AN AUGMENTATIVE SYSTEM WITH FACIAL AND EMOTION

RECOGNITION FOR IMPROVING THE SKILLS OF CHILDREN WITH

AUTISM SPECTRUM DISORDERS

by

Mohammed N. Alharbi

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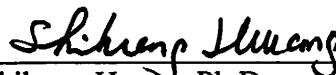Florida Atlantic University

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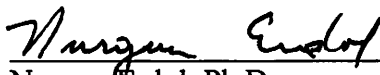
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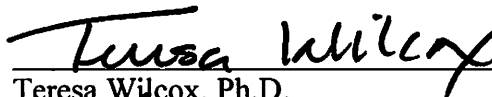Shihong Huang, Ph.D.
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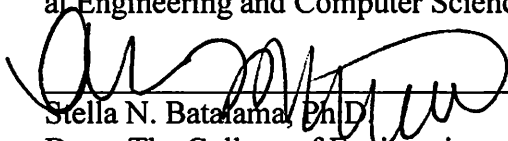
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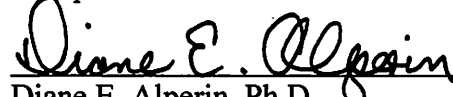
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ABSTRACT

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Autism spectrum disorders (ASDs) are one of the complex, pervasive, and multifactorial neurodevelopmental conditions which affect one in 68 children. Scientific research has proven the efficiency of using technologies to improve communication and social skills of autistic children. The use of technological devices, such as mobile applications and multimedia, increase the interest of autistic children to learn while playing games. This thesis presents the re-engineering, extension, and evolution of an existing prototype Windows-based mobile application called Ying to become an Android mobile application which is augmented with facial and emotion recognition. This mobile app complements different approaches of traditional therapy, such as Applied Behavior Analysis (ABA). Ying integrates different computer-assisted technologies, including speech recognition, audio and visual interaction, and mobile applications to enhance autistic children's social behavior and verbal communication skills. An evaluation of the efficacy of using Ying has been conducted and its results are presented in the thesis.

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DEDICATION

This thesis work is dedicated to my parents, to my brothers, and to my sisters who have

always loved me unconditionally and whose good examples have taught me to work hard

for the things that I aspire to achieve.

This work is also dedicated to my wife, Sundus, and my loving children, Badr and

Waleed who have been a constant source of support and encouragement during the

challenges of graduate school and life.

I am truly thankful for having you in my life.

AN AUGMENTATIVE SYSTEM WITH FACIAL AND EMOTION RECOGNITION FOR IMPROVING THE SKILLS OF CHILDREN WITH AUTISM SPECTRUM DISORDERS

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LIST OF ABBREVIATIONS

HCI   Human-Computer Interaction

ASD   Autism Spectrum Disorder

CAI   Computer-Assisted Instruction

CAT   Computer-Assisted Technology

CBI   Computer-Based Interventions

TEL   Technology-Enhanced Learning

AAC   Augmentative and Alternative Communication

PECS   Picture Exchange Communication System

VR   Virtual Reality

API   Application Programming Interface

ABA   Applied Behavior Analysis

CHAPTER 1:INTRODUCTION

1.1 Overview of Autism Spectrum Disorder

Autism spectrum disorders (ASDs) are defined as complex conditions which are pervasive and at the same time multifactorial neurodevelopmental conditions [1]. There are many symptoms related to this condition, but unusual behavior for those patients with autism is the basis of diagnosis for ASD, for example, having social communication difficulties, lacking interaction with others, showing unusual repetitive patterns and behaviors, and lacking interests and activities. One of the more recent study indicates that 1 in 68 children are diagnosed with ASD in the United States [2].

ASD is well known by weaken development in social interaction, communication, and behavior with others [2]. Autistic children have evidence of difficulties in interpreting social cues and understanding different emotions of the other. For example, some of autistic children could not differentiate whether their parents are anger or happy. Maintaining eye contact and understanding facial expressions are another important social difficulties with those children, so they usually do not maintain their eye contact while they speak with others. In addition, communication can be one of the biggest challenges with autism patients because they repeat what others say without understanding what is being said. They mix up the pronouns and are not able to start a conversation either. ASD children behavior may include rock, spin, and flap their hands repetitively [3]. While some children were born with delayed development since their births, other children can suddenly lose social or language skills later. Sometimes, language delayed, or loss of language are the

major effects. In another word, unusual behaviors seem to be the main factors that can observed in children diagnosed with ASD [2].

