

The other pre/ post therapy evaluations, training was carried out in a distraction free, quiet environment.

Materials

The verbal stimuli were recorded in a sound treated room using a laptop with adobe audition v3.0 software. An external microphone, connected to the laptop and covered by a windscreen, was positioned approximately 15 cm from the mouth of the speaker. The stimuli were spoken by a female native Kannada speaker who was judged to have a neutral accent, good voice quality and an appropriate pronunciation. The sampling rate set was 44.1 kHz along with 16-bit quantization.

A goodness test was performed on five normal hearing individuals to check the quality of recording. Any stimulus that was judged to be unclear was re-recorded. All the finalized sounds were then normalized using adobe audition software v3.0.

Pre therapy evaluation

Prior to involving the participants in therapy, their baseline assessment was done using listening age checklist **(**Integrated Scales of Development, Cochlear Ltd, 2010). The Integrated Scale of Development (ISD) is a questionnaire used to assess the speech development in children with hearing impairment. The scale has been adapted from a number of sources. This scale outlines typical developmental stages in various areas including listening age. Each child was assessed individually on the Listening domain which gives one final Listening age. This scale was used since currently it is one of the mostly used questionnaire to assess the listening age of children with hearing impairment. But one of the limitations of this is currently there are no test-retest

reliability measures for this questionnaire which can also be considered one of the limitations of the current study. Thus, pre-therapy baseline listening age of the child was noted.

Administration of therapy

Following the pre-therapy assessment, the participants were enrolled for individualized therapy. A quiet and distraction free environment was used for therapy. The software was run accessed with a laptop connected to the speakers. The first step was to adjust the loudness level of the stimuli to every participant's most comfortable level. This level was maintained throughout the session. However, minor adjustments in the volume were made in between, if necessary. Each of the speakers was placed at approximately 1m distance and 45 degree azimuth from the participant.

At the beginning of every session, the parent/ caregiver were oriented about the modules and levels to be taken up in that session. They were encouraged to ask for any help/ clarifications required from the clinician. Following this, the child was made aware of the category that was going to be presented. The child was alerted to carefully listen to the stimulus thereafter. Depending on the activity, the response obtained from the participant varied. Similarly, feedback was given by the software, depending on the activity and child's response. The session duration lasted for a maximum of 45 minutes. They were scheduled for three days/week over a period of one month (12 sessions). Because, based on the clinical knowledge of the investigators, 12 sessions are usually enough for demonstrating improvement. All the sessions were therapist driven with equal participation from the parents. Parents were motivated to get involved in the session to reinforce and motivate their child and elicit good responses. This also helped them give home training related to similar concepts.

Figure 8

Screenshot of the results displayed at the end of each session of the "Identification" module

NAME OF THE MODULE	Name of the Candidate:ravi					
		ANIMAL	VEHICLE	OTHER	MAX	TOTAL
IDENTIFICATION		-	-	-	10	0
RECOGNITION	LEVEL 1	0	0	0	30	0
	LEVEL 2	0	0	0	30	0
	LEVEL 3	0	0	0	30	0
	LEVEL 4	-	-	-	10	0

The modules began with the training phase of each level. After establishing familiarity of the concept and stimulus through a pass criterion of 70% with respect to the consistency of responses, they were advanced to the test phase. The pass criteria of every tests phase was also 70%. For example, Figure 8 displays the screenshot of the results displayed at the end of each session of the "Identification" module.

Database

The database consisted of details of all the registered participants. The training/test sessions of each participant were stored in this database along with their scores. They were accessible only upon logging in with participant specific username and password provided at the time of registration.

Post therapy

After the completion of therapy program, the post-therapy listening age was determined in all the participants of the study.

Interview

A detailed interview was carried out with the caregivers after the completion of twelfth session of training. They were encouraged to provide feedback and talk in detail about the positive as well as the negative aspect of computerized training from their perspective. They were asked to explain their child's auditory development and their own experiences during the training.

Scoring and statistical analysis

The responses for each test were scored and tabulated for both pre and post therapy evaluation. The improvement scores were statistically analyzed using Statistical Package for the Social Sciences (SPSS version-18). Between group comparison of improvement noticed in the listening training was done using a Mann-Whitney U test. The results of the study are reported and discussed in the following chapters.

RESULTS AND DISCUSSION

The current study attempted to develop and evaluate a computer based auditory training program in Kannada for children with hearing impairment. Based on the selection criteria, twenty participants with hearing impairment with Kannada as their mother tongue were selected and were divided into two groups - control and experimental, randomly. Each of these groups had ten participants, two for each module. Listening age checklist was administered pre and post therapy as an outcome measure. The training sessions lasted for 45 minutes each, thrice a week for four weeks (12 sessions).

