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Towards Developing an IoT Based Gaming Application for Improving Cognitive Skills of Autistic Kids

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Abstract. With the advancement of technology, a wide range of automated tools are now used to teach children with autism. One of the widely used therapies for children with Autism Spectrum Disorder (ASD) is Applied Behaviour Analysis (ABA) training that focuses on improving a wide range of behaviours like communication, adaptive learning skills, social skills and a variety of motor skills. Thus, the objective of this article is to design and develop a gaming application for autistic children for improving their cognitive skills. The Internet of Things (IoT) and ABA techniques were adopted to develop the gaming application that consists three games including a puzzle game, an object finding game and a road crossing game. The cognitive development (in terms of gaming scores) of a child over the time can be stored and analyzed using this application. A light-weighted evaluation study was carried out; and found that the proposed gaming application is usable, effective and useful for autistic kids to improve their cognitive skills.

Keywords: Autism Spectrum Disorder · Applied Behaviour Analysis (ABA) · Cognitive skill · Learning tool · Internet of Things · RFID · Sensors

1 Introduction

Cognitive skill development is an essential phase of any child's gradual growth process which primarily involves building attention, memory and thinking. Children with autism are the ones who go through a different development cycle than the ones who are normal by birth. Autism or Autism Spectrum Disorder (ASD), refers to a broad range of conditions characterized by challenges with social skills, repetitive behaviors, speech and nonverbal communication [1]. The common thread are the differences in social skills, communication, and behavior compared with people who aren't on the spectrum [2]. Studies have shown

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that they perceive the senses from the environment in a different way than any normal children. Thus, they are trained in some adaptive practical ways like Applied Behaviour Analysis (ABA) to develop normal senses correctly.

Statistics have proven that Autism Spectrum Disorders (ASD) are complex developmental disabilities affecting as many as 1 in 59 children [3]. In [4], Bakhtiari et al. mentioned that individuals with ASD are characterized by early onset impairments in communication and reciprocal social interaction as well as by the presence of repetitive and stereotyped behaviors. Again, greater autism symptomatology and lower intelligence were found among children who do not attain phrase/fluent speech, with nonverbal intelligence and social engagement emerging as the strongest predictors of outcome [5]. Often it becomes difficult for a teacher or parent to keep record of every such precise progress of the child. Thus if there is a system that can keep a regular track to analyze their development as well as be a good tool to keep them busy, then it may improve their development process.

Since technology these days have it's touch in almost every sphere of our lives, thus the application of technology for the development of autistic children is a matter of consideration. While various app based interfaces have been developed as their teaching tool, but survey says that they are better at learning if they have hands on experience of what is being aimed to teach them. Thus an interface incorporated with both hardware and software games would be a much more promising learning tool.

Considering this, the objective of this research is to develop a gaming application that will regularly track and record a child's gradual cognitive development according to their (autistic kids) gaming performance. The tool will be IoT based where both hardware and software games will be incorporated and individual's score will be stored and later presented graphically to analyze his/her mental progress and help in making recommendations for future improvement.

The organization of the paper is as follows: Sect. 2 highlights the related work to understand the background of the development. The conceptual framework highlights the overall idea of how different users interact with the device in Sect. 3. The actual implementation of the gaming system is discussed in Sect. 4 followed by discussing the evaluation of the prototype in Sect. 5. Finally, a brief concluding remark is presented in Sect. 6.

2 Literature Review

A significant number of children today are being affected due to autism spectrum disorder. Thus a number of studies have been conducted on the diverse applications of technology-based interventions in dealing with autism [6,7]. In this section we briefly present the related studies to this work.

First of all, a significant number of studies were conducted focusing on the development of assistive technologies for autistic children. Castillo et al. [8] developed an assistive tool for children with ASD in a web environment for teaching the basic emotions like anger, sadness, fear, joy, love and surprise.

Hwang et al. [9] reviewed sixteen empirical studies that investigated the effects of social interactive interventions designed to increase early social communicative skills of young children with autism. This study showed how the social interactive training could be a promising technique for promoting more advanced preverbal and verbal communication of children with autism in daily classroom activities. In [10], highlighted the relations between the assistive technologies and ASD and found that further research is required in developing assistive technologies for autism which focused on constructive skill.