ASD has three main categories: Autism, Asperger's Disorder, Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS). Some scientists recognize two more categories: Childhood Disintegrative Disorder, and Rett's Disorder. The main three categories are the most prevalent, and the degree of ASD can vary from mild to severe. Asperger's syndrome is considered the mildest form of ASD since it is mainly characterized by having difficulties with social skills. The ways in which ASD manifests can differ greatly. Levels of impairment and combination of symptoms also vary from patient to patient, which makes finding a treatment that fits all cases difficult that because each case can be unique [4].

1.2 Brief Overview of Human Computer Interaction

Human–Computer Interaction (HCI) is to study how computer technology affects our work and activities. This term currently includes both traditional PC computers provided with screens and a keyboard, smartphones, and intelligent environments. HCI is associated with Interaction Design which mainly focuses on how to design computer technology in such way that it is both easy and pleasant for the users to use [5].

Usability and functionality are the essential key factors of the Interaction Design which is often defined in terms of efficiency, effectiveness and satisfaction of that technology for the users [5]. Functionality is related to the functions; services usually provided by a system. Usability is when a user utilizes and interacts with the system's functions (e.g., services) easily, properly and clearly. These two important concepts may vary from one

system to another, and we can say that the system is said to be successful if there is a balance between both functionality and usability of that system [6].

Human-computer interaction is changing to the era of human- computer integration instead of just interaction. Integration here means that the relationship between computers and humans has become a partnership or symbiotic relationship in a way where humans (e.g., users) and computers act with autonomy instead of waiting to the user's inputs and commands to take an action. In the past, the relationship between humans and computers was described as human-dependent, which means the computer responded to users and took actions based on their input or commands, then the computers waited for further input. For instance, we click on an icon, the computer shows a menu or initiates an action based on that icon, and then the computer waits for the next input. It can be clearly seen that none of these traditional scenarios describe a real partnership between us and computers. Integration, on the other hand, creates a real partnership between us and our computers, which means computers adapt with us and can take actions depending on our states without getting our inputs [7].

1.3 Technology and Autism Spectrum Disorder

The benefit of using technology in the treatment of autism patients has been proven by past research. On the other hand, these technologies have only recently become widely available to interested researchers and users for an affordable price. Technology has advanced greatly in recent years, especially in the field of computer-based audio-visual systems. Things that were impossible a few years ago are now cheaply available to the general public through applications available on websites and smartphones. Therefore, these great leaps in technical and economic development encourage us to have further potentiated the utility

of computers in the treatment of patients diagnosed with ASD who are important parts of our societies [8].

Utilizing technology in ASD intervention was limited for many years and mainly depended on using videotapes for instructional video modeling. Despite the efficiency for using instructional video modeling in order to teach ASD individuals different skills, the potential of using technology extends far beyond using just simple video modeling to a new era such as dynamic or interactive computer programs and virtual reality. Interactive computer programs adjust themselves with each user according to his or her needs and progress, and innovative remote delivery systems make it possible and cost-effective to access interventions that aim to improve different skills for individuals with ASD [9].

Using and utilizing available technology has become popular and preferable among individuals with ASD for many reasons. Technology is predictable, consistent, free from social demands and specific in focus of attention. Thus, effective computer applications are considered to be helpful tools available for us for therapeutic and educational purposes, especially for individuals with ASD [10].

1.4 Problem Statement

As aforementioned discussion, most children who diagnosed with ASD have different levels of difficulties in verbal communication, interpreting social cues and understanding different emotions. While medication treatment has its limitations, behavior and communication approaches are the common treatment types used by many professional health providers around the world. Using computer-aided technologies has proven to be efficient by many researches to avoid some side effects for ASD in order to function better. Different technology has been used for decades to achieve this purpose with different

efficiencies [11]–[16]. However, most existing systems rely on using virtual reality technology such as avatars and video clips, very few systems have tried to use parameters from ASD children' own lives (e.g., their own pictures and their favorites) to help them to engage games play and learn.

