Interactive Speech Based Assistive Game for Improving Spoken Language Skills in Children with Learning Disabilities

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Abstract

Assistive technologies have proved to be one of the most powerful tools to aid people with learning disabilities to improve the quality of their lives. In the present study, an educational android application based on Hindi and English was developed to facilitate language learning in children with special needs. The main objective of this study was to provide a platform that is useful in enhancing the learning abilities and communication skills of children suffering from learning disability like autism, dyslexia, aphasia etc. The application was developed with three different complexity levels to cater to the needs of children with varied levels of severity of disorder. The proposed app based game was tested with a group of special kids and has reportedly shown positive results.

Keywords— Android, assistive technology, learning disability, speech recognition.

I. INTRODUCTION

Learning disability refers to disorders that involve lack of ability to listen, understand, speak or write the language, to do mathematical computation, short or long term memory loss, and attention deficiency [1]. Learning disability has nothing to do with an individual's intelligence. It is a problem that affects an individual's capability to store, process, and interpret information. There are distinct forms of learning disabilities. Some of the learning disabilities can intercede with an individual's capability to focus and perform certain functional activities, while other learning disorders can lead to problems with reading, writing, spelling, or solving analytical and, mathematical problems. Human brain's way to process information is a complicated task [2]. For instance, whenever human brain looks at an image, it forms lines into picture and then the brain interprets what that image stands for. It then relates that particular picture to other scenes stored in the memory, and finally saves the new information. Similarly, speech is another example of complex cognitive processing by the brain. In speech comprehension, listener has to identify the words, understand their meaning, and interpret the implications of the statement. Most of such functionality occurs in different segments of the brain, which is popularly known as localization of tasks in brain.

A person with learning disability takes more time to learn in contrast to an average person and may need assistance to communicate with others, cultivate new skills, and to interpret complex data and information. The kind of assistance a person needs depends on the level of disability [3]. For instance, a person with serious learning disorder might require permanent guardianship. Such person might also possess some physical disorder. People with some specific syndrome may also possess learning disorder. A person with Down's syndrome and some individuals with autism can also have learning disability. Researchers have discussed that at times learning disorder is generally misunderstood with intellectual disorders. Intellectual disorders may be

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recovered with some medical therapies, but it is not the case with learning disability [2].

Assistive technology can be broadly categorized as any technology that has the potential to enhance the functional capabilities of a person with disability [4]. Assistive technology offers a wide range of technologies varying from low to high technological devices[19]-[22]. The whole spectrum of assistive technology offers promising learning tools for individuals with learning disability. Since long, therapists have been using many affirmative tools that aid learning in this special population. Before the availability of computing devices, teachers used to take help of basic low technology equipment such as scale or ruler to aid persons with learning disability while reading. Similarly, a tape-recorder can be utilized by an individual with learning disorder to handle memory problems. In addition, numerous technologies have been developed for people with varying disorders.

It has been estimated that in India, 5-10% of children (approximately 3 crores) have learning disabilities. However, this count can be much higher due to lack of awareness among people who do not suspect any such problems in slow learners [5]. At times, parents are unaware about the presence of learning disability in their child, though the child might possess mild disorder. Sometimes, the parents of such children show a negative attitude as most of them perceive the feeling of dejection, guilt, and self-blame [6]. On the other hand, some parents are unable to provide proper care and support to their children because of limited exposure and resources. The attitude of parents towards their children can be improved by providing the required resources and spreading awareness about disabilities. In addition, there is a need of developing more rehabilitation centres especially, in rural areas to improve conditions of such children. However, due to limited funds that it is very challenging for government to scale such facilities. Technologies like mobile devices offer low-cost solution in such scenarios. Also, India is a multi-lingual country that has different languages for different regions, technological solutions can be devised in different languages. Therefore, it is beneficial to develop and provide low cost assistive technological aids for such special children.