Development of the software

The software consisted of five modules namely, Auditory Awareness, Auditory Identification, Auditory Discrimination, Auditory memory & sequencing and Auditory

Comprehension. All these modules were built up in appropriate hierarchy implementing suitable auditory stimulus and also visual representations. Once the software was considered final according to the researchers, it was shown to three different audiologists involved in auditory rehabilitation. They were asked to rate the software on the following aspects. These include familiarization, correctness, ambiguity, audibility and cultural acceptance of the test stimulus (Audio/pictures/Videos). A five-point rating scale was used which included categories like very poor, poor, good, very good and excellent. When the rating was less than good, appropriate suggestions provided were incorporated. Suggestions like – change of pictures, use of simpler words/sentences, audio clarity changes for some sounds were suggested and the changes were incorporated. A sample of the rating scale used is included in the Appendix 2. Output and feedback from them were taken and corresponding changes were incorporated in the final version of the software. This final version was used to provide listening training. Each module had a training phase and a test phase along with pass criteria. Thus, only if the participant achieved a pass criterion of 70% in the training phase, he/she was taken to the text phase. Next test/training phase was unlocked only if the participant had a score 70 % or more in previous test level.

The software was developed considering the following important aspects.

- It is simple
- It is organized
- It is easy to use
- It is efficient
- It is adaptive to client's progress

- The activities within the modules are appropriate to the corresponding listening level,
- Unambiguous pictures are used to depict the auditory stimulus
- It has uniform language being used throughout
- It can be reusable with the same participant.
- The stimulus presentation is random so that guessing factor is reduced, if any.

Database

Database has scores updated online for every session and the final responses could be accessed immediately after the session with the specific username and password with which they were registered for the first time. It is a very comprehendible output which was also used to counsel the caregivers after the session. The results involved in the database are the output of the test phase of the modules. Thus, the database had a list of scores for all the levels of the respective modules. This can also be used to check the prognosis of each participant.

This software will be useful because in today's world, children are well versed in using electronic gadgets especially for gaming than that of adults. There are several computer based rehabilitation programs for hearing impairment available in the market. However, very few of them have documented the efficacy measures. Computer based auditory training programs (CBATPs) for adults are one among them. The efficacy of currently available CBATPs for children with hearing impairment is not documented. Fu, Nogaki and Galvin (2005); Martin (2007) and Stacey Raine, O'Donoghue, Tapper, Twomey and Summerfield (2010) have provided some objective evidence to support CBATPs for adults. Clinical guidelines for the professionals for use of such software are lacking. Some of the commercially available auditory training programs for

children with HI include, Angel Sound Training (Tiger Speech Technology), Otto's World of Sounds, Programs offered by Advanced Bionics, Programs offered by MED-EL and Programs offered by Cochlear®.

Angel Sound Training is developed by TigerSpeech Technology and is distributed by Emily Shannon Fu Foundation. It involves PC based interactive auditory training. It also includes hearing assessment program. Thus it is a self administrable auditory rehabilitation program. When the researchers tried to compare the current software with Angel Sound Training, most of the features within the current software meet the designed features of the aforementioned software. Some of the concepts being, measurement of progress, levels adaptive to the participants progress, comprehensible in terms of concepts covered, covers a wide range of stimuli and activities ranging from nonverbal, words, sentences in quite. The current software does not include sentences in noise and also music.

One of the advantages of the Angel Sound Training software is that it can be used in therapist mode and in parent mode. It could be logged in as a therapist or as a caregiver. Based on which the complexity of the instruction and also inclusion of outcome measures would vary. When the software is logged in as a therapist, results of hearing evaluation, aided audiogram, Ling sound test, efficacy measures like listening age pre and post therapy, should be automatically be included. On the other hand, when it is logged in as a caretaker, instructions will be in simple language and the evaluation results will not be included. The current software has a comprehensive database development which is useful to comment on the prognosis of the child. This makes the current software superior to other software's used for training children with hearing impairment.

Otto's World of Sounds is another multimedia auditory training tool from Oticon. It is based on the French training software entitled "La Souris Bleue" (The Blue Mouse), developed in 1999 by the French audiologist Alain Vinet and the computer scientist Denis Barbier. It involves activities to improve children's detection, discrimination and also identification of sound. It uses sounds from the child's everyday environment. It includes discovery, memory, and recognition hierarchically. The current software has an advantage over Otto's World of Sounds in terms of modules and concepts covered. The current software covers activities on auditory awareness, auditory discrimination, auditory identification, auditory memory and sequencing and auditory comprehension. Involving all these levels improves the usefulness and also leads to overall development of child's listening age. Thus it does not restrict the age at which the software could be implemented.