The Android app Ying presented in this thesis is aiming at improving ASD children's behavior and communication skills, and serves as a complement to school and home therapy. The aim of this research is to develop a ASD children-friendly game (Ying) that incorporates different behavior and communication approaches, including "Applied behavior analysis (ABA), Floortime , TEACCH, occupational therapy, sensory integration therapy, speech therapy, and the picture exchange communication system (PECS)" [17] to enhance communication and social skills for children with ASD. The unique feature of Ying is that it is augmented with emotions recognition which uses children's own pictures instead of using other cartoon or video clips to improve their social behavior as well as reinforce their verbal communication skills. In this way, Ying reinforces their social and verbal communication skills by practicing different emotions through their own pictures which leads to a much familiar and high efficient system.

1.5 Emotion-Recognition Mechanisms Analysis and Comparison

Emotions are expressions about people's feelings and their relationships with others. Humans usually show how they feel by using their different facial expressions. Gestures, speech, and actions are also used to show a person's current feeling. Emotion-recognition is the process of defining and detecting the humans' feelings through their facial expressions, such as happiness, anger, deceitfulness, sadness, and others. These algorithms

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usually use either users' pictures or videos as their input, then determine a face area and finally, analyze the detected face in order to determine the emotions.

OpenCV is one of the powerful free open-source libraries developed by the Intel Corporation, which has been used in multiple fields like computer vision and machine learning tasks, such as real-time image recognition, face detection, and image processing [18]. OpenCV consists of 2500 optimized algorithms which are used for research as well as commercial applications from both global and small entrepreneurs. This library is augmented with a set of other libraries which are written in C language, with bindings to other languages and technologies such as Android, iOS, CUDA, and Python, and wrappers with other languages, such as C#, Haskell, Perl, and others. However, it works under both Linux and Windows.

Cognitive Services are another approach which was developed by Microsoft and is used for the same purpose to solve in several fields such as speech recognition, computer vision, machine learning search, natural language processing, and recommendation systems. These algorithms can be accomplished through Representational State Transfer (REST) calls over an Internet connection, which are open-source services which can be used by many languages such as C#, Java, Python, PHP, and implemented in mobile, web applications, console, and desktop [19]. This particular approach will be discussed in more detail in Chapter 5.

L. Antonio, Z. Komínkova-oplatková, and B. Prieto, introduced a study in 2017 which compared the performance of two common emotion-recognition mechanisms; OpenCV and Cognitive Services API [20]. OpenCV is one of the important open-source libraries and contains functions and packages which are used for computer-vision analysis and

applications. Cognitive Services API is the second mechanism which has used here in this thesis to develop the Ying system. Cognitive Services API is a set of APIs which contains artificial intelligence algorithms which are used for computer-vision, knowledge, language processing, and speech.

Two different Android mobile applications were developed in this study, in order to test the performance for these two libraries. For this research, one thousand tests have been performed per experiment in order to show the efficiency for these two mechanisms. In both cases, results show both of them are accurate with approximately a 7% difference, and the performance for those two different mechanisms can be improved by increasing the emotion sample size within the training step.

1.6 Approach and Contribution

This approach consists of re-engineering and extending the functionality of an existing prototype Windows-based mobile application which was developed at the Software Engineering Lab at Florida Atlantic University in 2014 [21]. Ying[1] was designed originally in 2011 to help identify the factors that make learning more effective for children with ASD, so I am going to provide the third edition for Ying system.

1.6.1 The Original Edition of Ying

Ying was designed in 2011 originally to be an adaptive computer interaction system which detects learning patterns in children with ASD and explores all possible the computer interactive possibilities. The system at that time tailored its content based on periodic performance assessments which offered a more effective learning path for children with ASD. The Welcome Page of the Original Ying is shown in Figure 1.1, which consists of

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[1] Ying is the name of this system which is derived from the Chinese word of owls or other birds of prey.