Assistive technology has two main objectives. Firstly, it can improve an individual's fortitude such that a person's capabilities counteract with pursuance of any disabilities. Secondly, technology can act as a support tool to perform a task so that disability is entirely bypassed [1]. For example, a person with reading disability might possess good listening capabilities rather than reading abilities. Similarly, a person with poor spellings might use the word processor automatic spell checker to write anything. Thus, technology acts as a support required to complete the task. Learning disability in an individual can lay down barriers to execute a task properly at school or at work. Assistive technology offers various methods to surpass these barriers [7],[8].

Numerous computing applications have been developed to improve the functional skills of persons with learning disability[23]-[25]. In [9], researchers developed an interactive computer game for children with autism. The main aim of the research was to enhance speech fluency of children. During their three months of monitoring, they used game software with increasing level of difficulty of the sentence. The game involves an instructor and a child. They are connected to each other via local area network. The instructor selects a set of images that form a sentence. The child is asked to recognize the image and pronounce the sentence. Initially, a single image appears on the screen, but as the difficulty level increases, it displays upto three images to form a single sentence. The sentences are of 2 words or 3 words. To increment the level of difficulty, they set a constraint to response time. They observed encouraging results during three months of intervention. A similar study proposed an interactive speech based gaming application [10]. The researchers developed a website that links two other desktop applications. Two games were implemented. These were Puzzle games and PECS (Picture Exchange Communication System) with the aim of providing an aid for children having difficulty with speech. Microsoft speech technology had been used to implement speech recognition and speech processing. In addition, the author's study [11] also proposed a game for children with autism. The main objective of this application is to aid children having communication problems. This game consists of two applications namely: physical game for the child and the other, a management application for the instructor/guardian /parent. The main difference between these applications is that one of them is used for learning and practice of words, while the second application concentrates on enhancing words learnt. It holds management of user results and data. The main aim of the application is divided into three main modules: Managing production of speech, processing speech signal, and obtaining results, managing visualization of user profile. For

speech recognition and processing, SPHINZ4 framework is used. The application was tested on 10 children with speech disabilities and the researchers attained positive results. Dehkordi and Rias[12] developed mobile application for iPhone devices that operates on iOS platform. The purpose of conducting the research by the authors was to make children learn managing simultaneous occurrences of different applications. Kozima, Nakagawa, and Yasuda illustrated interactive robotic application developed to improve social skills of special children with neurological disorders since the children suffering from such disabilities may not be socially interactive[13]. Like children with autism show no interest in communicating with unfamiliar faces, some even do not make eye contact, and posses stubborn behavior [17].

Therefore, one can say that assistive technologies can aid and act as supportive tools for children with special needs [14]. With the advent of time, mobile technology is available at substantially reduced prices resulting in deeper penetration of such devices in rural areas. Thus, there is an essential need of developing a low cost assistive technology for children with learning disability that can be used widely. The present study aims to address this need by developing low cost solution based on Indian native language Hindi for children with learning disabilities.

The study was conducted in collaboration with a rehabilitation centre for such special children located in the northern region of India to observe the functional needs of children. It was observed that some of the children who were non-verbal were suffering from severe learning disability, while others were verbal, despite the fact that their speaking skills were not very prominent. Further, it was noticed that they were particularly interested in playing games on interactive devices such as mobile phones and tablets. Thus, the purpose of conducting the present study is to develop an educational android application in Hindi and English language to enhance the learning abilities and communication skills of children suffering from disabilities like autism, dyslexia, aphasia, and specific language impairment. The paper is further divided into the following sections: Section II provides an overview of the application. Section III describes the interface of the application. Section IV illustrates the methodology that was followed to conduct our study. Section V presents the analysis and outcomes. Section VI presents the discussion of obtained results. Section VII presents the conclusion and future scope.

II. APPLICATION OVERVIEW

Speech is the medium through which individuals can express their emotions by producing articulate sounds [15]. As discussed earlier, the present study aims to improve the communication skills of children and enhance their speech accuracy, and fluency by developing an android application. This application is developed for children suffering from range of mild to severe learning disabilities. It is an educational application for such children with the aim of providing an interactive learning platform for them.