With the ever-growing population of children with autism, research on their instructional aids is being conducted. Goldsmith et al. [11] reviewed five technologies that can be used as a temporary instructional aid for autism including: (a) tactile and auditory prompting devices, (b) video-based instruction and feedback, (c) computer-aided instruction, (d) virtual reality, and (e) robotics. This study also presented how technology based interventions are often useful for and appealing to children with autism. In [12], Parsons et al. reports and reflects their experiences of co-creating digital stories with school practitioners in a project named *'Shape'* focusing on embedding innovative technologies for autistic children in classroom practice. The digital stories were short films or narrated sequences of slides and images to enhance children's social communication skills within the school environment. While Knight et al. [13] conducted a comprehensive review of articles published between 1993 and 2012 to determine the key concerns of using instructional technology to teach academic skills to students with autism and concluded that practitioners should use caution when teaching academic skills to individuals with ASD using technology-based interventions.

The study conducted by Bartoli et al. [14] showed that how autistic children behave when engaged in motion-based touchless gaming. In [15], a design of a novel collaborative virtual reality environment (CVE) for supporting communicative perspective-taking skills for high-functioning children with ASD is discussed. It concluded that CVE could form the basis for a useful technology-based educational intervention for autistic kids. Boucenna et al. [16] studied some of the interactive technologies for autistic children and found that robotic scenario is an excellent way to elicit behaviors of autistic children.

Children with autism have significant deficits in face recognition. Tanaka et al. [17] introduced the *Let's Face It!* program which is a practical intervention in face processing for children with ASD. They conducted a randomized clinical trial, where impaired face recognition was ameliorated through 20 h of computer based treatment. It has advantages of being cost-free, adaptable to the specific learning needs of the individual child and suitable for home and school applications. In [18], Zaki et al. introduced a cost-effective, portable and user-friendly interactive learning tool to provide autistic children with basic academics which consists of a pressure sensing keypad to provide an easy and flexible means of interaction for autistic kids.

As internet based support system for autism is the demand of the day for autistic children and their parents, Islam et al. [19] developed an online support

system (Autism Sohayika) for autistic children and their parents in the context of Bangladesh. Silva et al. [20] developed a web-based application for individual interests of children with ASD. It allows the teachers and peers to prepare a unique setup whose layouts and contents are customizable as per the child's need.

A set of existing technologies are briefly presented in Table 1. The review showed that the existing technologies mainly focused to improving the communication skills, basic academic learning or emotion/facial recognition skills of an autistic child. A few of them also focused to developing the cognitive skills of autistic kids. But none of them are explicitly focused to improve the cognitive skills of autistic kids through an IoT based gaming tool. Thus this research focuses to the development of an interactive IoT based gaming tool for autistic children which will regularly track their cognitive skill development.

Table 1. Summary of the existing technologies

References	Technology	Objective
[8]	Web environment	Teaching and identification of basic emotions
[10]	Assistive technologies	A review of the mobile learning apps
[12]	Digital stories (Shape Project)	Explore creative ways in which children's social communication skills can be supported in schools
[14]	Motion-based touchless mini-games	Promote attention skills, positive emotions and stress relief
[15]	Collaborative virtual reality environment (CVE)	Supports communicative perspective-taking skills (teaching how to relate to other people)
[16]	Robotic environment	Improve motor skills and interactive behavior
[17]	Let's Face It	Improve facial recognition skills
[18]	Portable learning tool	Teach basic academics particularly English alphabets using a pressure sensing keypad
[19]	Autism Sohayika	An online support system for autistic kids and their parents
[20]	Web-based application	Communication Skills training based on multimedia content
[21]	Learning tool	Developed for vocally impaired people of Bangladesh to learn Bengali alphabet without any assistance or supervision of another person

3 Conceptual Framework

A conceptual framework has been proposed to develop an automated progress tracking gaming tool for autistic kids as shown in Fig. 1. The framework shows the interaction of the tool with it's primary users (autistic children, therapists and parents) and how the child's progress is recorded, stored and viewed. The gaming tool have two components basically: a hardware device and a mobile application. The tool consists of three games which were designed following the ABA concept. These games generally improve basic cognitive skills of the child like remembering, reasoning, learning and attention skills.

