AutiAid: A Learning Mobile Application for Autistic Children

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***Abstract*—Autism Spectrum Disorder (ASD) is one of the major mental disorders in terms of neurodevelopment brain functions. The three types of symptoms which Autistic patients exhibit are: social development, difficulty in communication and unusual behavior. Unfortunately, based on the nature of ASD, it cannot be diagnosed through the help of applications. However, applications can be a tremendous help in monitoring and the treatment of patients. This work presents an architectural solution that enables the interoperability between an autistic person and caregivers to contribute on the treatment and monitoring to persons with ASD. The solution is implemented by creating a mobile application and tested with a population in an Autism center. The results show that the application made a positive treatment contribution to a person with ASD.**

Keywords— autism; learning; schedules; games; monitoring; mobile application

I. INTRODUCTION

One of the major mental conditions that exist today is Autism; a mental disorder which brings a great amount of difficulty in capturing and gaining abstract concepts, as well as making and forming trustworthy relationships. It is not a disease, but a neurodevelopmental disorder of brain function where it is often associated with intellectual disability or difficulties in motor coordination and attention or sometimes in physical health issues that involve sleep and digestion [1]. Obvious signs of autism develop from the tender age of 2 to 3 years. However, later signs of autism may be detected through behavioral reactions and readings or social interactions while meeting strangers. In some cases, autistic children may reach their development milestones normally after exhibiting some signs of improvement; however, there is a slight chance of a relapse.

Unfortunately, over the course of time, researchers have found that Autism has shown a ten-fold increase over the last half decade. Around 1 in 68 children are said to be identified with Autism Spectrum Disorder (ASD) [2] and that the disorder is more commonly found amongst boys than girls; roughly 4.5 times more. The work in [3] showed that ASD has increased to approximately double over the last few years, in contrast to other disorders which have shown slight improvement or no change at all.

One of the most important setbacks for an Autistic person involves the inability to converse and communicate their needs. In some cases, autistic persons do not even manage to develop their natural speech, hence, there is very little space for improvement in their communication skills. Communication lacks in Autistic persons since they feel more comfortable interacting and communicating with their loved ones (which sometimes may not be the case) as compared to acquaintances. This leads to a problem in terms of developing their learning skill especially when learning requires communication and familiarity between the teacher and the autistic person. Due to the need of necessary one-on-one attention, education may pose as a huge challenge to autistic persons where special techniques and tasks should be implemented towards developing conceptual and operational skills. In the event of the autistic child leaving the house for example, it can be difficult to keep peace of mind; not knowing where the autistic child is; can make parents quite anxious.

This work identifies specific features that use the current enabler technologies that exist now-a-days (such as mobile devices and cloud computing) that can contribute in the treatment (in the form of learning) and monitoring (both treatment progress and the physical location) of the autistic child. In this paper we propose an architectural and component design of the overall system and present the complete implementation. The system was tested with real autistic children and the results show improvements on the learning of those children.

This paper is organized as follows, Section 2 presents related work, Section 3 presents the functional requirements, Section 4 presents the system design and implementation, Section 5 presents the experimental results captured from this work, and Section 6 presents the conclusions.

II. LITERATURE REVIEW

A. Treatment and Learning

Most treatments involve the development of necessary skills such as communication, behavior and learning. Marchese [4] states that, it is believed that autistic children shall not only benefit with the use of interactive tools, but also their parents and teachers will be able to monitor and provide educational services as well as try attending to their immediate needs. Activity on an application makes it easier for caretakers to monitor the patient's activity, and based on the results achieved on specific activities performed, can then be decided what further action to take place. With the results garnered from all these tests over a period of time, a gradual progress may be monitored to see whether the user has been responding well to the treatment or not. Since autistic patients find it baffling to process multiple interactions at once, a system to break down such actions is recommended where every task may be subdivided into smaller operations. Whole Information processing can be a challenge to most autistic patients, however, every minute operation may be detailed according to the needs of the patient in terms of design and user interface.