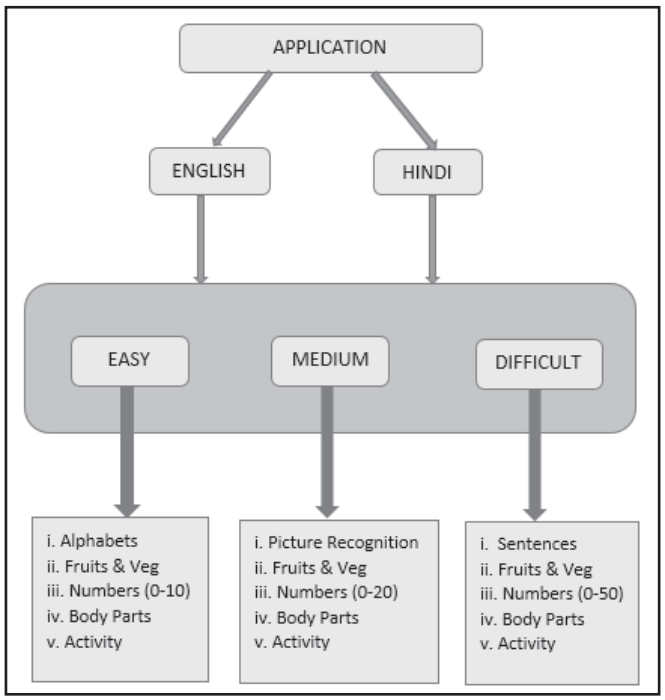

Fig. 1. Application Overview

The overview of developed application is provided in fig. 1. The application has been developed in the two languages Hindi and English because most of the population in northern region of India speak these languages. Further, the application has three different levels for learning namely: easy, medium, and difficult. The type of level a child plays is based on his/her performance. Each level of the application consists of five categories. These categories are defined according to the level of application. In the initial level, the categories are named as: alphabets, number, body parts, fruits and vegetables, and daily life activities. The number of images in the initial level are less. In the next level, the categories are named as: picture recognition in one word instead of alphabets, number, body parts, fruits and vegetables, and activity images. The number of

images in all categories increase in the last level . However, instead of picture recognition category, it has sentences. Each level has a different set of images. The application is implemented in an incremental manner of level of difficulty. It is expected that the child will progress across these three levels which represent different complexities.

III. APPLICATION INTERFACE

The application contains components that make it unique. Fig. 2 and fig. 3 represent the application interface. Fig. 2 presents initial level category of alphabets in both Hindi and English. Similarly, fig. 3 represents picture recognition category of second level in English and Hindi, respectively. Whenever an image appears on the screen, its audio file is played along with it. It helps the child to hear and memorize easily by playing the audio as many times the child wants, thus, making the application interactive. The most important element of the developed application is the recording button present on the top of the screen. It is used to record the speech response of the child.

Whenever the recording option is selected, the audio file of the images appearing on the screen stop playing and the response of the child is recorded automatically. The child's response is recorded and saved in the media files of the android device which can be later used for analyzing the correctness of the response. This feature especially makes the application distinct from other available applications. Moreover, another feature that marks this application distinct from others is that the application covers five different learning categories all together in one application.

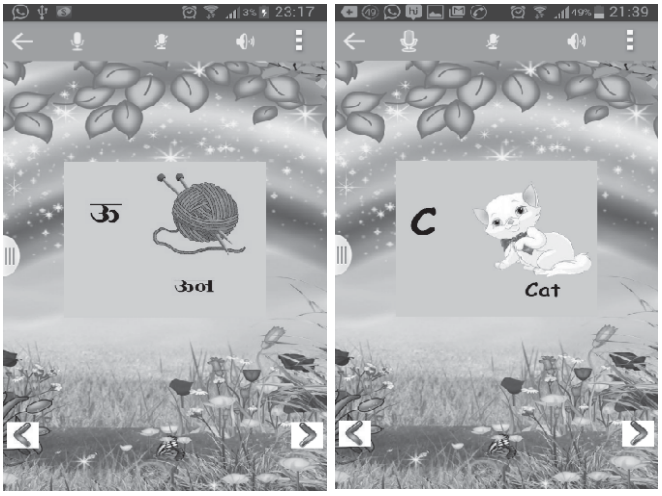

Fig. 2. Picture from alphabets in easy level of Hindi and English language

Fig. 3. Picture from picture recognition in medium level of Hindi and English

IV. METHODOLOGY

Fig. 4 describes the procedure followed to conduct the study, beginning from designing the interface of the application followed by data accumulation, developing, and testing phase of the application.

