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Speech development of autistic children by interactive computer games

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Abstract

Purpose – Speech disorder is one of the most common problems found with autistic children. The purpose of this paper is to investigate the introduction of computer-based interactive games along with the traditional therapies in order to help improve the speech of autistic children.

Design/methodology/approach – From analysis of the works of Ivar Lovaas, it is already known that there are several disadvantages to the "applied behavior analysis" approach to solve the problems of autistic children; so the authors' methodologies were to encourage children with Autism Spectrum Disorders (ASD) to "play," where playing is mediated through technology. By creating technological methods of interaction (visual displays and physical robots), play and comfortable interactions can be garnered from children with autism. There is a feeling of "safety" in having the main form of interaction occur with non-humans. Further, these devices allow the child, rather than a third party, to be in control of the interactions.

Findings – From the observations, it could found that the problems of autistic children have a wide range and it is almost impossible to design a single game for a group of children. Instead, each child needs to be treated individually. Hence, the authors are suggesting different types of games for different problems.

Research limitations/implications – The authors have proposed some computer game-based therapies for two types of autism that are discussed in the paper. Interactive games can be built for other types too. After having a group of these games it can be an experimental topic to determine the order of execution of these therapies. However, the proposed games heavily depend on the instructors. Research should be conducted to minimize the duties of instructor.

Social implications – The autism spectral disorders are defined by the qualitative impairments in social communication. Although the actual reason for autism is still unknown to the medical sciences, it has been proved to be the result of abnormal and irregular growth of cerebral neurons of human brains. People suffering from autism very often demonstrate a poor performance in social interactions and hence find it difficult to communicate with other people. So if vocalization can be encouraged at the age of 3, a pivotal age for children with ASD, this could lead to an increased communicative ability, which makes not only the child's life easier, but also increases their chances of functioning in the world around them.

Originality/value – This paper offers a hierarchy of speaking skills and suggests corresponding games for each stage to achieve a necessary level of efficiency.

Keywords Children (age groups), Communication skills, Social interaction, Autism, e-Learning, Educational games, Human factors

Paper type Research paper

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Introduction

The autism spectral disorders are defined by the qualitative impairments in social communication. Although the actual reason for autism is still unknown to the medical sciences; it has been proved to be the result of abnormal and irregular growth of cerebral neurons of human brains. People suffering from autism very often demonstrate a poor performance in social interactions; and hence find it difficult to communicate to other people. On the other hand, it is equally difficult for others to communicate to them in the usual ways. As the number of autistic children has been reported to increase at a high rate throughout the world in recent decades, it has become necessary to discover effective ways for communicating to them. One of the bigger challenges is to ensure good education to the autistic children in a proper way so that they can develop their skills and contribute to the society being within their limitations.

Although the actual reasons for the speech and language problems in autism are still unknown (Center for Disease Control and Prevention, CDC (n.d.)), many experts believe that the difficulties are caused by a variety of conditions that occur either before, during or after the birth effecting cerebral development. This interferes with an individual's ability to interpret and interact with the world while communicating. Different types of irregularities in speech communication have been addressed in literature including the followings:

- non-response;
- making low sounds in response;
- making unintelligible sounds;
- making delay in answering questions;
- answering incorrectly with articulate words;
- difficulties in making correct sentences with words; and
- lacking the sense of turn taking.

In this paper, we concentrate on the problems of "making unintelligible sounds" and "difficulties in making correct sentences with words". The term "intelligibility" refers to the proportion of a speaker's speech that a listener can readily understand. Many of the autistic children suffer from speech unintelligibility. Although they can produce sounds loud enough, the audience cannot get the meaning of those. Again, a good number of autistic children can utter a word or two correctly but cannot make a full sentence. We address these two vital problems of speech communication in this paper.

Actually, there is no definite treatment for autism. The best we can do is to help the autistic children in making proper social communication being within their limitations. Computer games have recently been proved to be very powerful tools in this regard (Hoque, 2008; Hoque *et al.*, 2009). By exploiting the interest of the autistic children to get rewards in the games, we have tried to develop their intelligibility skill in speech. In our experiment, with ten children over five months at Autism Welfare Foundation at Dhaka, this approach was proved to be fruitful. We do not suggest replacing the traditional therapies by our game therapies; rather we recommend introducing our games besides the traditional therapies for the best output.