On the other hand, autistic patients tend to respond well towards visual cues such as images or videos, which make it easier for concept processing. DISSERO, an application introduced to improve mental and social skills, shows how the

learning process may be developed along with apt media attention towards their needs [5]. This application provides a basic interface for the patient to select what they would like to perform, in terms of visualization. Providing a variety of necessary options such as learning and needs, it helps to branch out to the basic requirements of an autistic child. The learning page aims at providing an interface for math learning, to develop computational skills as well as to develop reading and writing skills through audible sounds and matching words as well as using visual cues to match the sounds. Once a child passes a level or performs a test at a faster time period than the last, will contribute towards the improvement and show towards their individual score scale.

Another service provided to the patient is the needs page. This page may be accessed in the event of when the patient requires the immediate attention of the parent for whatever reason possible. Depending on the location of the child, if the child is in the vicinity of their school, the teacher would receive a notification regarding the matter related to the child. However, if in proximity to the parent, a similar reaction will take place. Of course, this will require for a teacher/parent specific platform to be built solely for their respective roles, hence once again, coming back to the interactive system as stated earlier.

To develop more on the learning aspect, it should be considered that there may be different children standing at different progressions of autism. Hence, one development may not be matched to that of another. For a more accurate method of measuring a person on the autistic spectrum, it is recommended to use the Autism Spectrum Quotient (AQ), used for children from 4 years of age through adulthood [6]. The AQ measures to what extent an individual exhibits autistic traits. However, this does not provide assurance to the person who has undergone the test, that they are diagnosed with the condition. Hence, diagnosis is essentially performed by an expert.

For an autistic child to flourish both behaviorally as well as in an educative perspective, it is necessary to build a learning environment at all-time where it will begin the stimulation of interest for enhancing activities [7]. With touch screen enabled mobile devices, this makes it easier for children to respond to the device in a more cohesive way, with the flexible multimedia content present to make any interface more appealing and simple to use as well. A basic learning method that is proposed to be added in a mobile application is the use of picture cards where a word shall be written on it. For the majority of autistic children, a strong visual memory aids them towards skills development. Basic learning tools are found such as videos or DVDs to promote mental state recognition in a child. Of course, one of the learning exercises that can be discussed is the use of a listening mode where children would be able to match the voice with a picture of a loved one or that of an animal. Autistic patients can remember images better that words, hence, using this towards the advantage of building a daily routine for the child can prove to be advantageous into leading and following the schedule that a parent has set up.

Manipulating this skill, leads children to the understanding and memorizing these words. They can also be related to adjacent sounds so they may be able to recognize and probably use the word in the future. For this use, it is proposed that an application be built where a list of words is shown along with a few images for relational understanding between images and their details.

In a proposed portable application for the support of Applied Behavioral Analysis (ABA), Artoni et. al. [7] proposed an application that involves the use of a matching images game or the use of images as a form of receptiveness or expressiveness. It is crucial to provide patients with new and updated images to broaden their learning perspective, hence, it is essential to keep a rotation of the displayed images.

In discussion with other features that the games shall exhibit, the work in [8] exemplifies the use of mini games for learning development in order of sequence ordering along with a timed game activity. Autistic children will have to match between correct associations while being timed. This motivates the children to perform tasks at a faster pace. This is further elaborated in this research project in terms of the user interface applied to this as well as score recording.

B. Location Monitoring

In today's world, 80% of the people that are reported missing lie under the age of 18 [5] [6]. In addition, children with disabilities are about three times vulnerable to be the victims of such crimes as compared to non-disabled children [9]. Over 80% of people including children own a smartphone [8]. Nowadays, even economical smartphones come with basic GPS capabilities. This work uses this capability of mobile devices to notify parents the location of their child. The application notifies the parent of the location of the child using GPS coordinates and displayed using 'Google Maps' [10][11]. Alzimio [12] is an application that uses Geo-fencing approach that aims at detecting safe zones and possibly patient activity tracking based on the accelerometer readings. The prevalent feature in this application is to detect unsafe zones and destinations where the parents would be notified in case the patient wanders off. A constant scanning requires a GPS signal to be transmitted by the device, causing power to drain out. In this work, we offload the monitoring feature to a software component deployed as a cloud service.