There are few programs offered by Advanced Bionics for children like, AB Listening Adventures and VocAB Scenes. AB Listening Adventures suits children aged between 4 and 10 years. It involves story based games. Focuses on plurals, pronouns or minimal pairs, listening for multiple elements, listening for words in sentences. Although it includes variety of stimulus, it does not cover lower listening levels like, auditory awareness, auditory discrimination, and auditory identification. These levels are covered in the current software in detail.

There are other programs by MED-EL rehabilitation programs called SoundScape can be used for both children and adults. There are totally 8 modules out of which first 6 are concerned for children. The modules are designed in hierarchy for different age groups. It covers age appropriate stimuli ranging from words and phrases to sentences and paragraphs with different levels of difficulties. The current software also covers variety of stimulus ranging from non verbal

sounds, words, sentences and paragraphs in a hierarchy. An advantage of the current software over SoundScape is that the stimulus used in the current software is from children's everyday environment.

Cochlear®, a cochlear implant company also provides rehabilitation programs for all ages. The programs for children are- HOPE words and Kaci's games. Both of these do not cover all the aspects of listening training starting from auditory awareness to auditory comprehension.

Thus to summarize, there are no much literature on development and validation of these CBATPs. Considering the Indian scenario, it is sparingly been explored and validated. Multilingualism being an important consideration in Indian context, there is a need to develop CBATPs for children with HI including stimulus in their respective languages. The present study initiated it in Kannada based on the regional requirement. The salient features of the current software which will deal with if not all, but some of the needs for computer assisted training are:

- It includes stimulus from the child's own language, Kannada in the current context.
- It includes natural stimulus from child's everyday environment. It can supplement the usual listening training.
- Has multiple speakers' voice which can assist in speaker generalization.
- Includes new, innovative, animated stimulus display which can drag children's attention.
- Can increase child's attention span and concentration ability.
- Can motivate and encourage children by providing unique reinforcements.
- Can be customized by clinicians
- Digitize the client records and progress

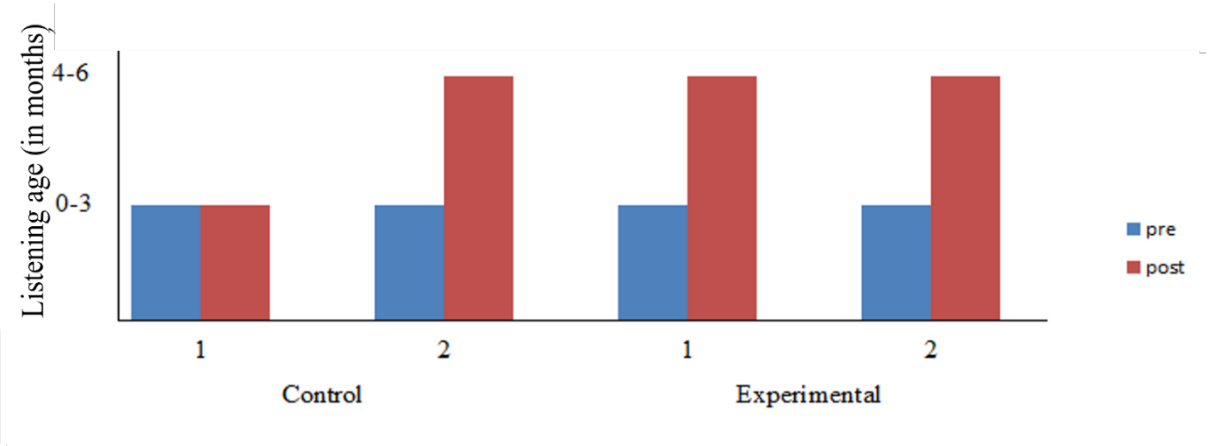
- Continuous monitoring of the progress
- Can be used as a means of structured home training.

Outcome of the therapy

Based on the pre and post listening ages and also the output of the database, the prognosis was studied. The following figures (Figures 9 to 13) depict the comparison between the pre and also the post therapy listening ages for both control and experimental group in all the modules. The graph clearly portrays the improvement noticed after therapy in the experimental group in comparison to the control group. Figure 9 represents the pre and post therapy listening age of both the groups in the auditory awareness module. Likewise, Figure 10 , Figure 11, Figure 12 and Figure 13 represents the changes in the listening ages due to therapy in both the groups for auditory discrimination, auditory identification, auditory memory and sequencing, and auditory comprehension respectively.