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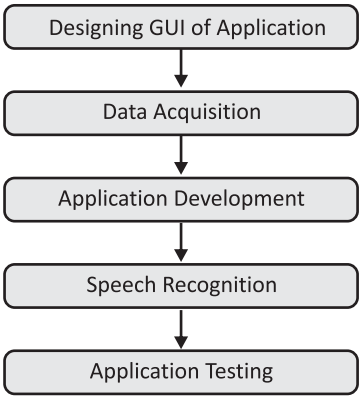

Fig. 4. Proposed Methodology

A. Application Modules

The application was developed in modular manner where distinct modules were constructed for different requisites of the application as shown in Figure 5.

The first module consists of two buttons for selecting the languge i.e. English or Hindi. By clicking one of the buttons, the language can be selected. The purpose of the second module is to choose the level of difficulty. The category selection modules were developed to choose one of the available categories. Module 3 contains different labels depending upon the difficulty level, namely: alphabets (easy level), picture recognition (medium level), and sentences (difficult level). Module 4 presents the numbers category. The number of images for this category is different for different levels. Similarly, module 5 presents category of body parts. Module 6 contains fruits and vegetables division and module 7 contains daily life activities category like washing hands, combing hair etc. The count of images in each level depends upon the type of level selected.

B. Data Acquisition

The challenging part of the application was to maintain the database of all the images of the application. Other than the database maintenance for images, the other task was to maintain the database for all the audio