four different modules at that time, which were assessments, play, progress, and configuration [22].
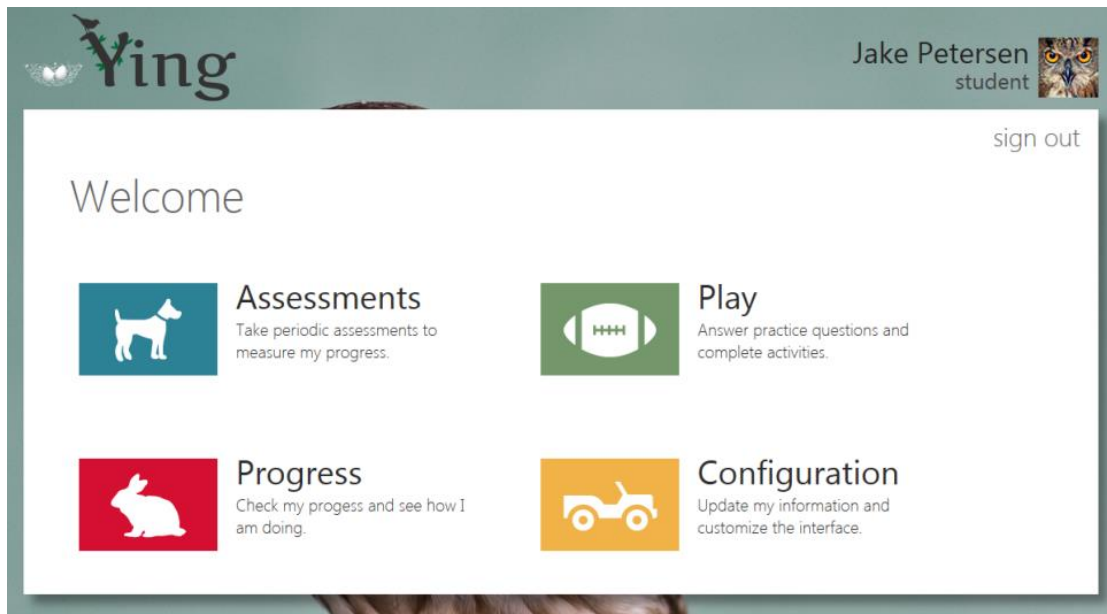
Figure 1-1: Welcome Page's Contents of the Original Ying [22]

The Configuration and Progress Modules were implemented to be used by the coach or assistant (e.g., the supervising adult) who provides an initial configuration for the system. What we mean by initialing the configuration for the system is setting up the accounts for the children with ASD. The coach here also could create, edit, determine the questions and responses, and set up the assessments through these two modules [22].
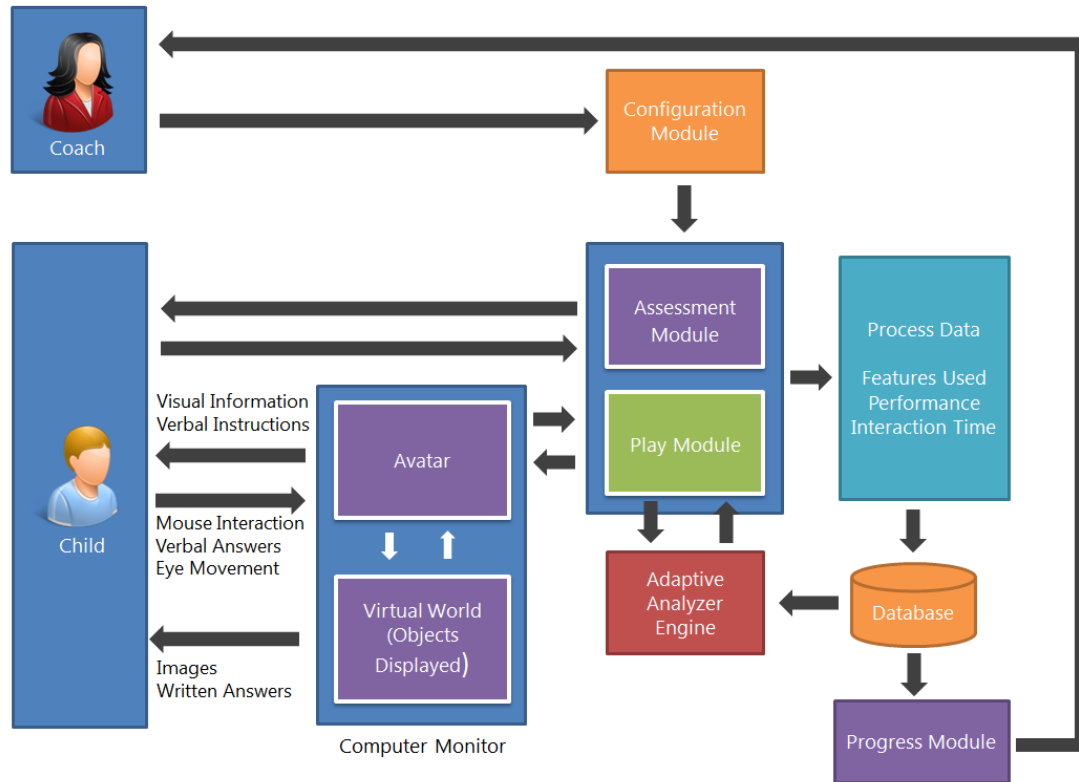
Figure 1-2: High-Level Overview of the Original Ying [22]