Figure 9

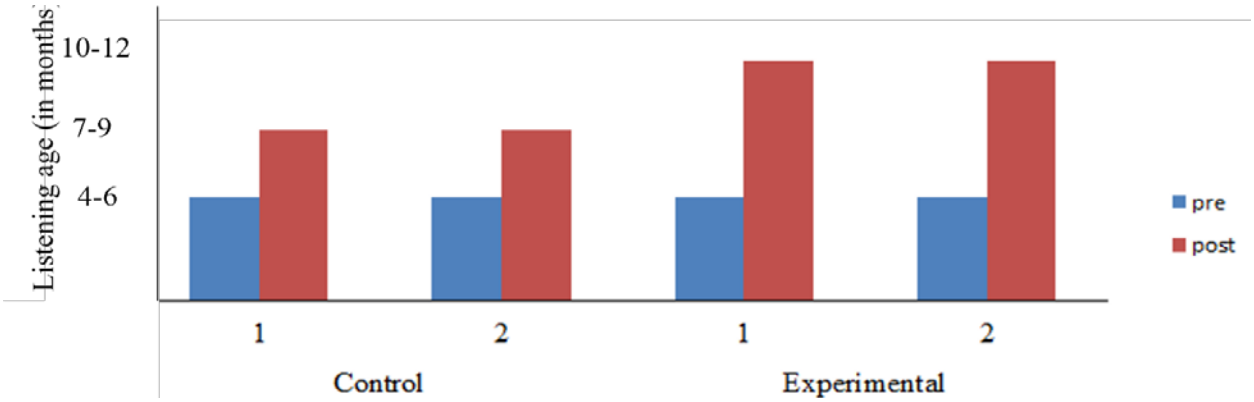
Pre and post therapy listening age of participants from the control and experimental group in the "Auditory awareness" module.



Although all four participants started from the same listening age, both the participants in the experimental group could cover a listening age span of 3 months, post therapy. While only one participant in the control group could cover the same listening span. This improvement could be attributed to the regular therapy attended by these children in the control group without the software. Thus, the experimental group showed better improvement, who attended training through the software.

Figure 10

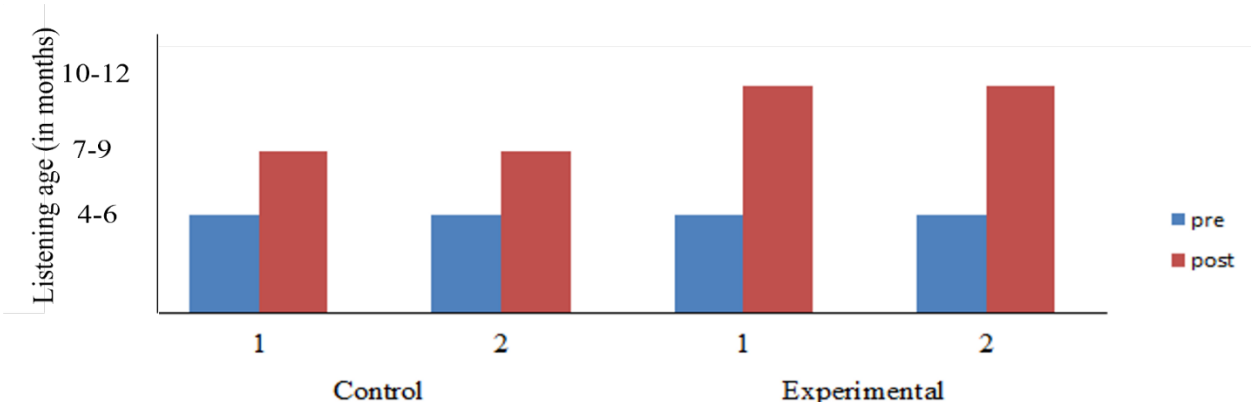
Pre and post therapy listening age of participants from the control and experimental group in the "Auditory discrimination" module.



For auditory discrimination, the participants in the experimental group had an improvement of around six months in their listening age after attending the computerized training. While their control counterparts showed an improvement of 3 months. Thus the experimental group showed better improvement, who attended training through the software.