The paper is organized as follows. We first discuss the related works about autism spectrum disorders (ASDs). Then we demonstrate our first interactive e-learning games for increasing intelligibility of the autistic children with its software

architecture and hardware and software requirements. We talk about the experimental results which prove its success in game therapy. Then we discuss our next computer game which helps children to develop fluency in their speech. We conclude with ideas for future works in conclusion.

Related works

The research for teaching autistic children is not new. In the 1960s, Ivar Lovaas began teaching children with autism new behaviors through a technique called "applied behavior analysis", in which a behavior is encouraged or discouraged as it encounters environmental consequences. In short, his technique relies upon using objects, foods, and actions as rewards for desired behavior (prompted by a researcher) (Lovaas, 1977; Charlop-Christy *et al.*, 2002). Over many trials and sessions, children with autism eventually learn to respond in a predictable fashion by interacting with people in their environment. There are three main drawbacks of this form of treatment:

(1) It requires many sessions with trained professionals who are in short supply. This can place a financial burden on the family.

(2) Teaching sessions require intense attention and prolonged contact from a practitioner or parent.

(3) The child must interact with a human being. One characteristic of ASD is anxious, detached, and "alone" interaction with other individuals (Baskett, 1996; Kanner, 1943). Thus, the interaction with a human being, as the primary mode of teaching, might pose some degree of built-in difficulty for the ASD child.

Existing works by researchers have approached ASD from three primary directions. Works by Hayes *et al.* (2004), Kientz *et al.* (2007) and Kientz *et al.* (2006) have explored the benefits of technology to aid the diagnosis process. This research is crucial, because early detection allows children to begin treatment earlier, allowing them to catch up faster to their non-autistic peers. Further, this work allows us to better understand how to identify autistic characteristics. Although greatly beneficial, this research does not provide a direct method to enhance the education of children with ASD.

Researchers have also explored the effect that technological environments have had on the process of assisting children with autism to learn how to interact with other human beings (Kerr *et al.*, 2002; Tartaro, 2006). This work uses virtual environments, as well as virtual peers, to create situations in which the children with ASD are comfortable. They are then able to learn person-to-person interactions, without the apprehension of having another person in the room (Rahman *et al.*, 2010; Sharmin *et al.*, 2011; Anwar *et al.*, 2011). This work, however, primarily has dealt with "high functioning" children, or those who already know how to speak and have a deficit in social interaction. Therefore, it is hoped that principles learned from this body of literature will have the potential to be applied to research targeting children with ASD who have not yet acquired speech.

The third approach seeks to encourage children with ASD to "play", where playing is mediated through technology (Lehman, 1998; Michaud and Théberge-Turmel, 2002; Parés *et al.*, 2005). By creating technological methods of interaction (visual displays and physical robots), play and comfortable interactions can be garnered from children with autism. There is a feeling of "safety" by having the main form of interaction occur with non-humans. Further, these devices allow the child, rather than a third party,

to be in control of the interactions. This research has much potential. To date, however, it has not focused on encouraging more communication-based activities, such as speech and human-to-human interaction.

Proposed speech disorder hierarchy

Autistic children, in general, do not concentrate into a particular subject for a long. So, it is difficult to teach them anything. They only concentrate into the objects they get interest in. Most of the times, they get the traditional teaching tools not much attractive and hence, it becomes difficult for the teachers to teach them. From our experiences, we could understand that most of the autistic children are very much interested in computer games. So, here we used interactive computer games to develop their speech. The main idea of this project is to keep their interest and concentration in computer games and teach them necessary things by those.

From our observation, we could find that the problems of autistic children have a wide range of variety and it is almost impossible to design a single game for a group of children. Instead, each child needs to be treated individually. Hence, we are suggesting different types of games with different variation for different problems here.