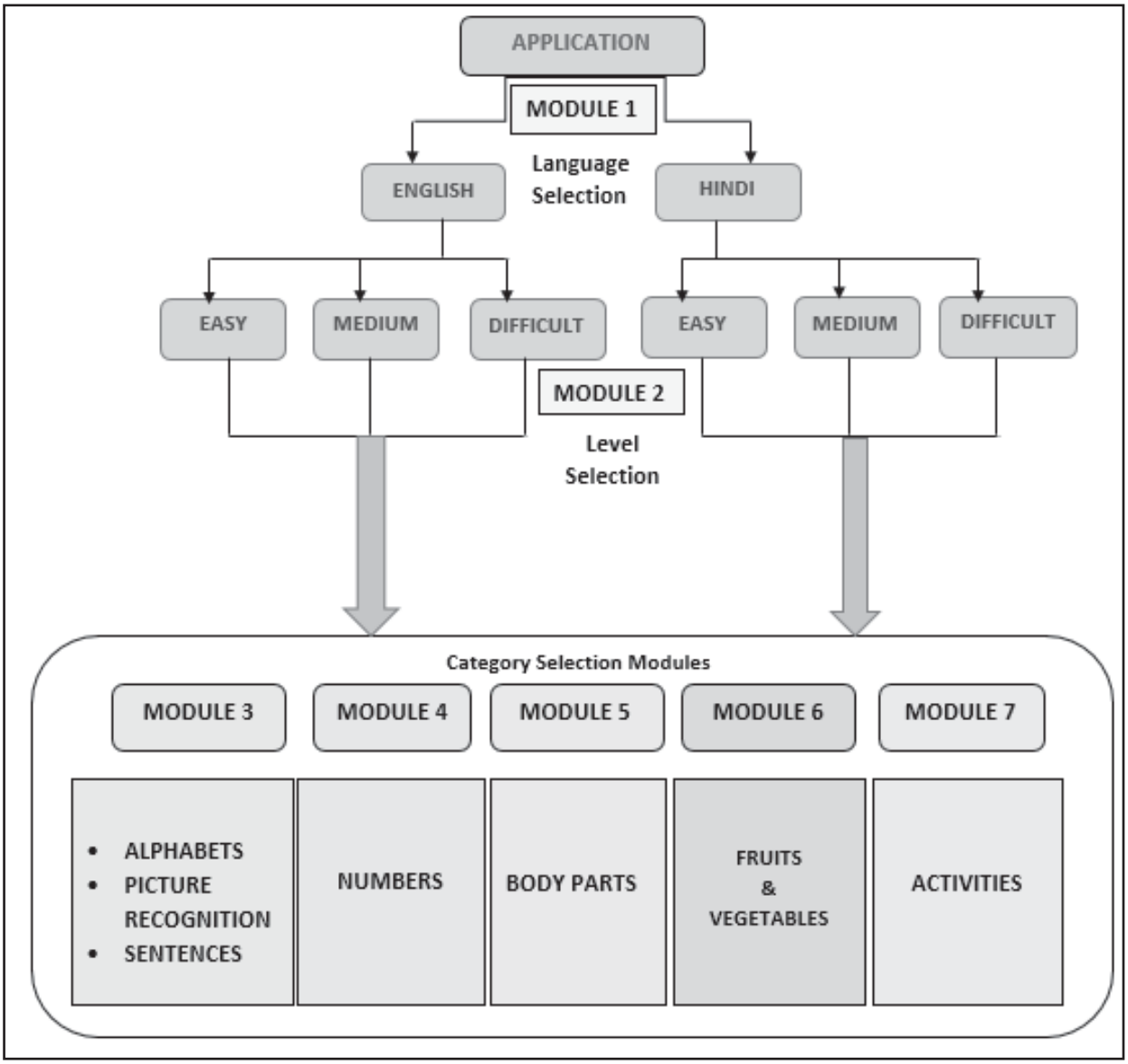

Fig. 5. Representation of Application Modules

files linked with each image of the application for both the languages, English and Hindi. The count of images and audio files used for Hindi Language is 186 and 165 for images and audio files used for English Language. Thus, a total of 351 images were used in the application along with the associated 351 audio files for the application.

TABLE I.
DATA OF IMAGES DEVELOPED FOR APPLICATION

Number of images developed for Hindi language	Number of images developed for English language	Total number of images developed for application
165	186	351

TABLE II.
DATA OF AUDIOS RECORDED AND DEVELOPED FOR APPLICATION

Number of Audio files developed for Hindi Language	Number of Audio Files developed for English Language	Total Number of Audio Files developed for application
165	186	351

Table I describes the total count of images developed for the application and Table II describes the total number of audio files developed for the application in which the count is directly proportional to the count of images used in the application. The audio files were recorded with the help of professional recorder at 16 bit PCM with sampling rate of 44 kHz. However, these audio files were not stored in a separate database, and instead these were included directly in the resource folder. The images and the audio files were all included in the package. While the application is running, it directly fetches the data from its resource folder.

C. Google Web Speech API

In our study, a speech recognition system was required for converting speech to text. Though there are a variety of speech recognition systems available for speech to text conversion, Google web speech API was selected because of its better performance and high availability [16]. It is an open source interface for speech recognition. It provides speech recognition competence in almost each of the available languages across the world. It includes a microphone icon and once the icon is clicked, a person can start speaking. However, in the present study, an input file of a child's recording to be recognized by this API was provided which was converted to text that was used for comparing with correct text answers stored in the database.

V. ANALYSIS & OUTCOMES

A. Application Testing

To test the developed application, subjects from a rehabilitation centre located within the city were approached. The instructors present there allowed the children to access the application. Four children participated who were verbal and in the age range of 7-14 years . All of the four children were suffering from different severities of learning disabilities. Table III presents the details of subjects for conducting test experiments.

TABLE III.
TEST EXPERIMENT CONDITIONS

TEST EXPERIMENT	
Participants	**Age**
3 Males	7-14 years
1 Female	8 year
Noise Free Environment	
Playing each Level twice	

Table IV describes test experiments performed in the first week and second week. During the first week, the subjects were provided access to all the categories of initial level of the application. They also learnt pronounciation of words by listening to audio files . However, during the second week, those who could score more than 60% in the first level were allowed to operate medium level of the application, while others continued to work on the same level. Similar policy for progression was followed with these subjects i.e. they were allowed to progress to the next level only after scoring more than 60% in the given level.