III. FUNCTIONAL REQUIREMENTS

This section presents the major functionalities considered in this work to contribute on the treatment and monitoring of the autistic child. Fig. 1 presents the four main subsystems. The four subsystems are presented using the Unified Modeling Language (UML) package diagram and they are: Account System, Schedule System, Game System, and Monitoring System.

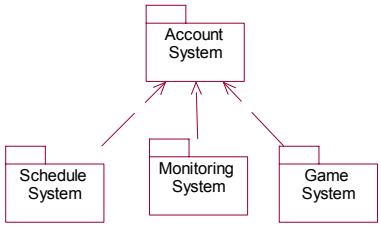

Fig. 1. Package View of the Application Logic

Fig. 2 presents the functionalities using UML use-case diagram delivered by the *account system* package. This package enables users to register and the ability to Sign-In. The account system also manages accounts and deals with associating supervisors, and caregiver to a specific Autistic child.

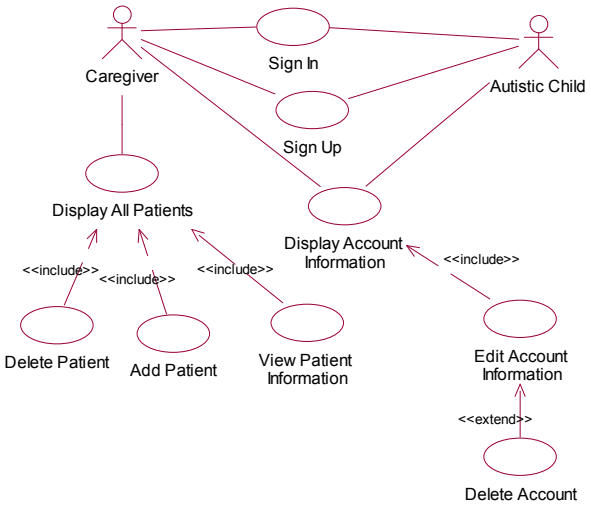

Fig. 2. Account System Use-case Diagram

The *monitoring system* package allows parents to manage safe zones boundaries for the Autistic person. The system monitors the location of the autistic person and sends a notification to parents if the autistic person moves outside the safe zone boundaries. Figure 3 represents the UML use-case diagram for the Monitoring System package.

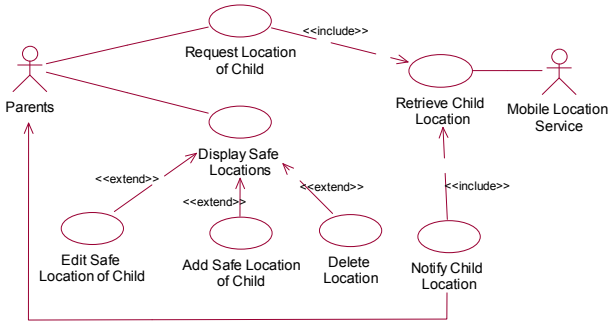

Fig. 3. Monitoring System Use-case Diagram

The *schedule system* is composed of three types of schedules: Medical, Learning, and Daily Schedules. The Daily Schedule enables parents to assign tasks to a child at a specific time. Those tasks can have the child be notified with the corresponding image and recording as the notification. Similarly, the Medical Schedule relates to allocating a doctor to see an autistic person at a specific time, and the learning schedule allocates a time between the teacher and the autistic person. Figure 4 presents the UML use-case diagram for the schedule system package.