The main idea for that edition was depend on an avatar which shown in Figure 1.3 which was the essential component of Ying at that time. The avatar switched his gaze to one of the surrounding object in his virtual environment through the Play and Assessment Modules. The child then was required to follow the eyes of the avatar and choose the direction of its gaze and determine which object the avatar looked at it. The performance of the child was evaluated through the Assessment Module, and the results of the evaluations were available in the Progress Module [22]. A high-level overview of the original Ying shown in Figure 1.2.

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Figure 1-3: Play Module & Assessment Module of the Original Ying [22]

1.6.2 Second Edition for Ying

Later, Ying was re-engineered in 2014 as a customizable, Windows-based mobile application prototype to improve verbal and social communication skills in children diagnosed with ASD. Ying consisted of two modules, which were Learn and Fun Time. The Learn Module which aimed to provide patients diagnosed with ASD with the required material they will be tested on in the Fun Time Module.

The learn Module, shown in Figure1.4, consisted of three different games, which were Virtual Flashcards, Story Teller, and Eye Gaze. Virtual Flashcards exposes children with ASD to different words divided into categories. The Story Teller activity helps show different stories involved with a variety of emotions that have a facial expression associated to them. Eye Gaze was another activity which encourages children to engage in eye contact by following the eyes of an avatar and select on the object the avatar is looking at.

Figure 1-4: Learn Module Activities: Flashcards Activity (Left Picture), Story Teller Activity (Middle Picture), and Eye Gaze Activity (Right Picture) [8]

The Play Module, shown in Figure 1.5, was designed to allow the patients to apply the different skills which were earned and obtained from the previous module. These modules consisted of five different games that improve the social and verbal communication skills which related to the Learn Module. These five games included Say My Name, Message in a Bottle, Take a Peek, Tappy Time, and Fill in the Blank.
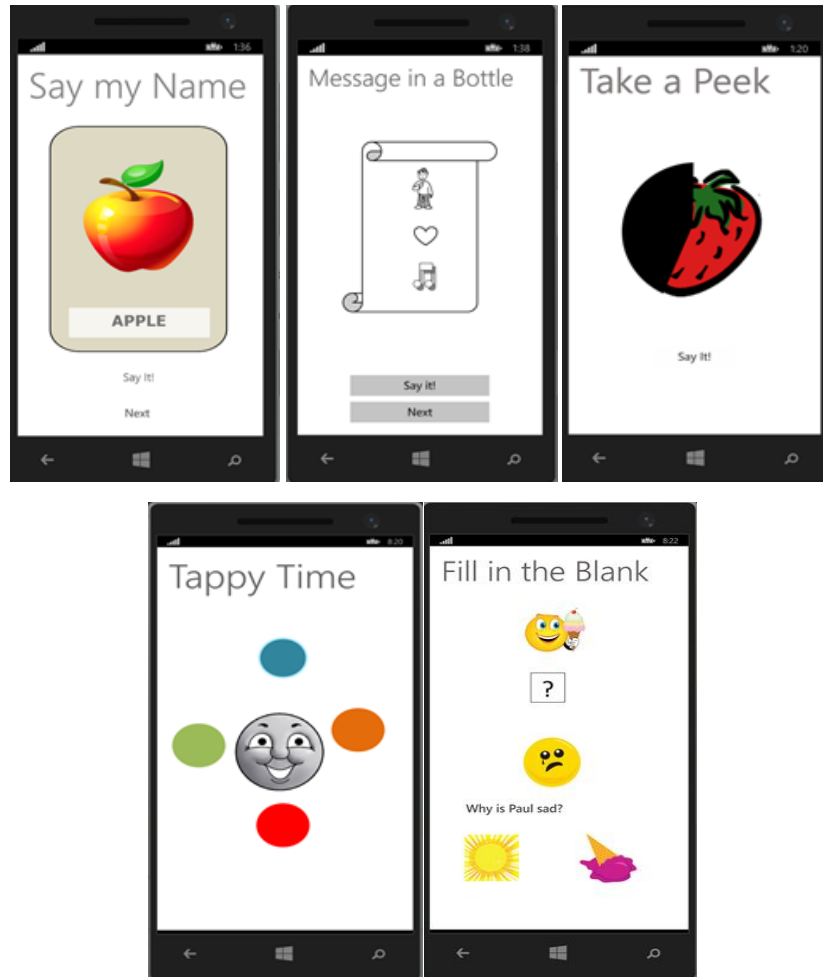
Figure 1-5: Play Module Activities [8]