B. Test Results

The children showed profound interest while interacting with the application interface. The results were obtained in the following manner: Once a child had accesed all the categories of a particular level, the instructor or the guardian selected the recording icon present on top of the screen. Then the child was asked to

Table IV.
TEST EXPERIMENT CONDUCTED IN TWO WEEKS

Week	Hindi	English
1st Week	Child plays easy level in the first week.	• Alphabets • Numbers • Body Parts • Fruits & Vegetables

		• Activities
2nd Week	Child plays medium level in the second week	• Picture Recognition • Numbers • Body Parts

recognize the image. Once a child had operated all categories, his/her recording was saved automatically. The recording was done in a noise free area to obtain error-free outcome. All the recordings of a particular subject are processed in speech-to-text recognition system (using Google Web speech API) .

TABLE V.

DEPICTING TEST RESULTS

TEST RESULTS						
Week 1	Child	Level	Gender	No. of Recordings	No. of Recording Recognized Correctly	Percentage Improvement
	Child 1	Easy	Male	10	7	70%
	Child 2	Easy	Female	12	8	66.6%
	Child 3	Easy	Male	10	4	40%
	Child 4	Easy	Male	10	3	30%
Week 2	Child	Level	Gender	No. of Recordings	No. of Recording Recognized Correctly	Percentage Improvement
	Child 1	Medium	Male	10	6	60%
	Child 2	Medium	Female	12	7	58.3%
	Child 3	Easy	Male	10	8	80%
	Child 4	Easy	Male	10	7	70%

Figure 6 and Table V present the results of various tests. The test results are attained by using following method : If the word uttered by a child is recognized then it is considered as accurate and correct outcome, otherwise, if the words uttered by the child are not identified by the speech recognition system then the outcome is considered as errorneous and inaccurate . If the percentage of improvement is less than 60, then the child is asked to repeat the same level again.

Figure 6(a) presents the percentage improvement of Child1,Child2,Child3, and Child4 during the first week. It was observed that in Week 1 , Child1 speaks 7 words correctly out of 10 , thus obtaining a 70% score. Similarly, Child2 speaks 8 words correctly out of 12 words obtaining a score of 66.6%. Child3 attained 40% by speaking 4 words accurately out of 10 words and