Figure 11

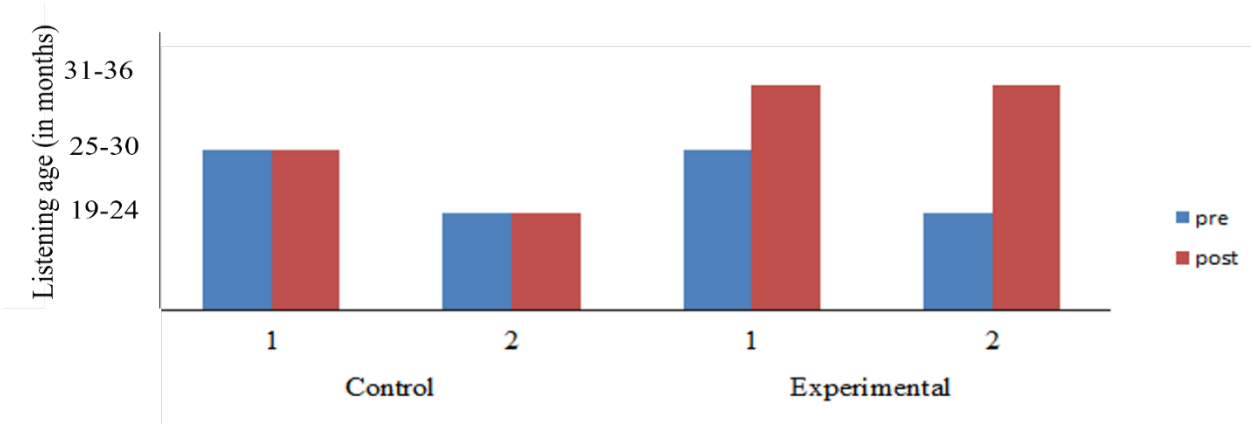
Pre and post therapy listening age of participants from the control and experimental group in the "Auditory identification" module



For auditory identification, the participants in the experimental group had an improvement of around six months in their listening age after attending the computerized training. While their control counterparts showed an improvement of three months. This improvement could be attributed to the regular therapy attended by these children in the control group without the software. Thus, the experimental group showed better improvement, who attended training through the software.

Figure 12

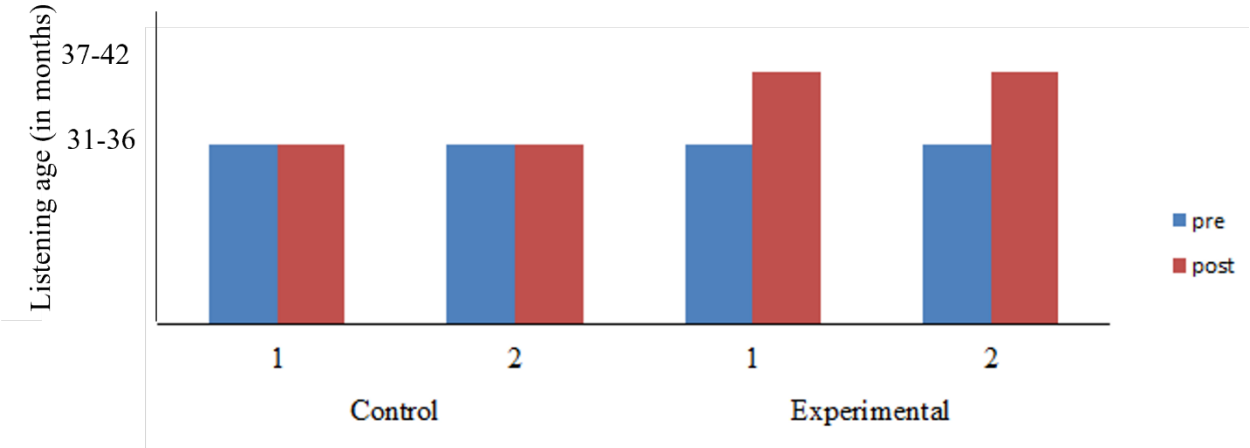
Pre and post therapy listening age of participants from the control and experimental group in the "Auditory memory and sequencing" module.



In the auditory memory and sequencing group, the listening age was found scattered between 19-24 and 25-30 for control 1 and 16-18 and 19-24 for control 2 respectively. After therapy, the listening age was 19-24 and 25-30 for control 1 and control 2 respectively without any scatter. However, in the experimental group, there was an improvement of 6 months and more. Thus, the experimental group showed better improvement, who attended training through the software.

Figure 13

Pre and post therapy listening age of participants from the control and experimental group in the "Auditory comprehension" module



With respect to auditory comprehension, the participants in the experimental group had an improvement of around six months and more in their listening age after attending the computerized training. While their control counterparts showed post therapy scores similar to the pretherapy scores. Thus, the experimental group showed better improvement, who attended training through the software.

Improvement in listening age

The mid-point of the age range was considered for the statistical analysis. On an average, there was a mean improvement of three months in the listening ages of the participants in the control group and it was 6 months in the experimental group. Therefore, along with the change in the listening age of individual data, there was an overall improvement in the post therapy listening age scores for participants attending training with the software.