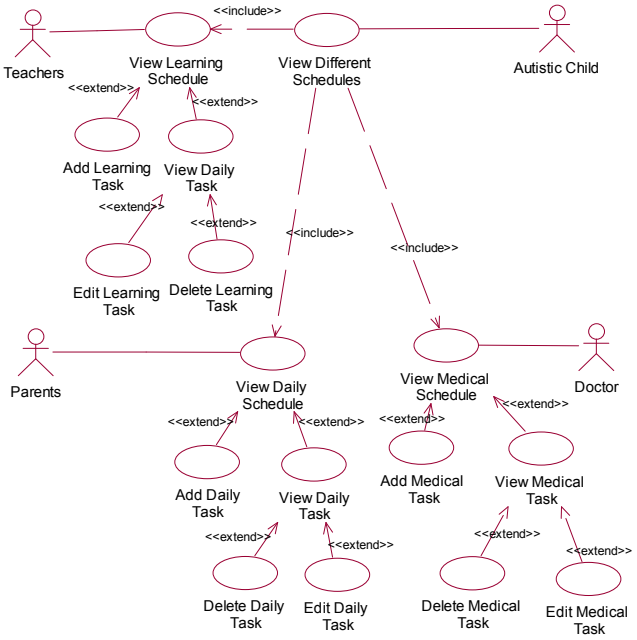

Fig. 4. Schedule System Use-case Diagram

The *game system* package contains four other packages as shown in Figure 5 that deals with managing treatment in the form of games specifically customized to the autistic child.

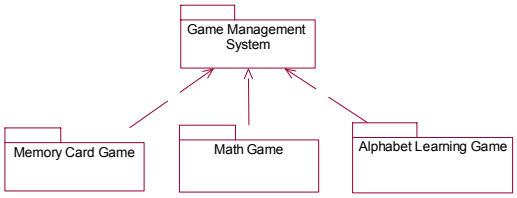

Fig. 5. Game System Sub-Packages

The manage game package main functionalities are presented in the use-case diagram in Figure 6. The Manage Game package handles the assignment of games and viewing these scores by the parent and teacher. The system includes functionalities that allows Teachers to customize the games and set them as an assignment for the child to play with, according to the pre-defined selections. In the event of a teacher has to assign a game, the teacher can select a level of the respective game and different customizations. The system saves the game preferences and allows the child to play the game according to the respective inputs.

This work implemented three different games as a proof-of-concept to integrate with the proposed game system to train the autistic person with specific skill set. Those different games are presented as UML packages in Figure 5 as: memory card games, math game, and alphabet learning game. The system can expand to more games that work on developing specific skill sets to the autistic persons.

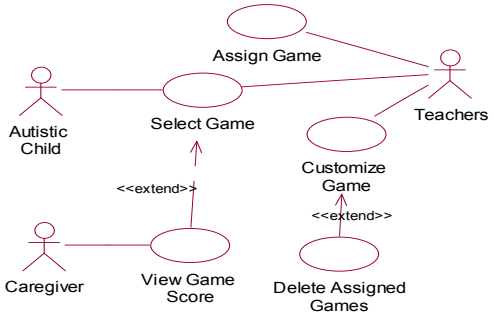

Fig. 6. Manage Game System Use Case Diagram

The Memory Card Game aims at improving the visual and relational cues of the child. The main functionality is to match cards. The game is timed for scoring purposes. These scores are notified to the parent and teacher. Figure 7 presents the UML use-case for the memory card game.

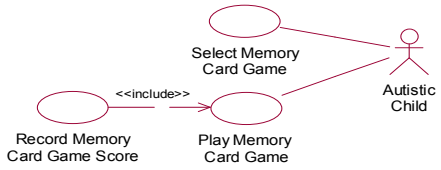

Fig. 7. Memory card Game Use-cases

The Math game is created for the children to enhance their computational skills. It involves the child to answer the questions on the screen according to the options available. The scores collected and saved at the end of the game and can be viewed by parents and teachers. Figure 8 presents the UML use-case diagram for the math game.