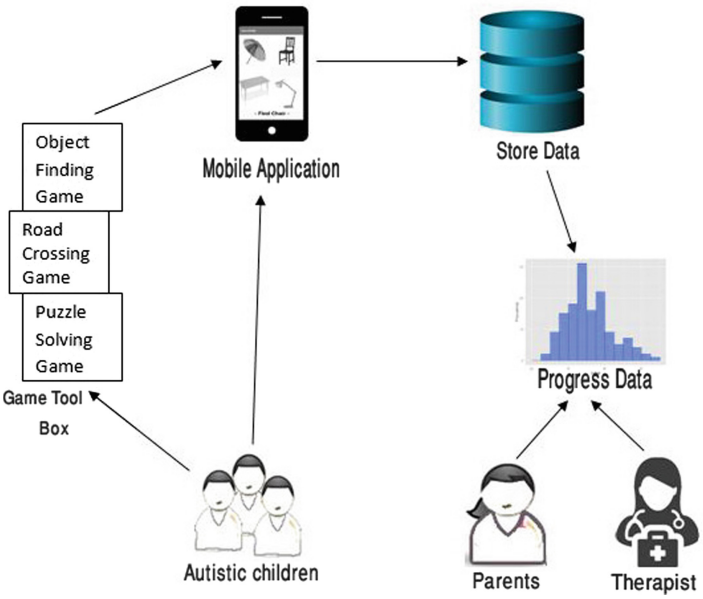


Fig. 1. Conceptual design of the proposed gaming tool

A detailed description of each of the games is discussed below:

(a) *Object finding game:* This game consists of some function cards each of which includes four images of similar type objects like animals, alphabets, fruits, etc. The child has to find the correct object as mentioned on the top of a card. It will also serve the purpose of teaching alphabets to the child. When an alphabet is pressed, an animation of the letter appears on the mobile screen. This game is designed with an aim to test the memory or remembering skills of the child and also aid alphabet learning purpose.

(b) *Puzzle game:* There are six cards which needs to be placed sequentially in order to either solve a puzzle or form the correct sequence of an event like brushing teeth, weather changing sequence, etc. The purpose of this game is to test the reasoning and learning capabilities of the child.

(c) *Road Crossing game:* This game is designed with a purpose to teach basic directions (left, right, top, down) and caution measures to the child to test his/her attention skills. It consists of an android game where the target is to cross a road safely avoiding the obstacles like car, objects, etc on the road and the movement of the person for crossing the road is controlled by a joystick.

Key features of the progress tracking gaming tool:

(1) *User account creation:* An user account will be created for individual kids to provide authorized access by therapists/guardians and maintaining privacy for the child.
(2) *Displaying result:* The success/failure of playing a game will be immediately shown through multimodal feedback like audio, animation and text or a combination of them.
(3) *Recording progress:* Data related to playing date, number of trials to accomplish the game, gaming results or scores will stored for each player which will be accessible only by the authorized person.
(4) *Generating progress charts:* The system will generate progress chart to show the individual's progress within a specific time period.
(5) *Viewing progress:* Individual's progress can be observed by any authorized person to take necessary actions for future improvement of a child.

4 Developing the Application

The gaming application was implemented considering the features stated in the above section and shown in Fig. 2. The entire development and implementation was carried out in an academic environment. The development tool consists of two parts: a hardware and a mobile application. The hardware is powered from a power source in order to activate the device. There are three switches corresponding to the three games on the device. When the respective switch is on, the connected devices get power. There are four piezo sensors fitted on the face of the game box in right side which is for the object finding game. It also has a slot for keeping the function cards there. In the left side of the tool, there are six RFID readers fitted on top which is basically the box for puzzle game. A joystick module is placed on the middle box which is for the road crossing game. It has an arrangement to keep the mobile phone standing while playing the game.