Parent's perspective

An informal interview was carried out with the caregivers and detailed information regarding the software was collected. Feedback related to the software was also noted down. They were asked to speak about the advantages and also limitations that they have experienced in the 12 sessions of listening training using the software from caregiver's perspective. The latter describes the summary of the interview carried out and it describes parent's observation. All the parents reported positive feedback towards training provided through the software. They felt that the children found the activities and also the images interesting. This led to an increased attention from them. The children almost concentrated throughout the session. Since each of the activity lasted for a lesser time, and it was possible to carry out a variety of activities in each session, children

found it very interesting. It was a fun learning experience for children as well. Children were curious to attend the sessions as though it was a play time for them. Thus, they learn the concepts necessary to improve their listening skills in a playful manner. Since similar activities were also carried out as a part of home training, children could learn the same concept in two different ways that is, normal parent to child home training and also through software in the session. Also, since the stimulus was presented through the external speakers there was no chance for the children to concentrate on speech reading. Thus, learning took place in a natural way. This indirectly had an effect on their ability to concentrate only through auditory modality. The reinforcements used in the software further motivated children. Overall, it indirectly motivated and encouraged parents to train their children with innovative activities. Some of the differences noticed by the parents in the listening abilities of their children, according to the caregivers are listed below.

Children are now able to spontaneously alert themselves to environmental sounds in new environments. Children in the lower levels of auditory training started producing well-formed syllables and syllable sequences recognized as speech. They can spontaneously alert to environmental sounds in the home without being told or prompted to do so. They spontaneously recognize auditory signals that are part of their everyday routines. They started demonstrating the ability to discriminate spontaneously between two speakers with auditory cues only. Children's ability to recognize people's voices without seeing who is talking has increased. Their ability to listen to sounds other than voices also increased. They have started speaking in meaningful 3-4 word sentences. Parents were also eager to attend sessions provided through the software in future as well.

Thus, on the whole, both qualitatively and quantitatively there was a positive outcome from the study. Positive feedback from the parents/caregivers qualitatively supported the efficacy. In addition, improvement in the listening age and the prognosis as per the database of the software added on to the efficacy of the training program quantitatively.

Limitations and Future directions

The study is just an initial attempt and it should be carried out on a larger group of population for generalization. The efficacy of improvement with training should be further determined using tests and questionnaires. The software can involve stimulus in noise. It can also include structured simulated stimulus to work on distance learning, localization, speech in noise and other higher aspects of listening in the future. It can also involve a module for training children with CAPD in future versions. The development of such software must be attempted in other Indian languages too.

Conclusions

The study included two phases- development of software and administration of the software. Computerized auditory training for Kannada speaking children with hearing impairment (CAT for KASHI) was developed considering some of the practically important aspects involved in auditory rehabilitation of children with hearing impairment. The software also has a database with details of the clients enrolled along with their test results. It indeed covers many concepts and activities for various levels of auditory training. It covers auditory awareness, auditory discrimination, auditory identification, auditory memory and sequencing and auditory comprehension. The training was provided with the software for twenty participants with hearing

impairment (10 in control and 10 in experimental group). The results show that the training was beneficial leading to significant increase in listening age for experimental group compared to their counterparts. In addition, the improvement was also acknowledged by the parents of children with HI. Thus, a new start can be given to the auditory rehabilitation of children with hearing impairment by using CAT for KASHI for Kannada speaking children with hearing impairment.

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Appendix 1

Stimulus for awareness module

	Low freq	**Mid freq**	**High freq**
Animals	Dog	Sheep	Snake
	Cow	Goat	Cat
	Lion	Chicken	Horse
	Crow	Elephant	Cuckoo
	Bees	Duck	Insects
		Monkey	Parrot
Vehicles	Train	Car horn	Auto
	Bike		Bicycle
	Airplane		
	Bus		
	Ship		
Other	Cough	Laugh	Cry
	Sneeze	Sing	Bell
	Rain	Fireworks	
	Water	Phone ring	
	Wind		
	Cooker		
Ling sounds	u, m	a	s, sh, i

Stimulus for identification module

Non verbal			
	Low freq	**Mid freq**	**High freq**
Animals	Dog	Sheep	Snake
	Cow	Goat	Cat
	Lion	Chicken	Horse
	Crow	Elephant	Cuckoo
	Bees	Duck	Insects
		Monkey	Parrot

Vehicles	Train Bike Airplane Bus Ship	Car horn	Auto Bicycle
Other	Cough Sneeze Rain Water Wind Cooker	Laugh Sing Fireworks Phone ring	Cry Bell
Ling sounds	u, m	a	s, sh, i