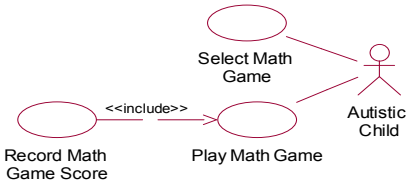

Fig. 8. Math Game Use-cases

The alphabet learning game has no score card involved. The Game is stored on the child's device and will be able to access the game as they wish. This game is to improve the child's learning skills and to help them learn the alphabet. Figure 9, presents the alphabet learning game use-case diagram.

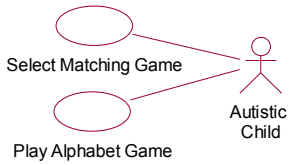

Fig. 9. Alphabet Learning Game Use-cases

IV. Proposed System Design and Implementation

A. System Design

The overall system architecture uses the data-centered architecture style, as shown in the Figure 10. With this architecture, each mobile application is independent from one another. Mobile nodes interoperate with each other through the database node.

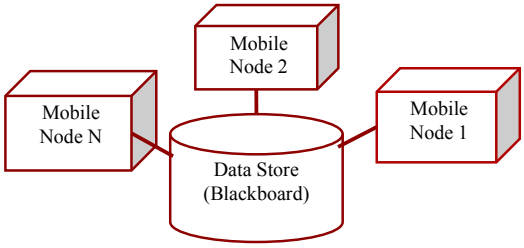

Fig. 10. Data-centered System Architecture

The mobile application on the other hand is designed using the Three-Tier architecture style as shown in Fig. 11. Each layer depends on the layer below it. Such architecture increases cohesion, reduces coupling, and increases abstraction, reusability, and flexibility.

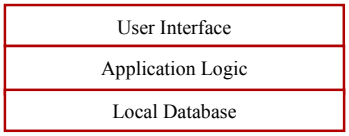

Fig. 11. Mobile Application System Architecture

Figure 12 presents the UML component diagram of the whole system which includes the components deployed in the mobile node as well as the components deployed in the cloud to interface with the database and enables the interoperation between mobile nodes. As shown in Figure 12, all components except for the data monitoring system component are deployed in the mobile node, while the data monitoring system component is deployed as a cloud service. The mobile node contains six components:

- User interface: this component contains the elements related to the user interface layer as presented in the architecture in Figure 11.
- The account system delivers on the functionalities presented in the use-case model presented in Figure 2. This system resides in the application logic layer presented in Figure 11.
- The gaming system component delivers on the functionalities delivered by the functionalities presented in Figure 5. This system resides in the application logic layer presented in Figure 11.
- The scheduling system delivers on the functionalities presented in the use-case model in Figure 4 This system resides in the application logic layer presented in Figure 11.
- The child monitoring system component delivers on the functionalities presented by the use-case model in Figure 4. This system resides in the application logic layer presented in Figure 11.
- The database manager component deals with accessing and storing local copies of the data within the mobile device. This system resides in the database layer presented in Figure 11. This component depends on the data monitoring system component that resides on the data centric node.

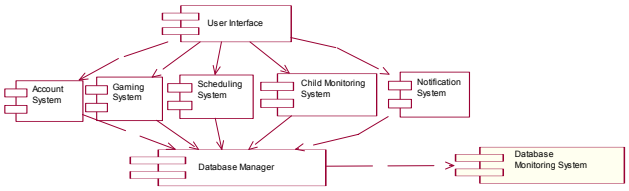

Fig. 12. UML Component Diagram

Using a cloud service provider, the database monitoring system component is deployed as a service. This component represents the data centric architecture to integrate the different data sources arriving from the mobile nodes and enables the interoperability between the mobile nodes and the notification functionalities.