The main hardware component was the Arduino Mega that connected the other components or modules. Data from the piezo sensors, RFID, joystick modules are received in the Arduino. Then, this data is passed to the android application through the bluetooth module connected to Arduino where the results or animation can be viewed. In the object finding game (Fig. 3), when a card is placed on the corresponding position of the box, the RFID tag attached to the

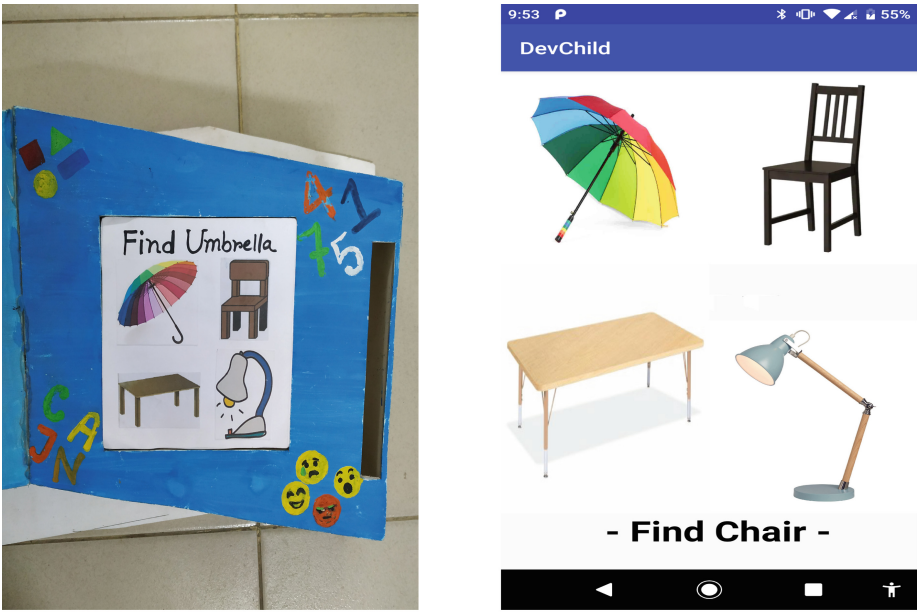
Fig. 2. The developed prototype

function card is read by the RFID reader on the box and this card is then shown on the mobile app. There is a piezo sensor under each of the object or character on the card. When an object is pressed on the card an animation of correct or wrong answer is shown on the app and the result is recorded in the database.

The puzzle game can be selected when the corresponding switch is on. The RFID readers on the game box in the left side read the tags on the back of the puzzle cards and then send the data to the mobile app where the puzzle parts are shown (in the similar way the players placed the cards on the game box) which is demonstrated in Fig. 4.

When the switch for the road crossing game is selected, a player can be seen on cross the road game on the android app. The player can be controlled by moving the joystick on the game box. User needs to make the player cross the road through zebra crossing by controlling him/her through the joystick/switch and the corresponding result is stored on the database. Game is won when successfully crossed the road avoiding any kind of obstacles (Fig. 5b).

An Android application was developed as software part of the proposed gaming system. The firebase authentication and database was used for account creation and result storage. Primary users of the app are autistic kids who will play the games and their parents/teachers/doctors to monitor or observe the progress of the kids. Guardians/teachers of the autistic child needs to open an account for a child to initiate game playing and to keep his/her progress through this application. Parents or authorized users can log in to the system with the mobile app, select the game that the child wants to play and also modify any kind of game settings from the *student/child view*. The parents/doctors can regularly check the progress of the child through a graphical view on the mobile app (Fig. 5a) and get a general overview of a child's gradual progress by selecting the *parents/doctor view* on the app. This progress is calculated from the results or performance of playing the games.