Proposed speech disorder hierarchy

For our intervention, we designed a speech disorder hierarchy for autistic children. This hierarchy is made upon our experiences we had while working with autistic children.

Here are the stages.

Stage 1: non-response. Children at this stage do not respond verbally to any question. Some children respond non-verbally by making some physical gestures, eye contacts, etc. while some of them remain completely unmoved in response to a question thrown at them. After investigation, we could determine some of the possible reasons why autistic children at this stage do not respond verbally. They are as follows:

- They do not realize that a question has been thrown at them. This can be the result of their hearing imparity or inability to distinguish a question from other sentences.
- They do not know that they need to respond if a question is thrown at them.
- They do not feel that they have to answer the question. Sometimes they wait for other people to answer the question.
- They do not know what to answer. This may happen when they do not know the answer or cannot understand the question.
- They feel shy to answer.
- They prefer non-verbal ways of responding to talking.
- They do not find the answering task interesting.
- They cannot keep their concentration into the subject matter for a period of time.

Stage 2: making low sounds in response. Children at this stage make some low sounds in response to a question. Most of the time, the sounds they produce are meaningless and those are too low to be heard by the audience. Children at this stage are expected not suffering from the problems of stage 1. That is, they can recognize if a question

is asked to them. They know that they have to answer it verbally and they do not feel shy to answer them. But they do not make loud sounds in reply. We could identify some reasons why they do not produce loud sounds. They are as follows:

- They have problems in their oral structure and they cannot produce loud sounds because of this limitation. We have to remember that many of the autistic children suffer from other physical disabilities, too.
- They do not get enough motivation to produce loud sounds.
- They hate loud sounds.
- They think loud sounds are made for special reasons only, such as, calling someone, rebuking somebody, etc.

Stage 3: making unintelligible sounds. Children at this stage can generally produce loud sounds in reply of a question, but the sounds they make are not intelligible. Although those are loud enough to be heard, the audience cannot get the meaning of those. Sometimes those seem to be the distorted forms of the answers but sometimes nothing can be assumed from those. We have found some reasons why this problem takes place:

- This problem may be the result of the distortion of their oral structure. They cannot produce articulate words because of this limitation although they know the actual pronunciations.
- They do not know the actual pronunciations.
- They do not get the motivation to utter the words clearly; rather they just try to finish answering quickly. They do not find it interesting to answer the questions with articulate words.
- They do not feel that uttering clearly is actually necessary.

Stage 4: making delay in answering questions. At this stage, the autistic children take too much time in replying to a question. After getting the question they begin to think about it. After taking a long period (ranging from five to 50 seconds) of time, they make the answer or simply do not respond if the answer is not known to them. We could find out a reason for this type of delay. That is:

- Their cognitive ability is not fast enough to respond to a question quickly. It takes time to analyze the question and get what is asked in the question. Then they start searching in their memory for the answer. If they get any answer, they reply, otherwise they just continue searching. For weak cognitive power, their searching process is slower than the normal human being. As a result, the make this delay.

  By experimenting with different type of questions, it was clear that many of them memorize the answers by visualization or audio clues. If we tell them the answer once and ask the same question, they take less time to answer it. But if we ask the same question in different way, it takes more time for them to answer.
- Poor vocabulary.

Stage 5: answering incorrectly with articulate words. At this stage the autistic children answer any question thrown at them, but their answers are not correct. They make answers to almost all the questions with loud and articulate words, but the answers are

not correct although they know the correct answer. Very often they are found to make irrelevant statements or repeating the question. We could chalk out some causes behind this:

- They are not capable of making the answers. Many of the autistic children are not capable of bearing the cognitive load of answering a question or it takes them too much time. But when they feel that they have to answer the question quickly, they just start saying whatever they get. Most of the time they repeat the question.
- They look for the answers around them and expect someone to help them in answering.
- Sometimes they feel that answering the question is a good thing and they do not need to be correct.
- They do not have the motivation to make the correct answer.