B. System Implementation

Figure 13 presents the conceptual implementation representation to deliver on the account system component. In this component, we enabled the integration with external account systems such as Google and Facebook account system. The account system component verifies the credentials and retrieves account details and stores them in the user profile details. Before creating a profile, it is also required for the user to select a role within the application. Caregivers (parent and teacher) and autistic children can use the application at the same time on their respective mobile device.

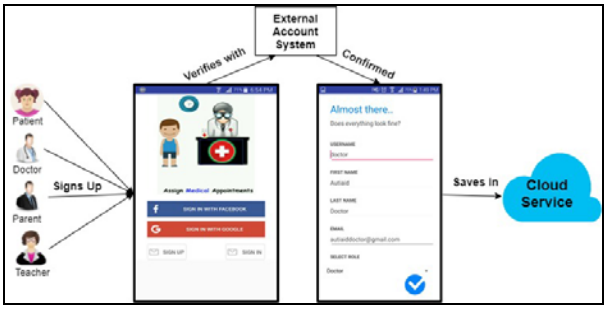

Fig. 13. Conceptual Implementation View of the Account System

Each user role has specific privileges and features. Teachers, for instance, have a major role in using the gaming system as shown in Figure 14. The teacher initially assigns a game to the child where the child is notified of the assignment and plays the game according to the assignment details. The game scores are saved in the cloud database where the database monitoring service deployed in the cloud will notify the parents and teachers on the respective scores.

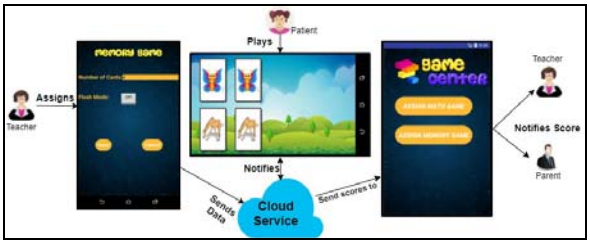

Fig. 14. Conceptual Implementation View of the Gaming System

The scheduling system implementation view is shown in Figure 15. The system is available for all caregivers to use. Parents can send daily schedules to the child to follow, teachers can create learning schedules, and doctors can create medical schedules. These schedules are saved in the database in the cloud where the database monitoring service deployed in the cloud automatically creates reminders on the child's mobile node to notify him/her when a particular task is to be done.

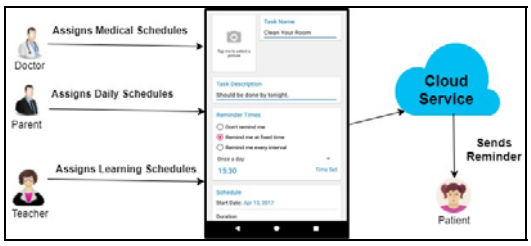

Fig. 15. Conceptual Implementation View of the Scheduling System

The monitoring system conceptual implementation view is shown in Figure 16. Parents enter a Geo-fence over a particular radius where the location is saved in the database in the cloud. Once the child enters or leaves the location, the child's phone automatically sends the current location to the database, then the server implemented in the cloud notifies the parent of the child's location status through the database monitoring system deployed as a cloud service.

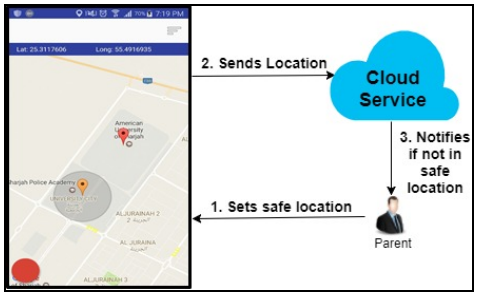

Fig. 16. Conceptual Implementation View of the Monitoring System

V. Experimental Results

The proposed system was tested in an autism center in Sharjah, United Arab Emirates (UAE). The center had autistic children, doctors, and teachers. Teachers, doctors, parents, and autistic children were placed in separate rooms. The objective is to emulate a real-life situation where autistic children can access the application on their own and access the assigned tasks. In this experimentation, we looked into the impact that the system has towards the learning of the autistic children, as well as the provided tools to manage, keep track, and monitor the autistic children.