(a) (b)

Fig. 3. Object finding game (a) tool box and (b) app user interface

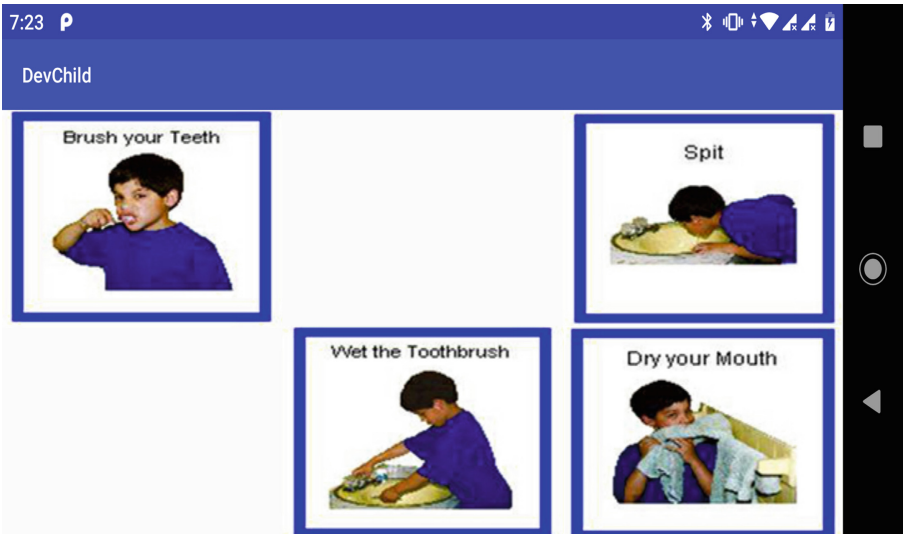


Fig. 4. App user interface of puzzle game

Fig. 5. App interface of (a) Progress chart and (b) Road cross game.

A flow diagram to show the working procedure of the proposed gaming application is shown in Fig. 6.

5 Evaluating the Application

A light weighted evaluation was carried out at the Software Engineering Laboratory of the authors' institute. Five faculty members who are familiar with autism related issues were invited as a test-subject. During the evaluation study, firstly a brief presentation about the objective of this study was given to the participants. Secondly, the proposed system was demonstrated to them and gave them the opportunity to explore and use the tool for around 5–10 min. Finally, participants were asked to play each of the game. Data related to the *number of trials* for success and *game completion time* in seconds were collected while they played the games. Finally they were asked to provide opinion about the usability and effectiveness of the proposed system and give any other related recommendations. A brief summary of the recorded data is given in Table 2.