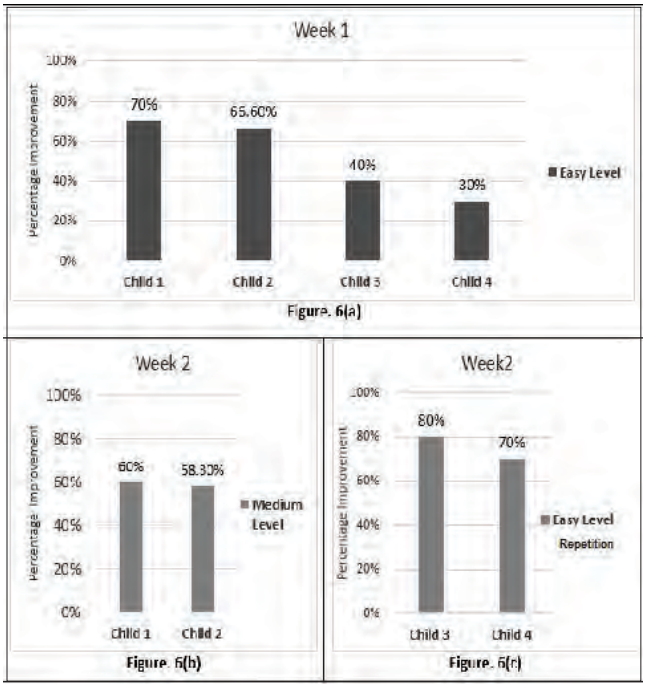

Fig. 6. Graphical representation of percentage improvement in Week 1 and Week2

Child4 obtained 30% by speaking 3 words accurately out of 10 respectively . Since the performances of Child 3 and Child4 in week 1 were not satisfactory , they repeated same level again in week 2. Figure 6(c) represents the percentage improvement graph of Child 3 and Child 4 during week 2. While based on performance measure of child 1 and child 2, they were allowed to play medium level of application. In week 2, by processing the recordings, remarkable improvements were obserevd as shown in Figure 6(b) . Child 1 uttered 6 words accurately out of 10, thus, attaining 60% score. Child 2 achieved 58.3% by speaking 7 words correctly out of 12 . Child 3 attained 80% by correctly speaking 8 words out of 10. Child 4 uttered 7 words correctly out of 10 words gaining 70 % respectively.

VI. DISCUSSION

The present paper describes the application developed for providing speech and language learning tools for children with learning disability. The application is an Android App based learning tool with three different levels of complexity that are made with the assumption that subjects will progress through these levels with practice. The authors worked with instructors at local rehabilitation centre to perform the test experiments. The children were initially made to learn and operate only on easy level of the application with

help of the instructor. The children were allowed to access different modules of the application however the children performed according to his/her ability. However, results indicate that children were able to perform better with practice. During the first week, all four children played easy level of the application.

Child1 and child 2 performed well in the first level during the first week obtaining 70% and 66.6% respectively, while performances of child3 and child4 was not up to the mark as they obtained 40% and 30% respectively. Since the percentage improvement of child 3 and child 4 in the first week was less than 60%, they were made to repeat easy level again. In the second week, child 1 and child 2 were allowed to play medium level of the application. However, their performance was satisfactory and they scored 60% and 58.3% respectively. Also, child 3 and child 4 who were made to repeat the Easy level again in the second week performed much better this time and attained 80% and 70% respectively. Thus, from this observation, it can be deduced that the application is beneficial and effective for improving functional spoken skills of such especial children.

VII. CONCLUSION AND FUTURE WORK

The Android application development for mobile devices can be aforethought as an appealing solution to enhance the speaking skills of individuals with learning disability whether mild or severe. In distinction to this work conducted so far, it was found that children are proved to be more attractive towards gadgets and devices. Therefore, developing such kind of applications and assistive technology is needed to enhance the daily life conditions of such especial children. While the children were about to operate the application they showed curious behavior towards it and got convoluted in running the application. The application has been tested and proven to be effective to improve speech skills of such special children in a particular manner. More experiments needs to be performed to generalize this conclusion. Moreover, in future there is scope of developing an educational multi-lingual assistive application for such special children since India is a multi-lingual country and it will be beneficial for such special children to learn and speak in their native language. In future, the application can be extended by establishing and maintaining a server in which all the parents or the guardians can upload the speech recording of their children from their specific account, and then the application can download the recordings to process them and upload their child's result on the server.

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Dr. Latika Singh is an Associate Professor and joined NCU is working as Assistant Professor in the Department of CSE/IT. She has done her B.Sc. from Kurukshetra University, M.I.T. from Guru Jambeshwar University, and Ph.D. from National Brain Research Centre, Manesar. Her research interests include using computation and machine learning tools in various applications including diagnosis of neuro developmental disorders, detection of android malwares, blind steganalysis etc. She has guided one Ph.D. in feature reduction for blind steganalysis.

She has managed 3 sponsored projects from various funding agencies including DST, AICTE, and DST-CSRI etc. She has published more than 30 papers in various journals and conferences of international repute. She was the convener of IEEE sponsored 4th IACC conference and was organizer of AICTE sponsored National Conference on Soft Computing. She has been awarded best faculty award twice at The NorthCap University for her contribution in teaching and research. She is a member of Computer Society of India and ACM.

She has guided more than 10 M.Tech. thesis and more than 20 B.Tech. projects in various technologies. She has taught a wide range of courses including Internet of Things, Data Mining, Text Mining, Web Mining, Ruby on Rails, Programming (C, C++, Java, Ruby, Python), Business Intelligence etc.