Stage 6: difficulties in making correct sentences with words. At this stage the autistic children can respond with correct words articulately, but they get it difficult to make a complete sentence with the words. Varieties of problems were found with the children at this stage. For example:

- Some of them cannot use proper possessive words for themselves. They do not use "I" or "mine". Instead, they use their names.
- Some of them cannot use the proper form of verbs.
- Some of them cannot combine the nouns and verbs properly.
- Some of them have problems with tense.

Stage 7: lacking the sense of turn taking. By turn taking, we mean understanding and responding to the turns in group activities, such as conversation or playing with others. For example, when two or more people make a conversation, one of them talks while others listen. Then s/he stops talking and another person starts talking. It is important to understand when one should start talking and how long s/he should talk. Similarly, in playing games or in some other group activities, this sense is important for a child for being social. Many of the autistic children do not have this sense. They cannot recognize when they should start talking and when they should stop. We could find out some reasons why they do not take necessary turns. They are:

- An autistic child suffering from the lacking of the sense of turn taking does not understand that there are more people like him/her around. S/he either thinks all the things happen around him/her are only for him/her or thinks none of them are for him/her.
- They do not have the patience in them to wait for their turn.
- They do not find taking turn an interesting thing; rather they consider it as a sacrifice that they do not like.

Proposed interactive game

Since our main concern in this paper is on the problem of "making unintelligible sounds" and "difficulties in making correct sentences with words", we proposed here two interactive games.

I. Interactive game for the problem of making unintelligible sounds

In this section we present the overview of and the architecture of the game, and our implementation procedure with software and hardware requirements for the problem of "making unintelligible sounds".

A. Overview of the interactive game. The game we developed is an interactive e-learning game in which an autistic child who makes unintelligible sounds will try to produce clear words to communicate to the computer. The basic idea of this game is very simple. Various kinds of interesting pictures appear in the graphical user interface (GUI) as shown in Figure 1(a) one by one and the autistic child who can pronounce the name of the picture clearly and loudly can score and win the game. As a result the autistic child will try to make clear and loud pronunciation to win the game which in turn helps them to overcome their unintelligibility problem. While selecting images we emphasized the familiarity of the objects to the autistic children. We also set the word for each of these images based on their familiarity to avoid the possible problem regarding synonyms. There is provision for extending this game for others language and themes.

In Figure 1, we show a simple example of this game. For example, after running the game, the main game window (Figure 1(a)) appears. We must make sure the microphone is ready. The speech recognition engine is automatically started. Now the speech engine is ready to detect the desired word as shown in the figure. There is a timer which keeps track of time. Every image is given some fixed time to be uttered. After this time the uttered word is matched with the correct word. If the word is correctly pronounced the student will get points and in this way the game proceeds. If the word does not match with the word specified in the XML grammar file, she will not get any points and next image will be shown. There is a set of images and the game concludes if all the images are successfully uttered. Finally, after winning the game a dialogue window will come as shown in Figure 1(c) and it also makes sound "Wow, you won!".

B. The architecture of the game. The core of the game consists of the following part:

- Speech engine at the back-end for speech recognition.
- XML grammar files containing the grammar of the specific words.
- GUI at the front-end for communication.

(a) (b) (c)

Notes: (a) Main game scene 1; (b) main game scence 2; (c) winning stage

Figure 1.
An example of the interactive game

Figure 2 shows the data flow diagram of our interactive game. At the beginning a GUI appears with specific image. Next an autistic child with microphone makes voice or pronounces the name of the picture (Figure 1(b)) which passes through the microphone to the speech engine. When it times out the last saved word of the child is passed to an internal procedure that converts it as text. Now this word is passed to the grammar checker function which in turn calls another internal procedure that loads the XML grammar file from directory. Then this XML grammar file is parsed for that specific word. Finally, another image is loaded from the directory by another internal procedure which is shown in GUI. And in this way the data flow continues in the game.

To implement speech engine for speech recognition we have used Microsoft Speech Engine for English Speech SDK 5.1, Microsoft. NET Framework 3.5. We have used Microsoft Visual Studio 2008 for GUI purpose. For operating system we have used Microsoft Windows XP Service Pack 2.