The autistic children that tested the memory game were within the two age groups 12 and 14 years old. The results collected over five tries from five children from each age group. The results showed a noticeable improvement over the number of tests collected. The game was played on a four cards level. Figure 17 shows the number of tries it took for the child to complete the game versus the Number of tests collected.

Similarly, Figure 18 exemplifies the Time it took for each child to complete the game. This proves that the game does promise learning improvement. Autistic children are known to pick up instructions very quickly. Hence, the quick advancement in developing their skills are given from the children's uniqueness.

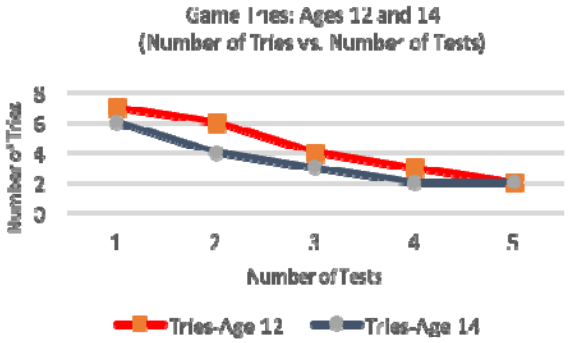

Fig. 17. Memory Game Test Result (Number of Tries vs. Number of Tests)

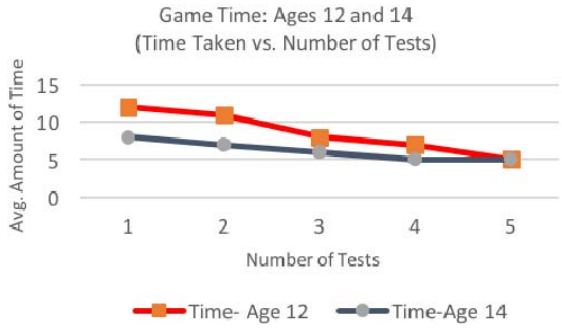

Fig. 18. Memory Game Test Result (Time vs. Number of Tests)

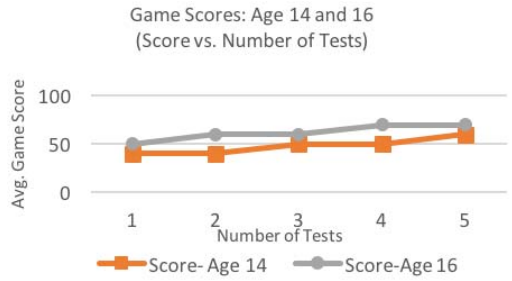

Fig. 19. Math Game Scores for Ages 14 and 16

Authorities suggested that the math game that was designed is applicable to a higher age groups from ages 14 and above. The game was tested on autistic children between the age of 14 and 16. Mathematics is considered as one of the most challenging subjects amongst autistic children. Hence, scores did not go up to a 100. However, as shown in Figure 19, there is a noticeable improvement in solving the mathematical problems over time. These tests were taken with settings of a beginner level with addition constructors. It can be seen from the graph that the math game has contributed in improving the learning process for children.

VI. Conclusions

This work captured the functionalities required to contribute on the treatment and monitoring of an autistic child. Furthermore, the work proposed a design and implementation related to those requirements. With the evolvement of the current technology (mobile devices and cloud computing), as shown in the literature, there are no current solutions that deal with the autistic patient treatment and monitoring. As presented in the design section of this work, the proposed architecture is loosely coupled and provides the ability to expand with more games in the future for different types of treatments. The results show that the provided application made a positive impact on the autistic patient treatment.

Acknowledgment

The authors would like to thank the authorities at Al Manzil Center for allowing us to test the proposed application and providing us with beneficial feedback.

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