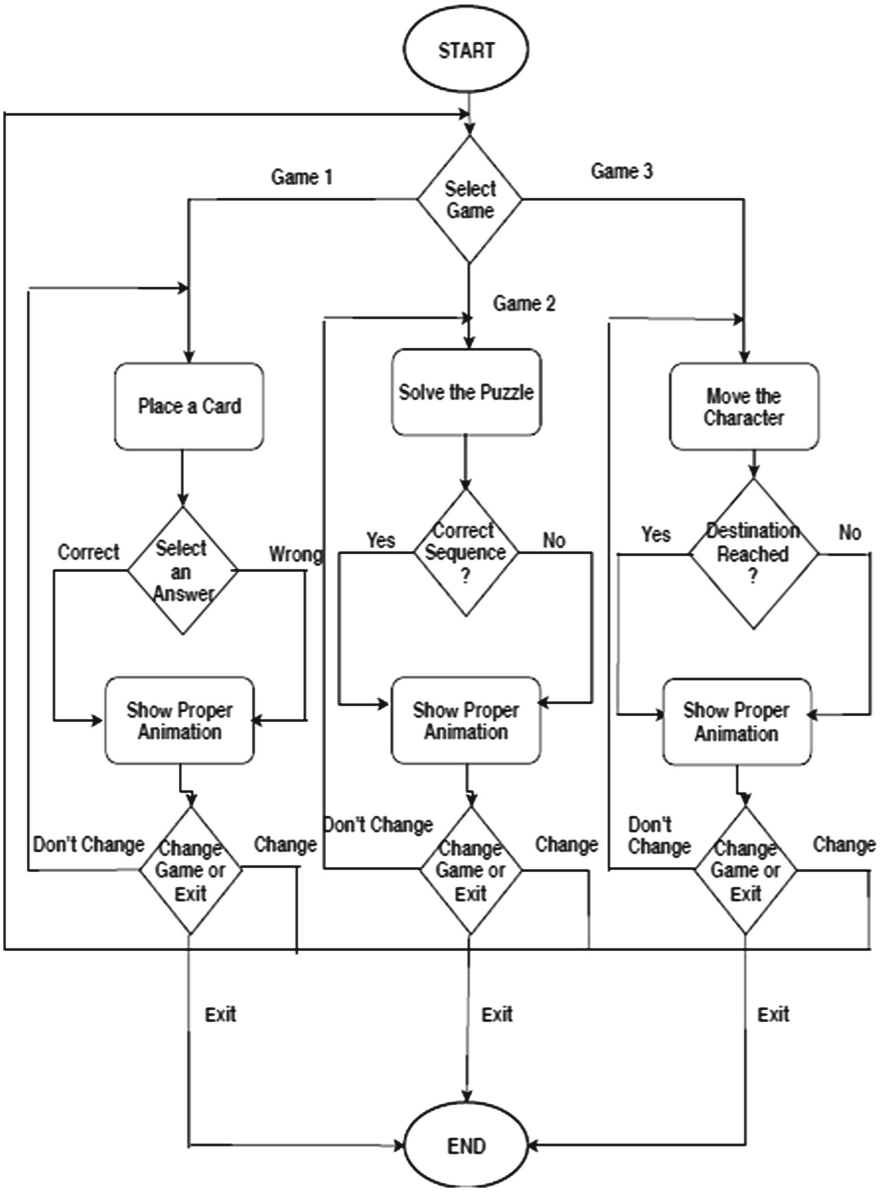


Fig. 6. Flow diagram of the developed games.

Table 2 showed that though the optimum number of trials for each game is 1, but the average number varies due to some reasons. For example, in the object finding game, the average number of trials required to successfully complete the game is 1.6 due to sometimes pressing outside the sensor's range. For the

Table 2. Summary results of the evaluation study

Object finding game		
Participant No.	Trials to success	Completion time (Sec)
1	2	14
2	1	11
3	1	8
4	3	13
5	1	9
Total = 5	$1.6 \pm .8$ ($Mean \pm$ SD)	11 ± 2.28 ($Mean \pm$ SD)
Puzzle game		
Participant No.	Trials to success	Completion time (Sec)
1	2	25
2	1	28
3	3	22
4	3	30
5	2	26
Total = 5	$2.2 \pm .75$ ($Mean \pm$ SD)	26.2 ± 2.7 ($Mean \pm$ SD)
Road crossing game		
Participant No.	Trials to success	Completion time (Sec)
1	1	17
2	3	13
3	2	18
4	2	12
5	1	15
Total = 5	$1.8 \pm .74$ ($Mean \pm$ SD)	15 ± 2.28 ($Mean \pm$ SD)

puzzle game, the average number of trials is 2.2 for not understanding the correct sequence initially. Finally in the road crossing game due to not being able to avoid the obstacles or cross the road safely, the average trials for success is deviated to 1.8. This result indicates that though the games can be played effectively but there are some difficulties. These issues were noted to improve it's effectiveness in the future.

The participants also viewed the graphical results generated by the tool and opined that it would be an efficient way for the therapists to view and maintain progress results of kids in the autism centres and similarly will be helpful for the doctors while giving recommendations for improvement.

6 Conclusions

In this research, an IoT based gaming application was developed for developing cognitive skills of autistic kids. This application can store and process player's gaming results to show (graphically) their progress within a specific time range. The proposed gaming application includes both hardware and software games which add a new dimension in the learning methods of autistic kids. A light-weighted evaluation study showed that each function or feature of the games is executed correctly. Moreover, the participants found the games interesting for autistic kids and useful for improving their cognitive skills. Some limitations of this research were that the proposed application was evaluated in an institutional environment with limited number of participants; and that the application was developed only for autistic children who are 3 years or above. In future, the proposed gaming application will be updated by addressing the minor problems found during the evaluation study. The updated application will be evaluated with real end users (autistic kids/therapists/guardians) through field study to show it's effectiveness and efficiency.

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