C. Experimental results. For those autistic children those who made unintelligible sounds, we have found that the following level-wise experiment is very effective. Since in "English language" most of the words are mono-, di- or tri-syllable we divided the experiment into three distinctive sessions which we called levels. For the sake of simplicity and ease of discussion, all the chart and graph we have provided in the following experiment considering only one autistic child.

Level 1: mono-syllabic words with unlimited number of attempts. We started our experiment with mono-syllabic words. At this early stage of the experiment an autistic

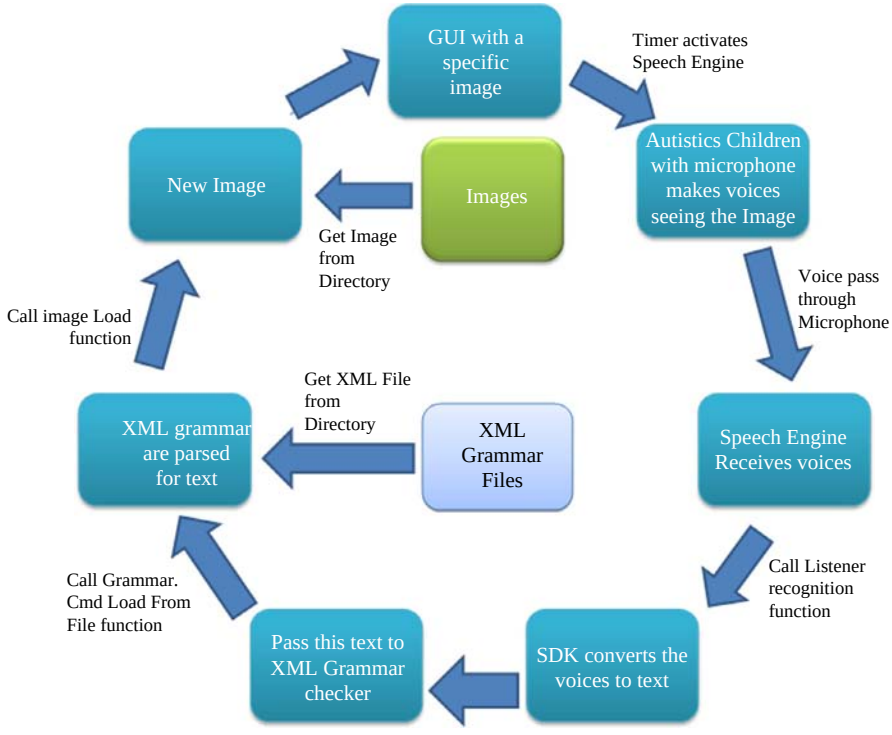


Figure 2.
Data flow diagram

child would get unlimited opportunity to pronounce the word correctly. No matter how many attempts they took, they would get rewards. The results are shown in Figure 3.

Level 2: mono- and di-syllabic words with fixed number of attempts. After successfully completing the level 1 experiment these autistics children were taught to pronounce both mono- and di-syllabic words. However, at this stage of the experiment they would get only a fixed number of chances. If they could do it within the limits it was considered as a success otherwise it was failure.

Level 3: mono-, di- and tri-syllabic words with fast response. Since at this stage, the autistic children were familiar with both mono- and di-syllabic words, so we tried to increase the speed of their speech. For computing the effectiveness we counted how fast an autistics children response with the image and correctly. Based on this analytical reports (Figures 3-5) generated by our software a teacher decides which child is making improvement or who needs further assistance.

II. Interactive game for the problem of difficulties in making correct sentences with words

In this section, we introduce the basic of our second e-learning game, the core components of the game, and our implementation procedure with software and hardware requirements for the problem of "difficulties in making correct sentences with words".