Verbal		
Family members	Body parts	Fruits
• Father • Mother • Son • Daughter • Grandfather • Grandmother • Brother • Sister	• Ears • Eyes • Mouth • Nose • Head • Hands • Legs • Stomach • Fingers • Neck	• Apple • Mango • Banana • Orange • Guava • Papaya • Pomegranate • Jackfruit • Grapes
Vegetables	Colours	Opposites
• Tomato • Carrot • Potato • Cucumber • Onions • Beans • Cabbage	• White • Black • Red • Yellow • Blue • Brown • Green	• In out • Under above • Hot cold • Tall short • Correct wrong • Fat thin • Hot sweet

- Lady's finger
- Brinjal

	GROSS
Non Verbal	The sounds used in the previous modules are used here, with all categories mixed.
Frequency	Sounds from different frequency groups are taken as stimuli. Example, low vs. High frequency, mid vs. Low frequency, etc.
Intensity	A sound is presented at two intensities, one loud and one soft. The stimuli will have a difference of >30 db between them.
Duration	A sound is presented for short and long durations.
Verbal	Only verbal stimuli are used in the following levels.
Frequency##	The words from the identification module are used here. Differentiating between low frequency consonants and vowels vs. High frequency consonants and vowels will be the task.
Intensity	Random words from those introduced in identification module will be presented. Each word will be presented at two intensities, with a difference of > 30db.
Duration	Ling sounds will be presented at two durations. One short and the other prolonged. Example, a vs. A:, U vs. U:, etc.
	FINE
Non Verbal	
Frequency	Two randomly chosen sounds, from same frequency groups are presented for the child to discriminate between the two.
Intensity	A random sound is presented with the difference in intensity between the two sounds maintained at 5 dB.

Duration	The level of difficulty is increased here as compared to that in gross discrimination.
Verbal	
Frequency**	Minimal pairs that can be pictorially represented are the stimuli for this level.
Intensity	The stimulus is the same as that used in gross level. However, the difference in intensity between the two sounds maintained at 5 dB.
Duration**	Stimulus is taken from 'Auditory Learning manual for Kannada speaking hearing- impaired children- Vijayalakshmi C.S.'. Word vs. Phrase is used as stimulus.

Stimulus for gross verbal frequency discrimination

- jeenu – hotte
- baaṭu – haladI
- male – seenU
- koLI - sImha
- nayI – haadU
- bILI – sebU
- daLimbe – hasIrU
- beans – hULa
- carrot – sautekaI
- drakshI – hadagU
- vImana – tomato
- maavU – sImha

- bekkU – patakI
- mu:gU – kemmU
- ni:lI – ha:vU

****List of minimal pairs**

- baLe – ba:Le (central vowel contrast)
- kudI – kodI (short vowel contrast)
- apa:ja – upa:ja (short vowel contrast)
- kurI – gurI (voiced- voiceless contrast)
- mu:ru – nu:ru (nasal contrast)
- a:ne – a:me (nasal contrast)z
- a:Ta – u:Ta (long vowel contrast)
- va:sa – ve:ʃa (fricative contrast)
- sara – mara (initial consonant contrast)
- hurI – huLI (lateral- trill contrast)
- kappu – kabbu (voice- voiceless contrast)
- u:du – o:du (long vowel contrast)
- huli – huLi (lateral contrast)
- ba:vi – ba:yi (semi vowel contrast)

****List of stimuli taken from Auditory Learning manual for Kannada speaking hearing-impaired children- Vijayalakshmi C.S. for verbal fine discrimination of duration**

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Stimulus for memory and sequencing

	WORDS
	The lexical items familiarized in the previous modules are used as stimuli here.
Level 1 (within category)	Each category is associated with a relevant context. The child is encouraged to listen and remember items from the given situation (closed set) and then identify them from the same as response. Categories: • Animals- zoo • Vehicles- road • Fruits- shop • Vegetables- shop
3 words (Memory; Memory and Sequencing)	Here, only 3 stimuli are given that need to me memorized. This level has two components- memory; memory and sequencing. In memory, the child is expected to only remember the items. He/ she is free to interchange the order of the stimulus. In memory and sequencing, the child is expected to retrieve the stimuli in the same order in which it was presented.