A. Introducing our gaming software. We developed an interactive game where an autistic child who has already a rich set of vocabulary but is unable to complete a whole sentence has try to pronounce the names of the objects shown in computer screen within a short period of time. The core idea of the game is to simulate a sentence with a help of different object at the same time in computer screen as shown in Figure 6. However, the process of object selection in this simulation is controlled by a human instructor from a remote computer. For example, if we want to simulate the sentence, "I eat ice-cream", then human instructor has to select the images of "A man" (it can be the image of the participant), "ice-cream" and finally "A man eating ice-cream" from our image database sequentially. After the process of selection, the images are sent

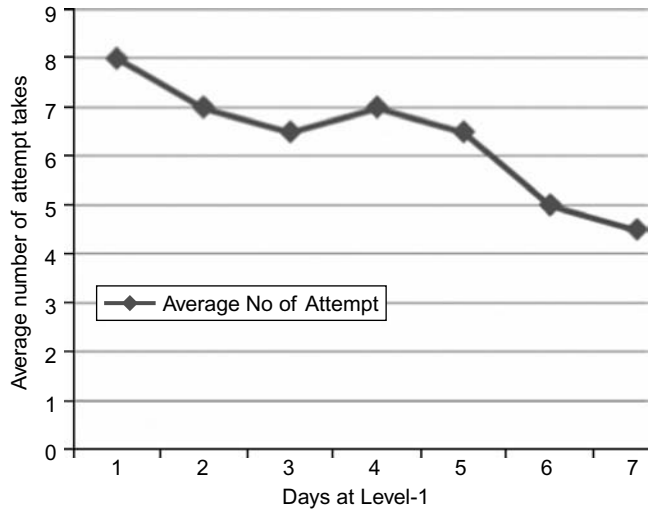


Figure 3.
Average number of attempt takes

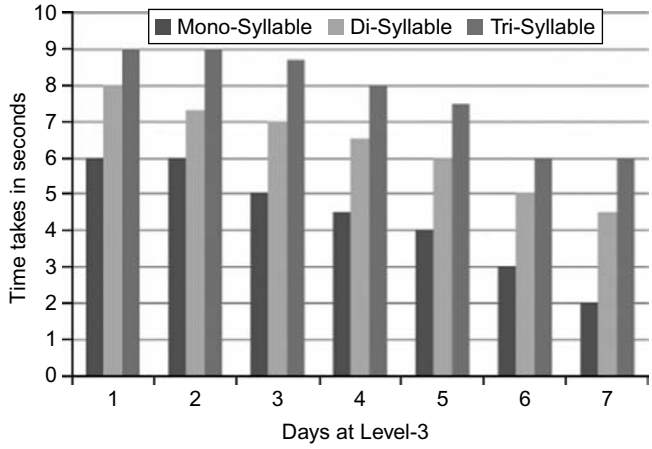


Figure 4.
An autistics child's promptness at level 3

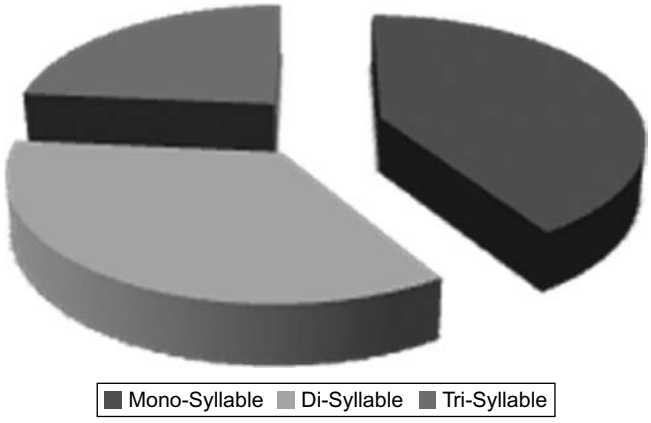


Figure 5.
An overall performance of an autistic child

to the autistic child's computer through local area network (LAN) and displayed in the GUI. If he or she can pronounce the sentence correctly and completely, will receive a virtual award (i.e. animated cartoon or any fancy thing they love).

In Figure 6, we show a simple example of this game. For example, after the initial set up, a user interface will appear at the instructor part as shown in Figure 6(a). Then the instructor will decide which sentence to simulate and select images accordingly from the database. However, there are many predefined simulated sentence in our database, so he or she can select directly that simulated sentence considering the level of ability of the autistic child. Then these images will be sent to the autistic child's computer and will be appeared in the screen as shown in Figure 6(b). Besides, there is a counter to count how many words of the simulated sentence the player has been able to pronounce within certain time limit which ultimately helps the instructor to decide whether an autistic child is performing better or worse. Depending upon his or her success of pronouncing the whole sentence correctly the score will be saved in our database along with the corresponding difficulty level for future reference. Results will

be also shown in the computer screen of the instructor's computer, so that he or she can decide which simulated sentence should be generated next for developing his or her (autistic child) fluency in speaking. There is also a provision in our game where the uttered sentence is directly caught by the speech engine, converts to text and passed to the instructor if he or she (instructor) does not control the procedure manually.

B. The core components of the game. The main portion of the gaming software consists of the following parts:

- Java Socket technology for connecting two computer.
- Swing Component of Java for the design of front-end.
- MySQL Database for storing images and score.

Some of the interesting features of our newly developed game are:

- Completely platform independent (i.e. compatible in all kind of operating system provided the compatible JDK is available).
- Very easily extensible image database with click and update option, etc.

C. Our implemented approach and result. During our five months of intervention, we had used our gaming software in an incrementing manner of the difficulty level of the sentence (i.e. two or three words sentence, etc.) to improve the fluency level of the participant. We not only increased the difficulty levels of the sentence but also set some certain time limits to pronounce the sentence correctly and completely:

(1) *Experimental setup*. In Figure 7, we have shown the experimental setup that was used for improving the fluency in the speech of the autistic children. The instructor and the participant would use different computers connected by an LAN.

(2) *How to play the game*. First the instructor chose a set of images that could form a sentence and pass those to the participant's computer through LAN. The images would appear at the left of the screen and move toward the right until those finally vanished. We introduced this feature considering the fact that, this would give the autistic child a more exciting gaming environment which in turn helps them to pronounce the complete sentence more quickly. We also introduced different difficulty levels determined by the number of words used in a sentence.

(a) **(b)** **(c)**

Figure 6.
Three-sample screen shots of our game

Notes: (a) User interface for the intstructor; (b) a GUI with two objects at the autistic chid's end; (c) a GUI with three objects

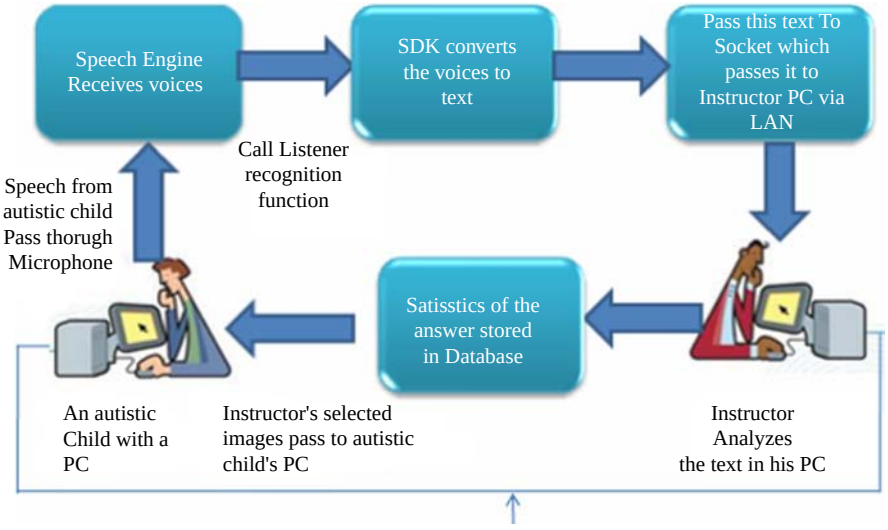


Figure 7.
An overview of the experimental setup

(3) *Experiments and observed results*. Although the main target was to develop the fluency in the speech of the participants, we had to teach her some words first to enrich her vocabulary. We taught her new words using both traditional the picture exchange communication system (Charlop-Christy *et al.*, 2002) method and our gaming software. In Figure 8, we have shown the result obtained during these two processes. In Figure 8, we see that the points in the curve for manual picture method is always either above or on the every point of the curve of our proposed method which eventually indicates the supremacy of our gaming method for learning worlds quickly and efficiently.