4 words (Memory; Memory and Sequencing)	In this component, 4 stimuli are given that need to me memorized. This level has two components- memory; memory and sequencing. In memory, the child is expected to only remember the items. He/ she is free to interchange the order of the stimulus. In memory and sequencing, the child is expected to retrieve the stimuli in the same order in which it was presented.
Level 2 (across category)	In this level, the lexical categories are mixed and presented as stimuli. The activity remains the same as in level 1. The context of shopping at a mall is used here. The child is encouraged to remember the items from the shopping list and choose the same from the shop and place in a shopping bag.
3 words (Memory; Memory and Sequencing)	Here, only 3 stimuli are given that need to me memorized. This level has two components- memory; memory and sequencing. In memory, the child is expected to only remember the items. He/ she is free to interchange the order of the stimulus. In memory and sequencing, the child is expected to retrieve the stimuli in the same order in which it was presented.
4 words (Memory; Memory and Sequencing)	In this component, 4 stimuli are given that need to me memorized. This level has two components- memory; memory and sequencing. In memory, the child is expected to only remember the items. He/ she is free to interchange the order of the stimulus. In memory and sequencing, the child is expected to retrieve the stimuli in the same order in which it was presented.
	PHRASES
Level 1 (2-3 word phrases)*	The phrases are given below*

Level 2 (commands)**	2 step commands are given. It has four situations in which the child is expected to select pictures according to the commands given. • Daily activities • Classroom situation • Making lime juice • Playground situation There will be ten stimuli in each.

***Phrases- level 1 stimulus: training**

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****Phrases- level 2 stimulus: (to be approved and then translated)**

Daily activities

Training sequence:

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Classroom situation

Training

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9. [illegible]
10. [illegible]

Test

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5. [illegible]
6. [illegible]
7. [illegible]
8. [illegible]
9. [illegible]
10. [illegible]

Make lime juice

Training

1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible]
5. [illegible]
6. [illegible]
7. [illegible]
8. [illegible]
9. [illegible]
10. [illegible]

Test

1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible]
5. [illegible]

6. [illegible]
7. [illegible]
8. [illegible]
9. [illegible]
10. [illegible]

In a playground

Training

1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible]
5. [illegible]
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Test

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10. [illegible]

Stimulus for comprehension module

	PHRASES
	The ability to focus and understand a sentence as a whole is focused here through two levels. Common public places are taken in this module. A pre requisite knowledge of the same is expected.
Level 1 (concatenated sentences)	Words will be presented in the form of **subject-number-object-verb** as recorded stimuli. The same words will be given under their respective columns in a jumbled form. The child is expected to select the words heard from each column and form the correct sentence.
Level 2 (public places)	Public places are described in 2-3 phrases. These descriptions are used as stimuli with pictures of public places as foil items. Each stimulus will have 3 foil items. • Bus stand • Railway station • Zoo • Market • School
	PARAGRAPHS
Stories	Five commonly known stories will be narrated with the help of pictures and videos.
Level 1 (open set)	Questions based on the story will be asked. Options in the form of pictures will be provided as foil items.
Level 2 (closed set)	Questions related to the story will be asked but with no foil items. The parent/ caregiver will have to verify the answers.

I. <u>Sentences</u>

Concatenated sentences

- ***Level 1***

SUBJECT	OBJECT	VERB

Avalu	Mango	Bring
Avanu	Tree	Eat
	House	Climb
	Book	Come
	Newspaper	Go
	Banana	Drink
	Hill	Read
	Water	
	Juice	
	Train	

Trial-

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Note: Gender concept is also included in the above sentences. Sentence error identification is the task. The child should identify the error in the sentence in terms of the gender and correct the same. Reinforments will be provided appropriately.

- ***Level 2***

SUBJECT	**NUMBER**	**OBJECT**	**VERB**

Avalu	Four	Ball	See
Avanu	One	Dosa	Bring
	Nine	Cloth	Throw
	Five	Bird	Take
	Seven	Flower	Give
	Two	Dog	Draw
	Six	Book	Keep
	Ten	Biscuit	Eat
	Three	Cat	
	Eight	Cow	

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6. Public places

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Options- **bus stand**, zoo, school

2. Stimulus-

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Options- **school**, railway station, market.

3. Stimulus-

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Options- market, **railway station**, school.

4. Stimulus-

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Options- school, zoo, **market**.

5. Stimulus-

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Options- railway station, **zoo**, school.

6. Stimulus-

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Options- **bus stand**, zoo, school.

7. Stimulus-

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Options- school, market, **railway station**.

8. Stimulus-

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Options- bus stand, **zoo**, market

9. Stimulus-

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Options- school, zoo, **market**.

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Options- market, **school**, bus stand.

II. <u>Stories</u>

- ***Hare and the tortoise***

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- ***Monkey and the cap seller***

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- ***The thirsty crow***

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- ***Fox and grapes***

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- ***Lion and the mouse***

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Appendix 2

Rating scale used by the audiologist to rate the software

Parameters	Very poor	Poor	Good	Very good	Excellent
Familiarization					
Correctness,					

Ambiguity,
Audibility
Cultural acceptance