Now, for developing fluency, our approach consisted of the following strategies:

(1) Initially a single word appears in the screen.

(2) Then a simulated sentence consists of two words.

(3) Then a simulated sentence consists of three words.

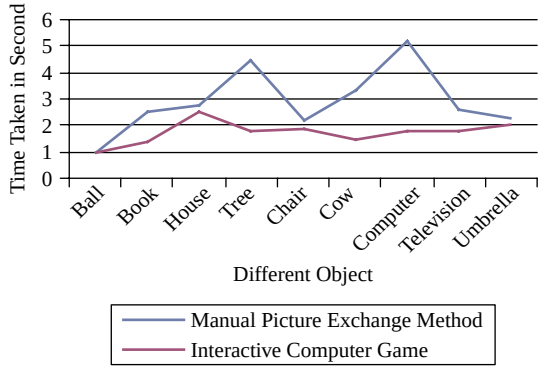


Figure 8.
Comparison between two learning methods

We also maintained data regarding the time taken by the autistic child to pronounce the words along with data of number of words they could pronounce in a single sentence. In Figure 9, we show a fraction of our data collected during our experiment. If we go from left to right in any row, we will notice that the time limit for pronouncing the word of the sentence is reducing. And if go from top to bottom in any column, we will observe that the difficulty level of the sentence is increasing. So, the leftmost top cell is the easiest and the rightmost bottom cell is the hardest. In any cell the "(" mark represents that the autistic child was able to pronounce the word of the corresponding row within given period of time. Similarly, the "X" mark indicates that the autistic child was unable to pronounce the word of the corresponding row within the given time. Besides, there were

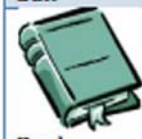
Time Limit → Object	10 seconds	7 seconds	5 seconds
 Ball	✓	✓	✓
 Book	✓	✓	✓
 Tree	✓	✓	✓
 Computer +TV	Computer(X) Television(✓)	Computer(X) Television(✓)	Computer(X) Television(✓)
 Umbrella + Bicycle	Umbrella(✓) Bicycle(✓)	Umbrella(✓) Bicycle(✓)	Umbrella(✓) Bicycle(✓)
 Cat + Dog + Lion	Cat(✓) Dog(✓) Lion(✓)	Cat(✓) Dog(✓) Lion(✓)	Cat(✓) Dog(✓) Lion(X)
 Mango+Banana+Apple	Mango(✓) Banana(✓) Apple(✓)	Mango(✓) Banana(✓) Apple(X)	Mango(✓) Banana(X) Apple(✓)

Figure 9.
Time taken by the autistic children at different level of difficulty of the sentence

provisions for generating different kinds of reports (i.e. individual performance analysis in terms of difficulty levels, per week, month, etc.). These reports could be generated by our gaming software to help the instructor to analyze the performances easily.

Future direction

Disorders in speech are commonly found in autistic children. In this paper, we tried to address some types of speech disorders. These types are found from active experiment with some autistic children. So far, we have proposed some computer game-based therapies for two types of autism that we discussed earlier. Interactive games can be built for other types too. After having a group of these games it can be an experimental topic to determine the order of execution of these therapies. The interface should be enhanced to attract the children and their interests. The proposed games heavily depend on the instructors. Research should be conducted to minimize the duties of instructor. Artificial intelligences can be introduced to measure the interest and performances of individual child.

Conclusion

To date, very little research has been reported on using technology to teach low functioning children with ASD to learn to vocalize or speak. However, the field of augmentative and alternative communication embraces technology primarily as a medium of communication and not as often as a method of instruction. If we can encourage vocalization at the age of 3, a pivotal age for children with ASD, this could lead to an increased communicative ability, which makes not only the child's life easier, but also increases their chances of functioning in the world around them.

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