The objective of Say My Name is to say the name of the shown object after pressing the `Say It' button. Message in a Bottle activity focuses also on enhancing patients to form sentences by showing three images and challenging the patients to say it. In Take a Peek, the user is given an image which is completely covered, and this image then reveals itself in 10 seconds. The challenge for the patients is to identify the object within seconds and saying the correct name for the object. Tappy Time is similar to Eye Gaze, which asks the users to replicate the same pattern for the avatar which looks at the different circles around it. Fill in the Blank asks the patients to figure out the missing scene in a story that consists of three scenes.

1.6.3 The New Era for Ying

The new era for Ying in this thesis is re-engineered to be a mobile application which could be downloaded on all Android devices. Android devices dominate the market with a whopping 87% around the world [23]. More patients could benefit from accessing Ying while supported on Android devices. Ying is augmented with more effective approaches which have been approved its efficiently by Human Computer Interaction experts. Facial and emotions recognition are added that reinforces varieties of social behavior skills as well as their verbal communication skills in children with ASD. Analyzing and reviewing the existing augmented technology involved to reinforce different communication and adaptation skills in patients diagnosed with ASD is one of the main contributions of this thesis. Re-engineering of Ying prototype is another important contribution for this update of Ying, which included migration to the Android Mobile Platform, as well as re-designing its architecture and database.

- The new era of Ying includes:

    o Reinforcing its efficiency with facial recognizing software.

    o Integrating emotion recognition.

    o Modifying its modules.

    o Adding new activities

1.7 Thesis Organization

The rest of this thesis is organized as follows:

- Chapter 2 presents a more detailed overview of ASD (ASD symptoms, types, and diagnosis, and traditional therapy are discussed) and augmented technologies involved in computer interaction systems for ASD.

- Chapter 3 covers literature review of different technology used to help the autistic children which are relevant and related to the goals of this study.

- Chapter 4 discusses the main areas of focus of this study.

- Chapter 5 describes the research methodology for Ying including objectives, hypothesis, and approach.

- Chapter 6 describes the research implementation for Ying including design of the proposed approach. and all that entails, i.e., the architecture, features, components, and design.

- Chapter 7 discusses experiment and analysis for Ying's system.

- Chapter 8 concludes this thesis.

CHAPTER 2: BACKGROUND OF AUTISM SPECTRUM DISORDER

2.1 Autism Spectrum Disorder

Autistic Spectrum Disorder (ASD) is a general term which includes different types of disorders, but it usually refers to 'autism' [24]. In other words, we can define Autism Spectrum Disorders (ASDs) as a group of developmental disabilities. Until now, the causes of ASD have been difficult to identify. ASD can affect a person's behavior at different levels from very mild to severe, which also differ from patient to patient. However, patients with ASD may communicate with, interact, behave, and learn in different ways than other people. Children diagnosed with ASD thinking and learning abilities are varying from gifted to severely challenged. Autistic disorder is the most commonly known type of ASD, and there are also other types of ASD, including "pervasive developmental disorder-not otherwise specified" (PDD-NOS) and Asperger Syndrome [25].

Scientists do not know exactly all of the causes of ASD, but they have collected many causes and factors for ASD types. There could be many different factors that make a person more likely to be patient diagnosed with ASD, including environmental, biological and genetic factors. The following factors are the common causes for ASD [26]:

- Genes are one of the most important factors that can make a person more likely to be an ASD patient.

- Having a family member diagnosed with ASD increases the odds of being diagnosed with ASD.

- Having an identifiable genetic disorder, such as Fragile X syndrome, tuberous sclerosis, and Down syndrome may lead to diagnosis of ASD.

- Taking harmful drugs during pregnancy may cause newborns diagnosed with ASD.

- There is some evidence that the critical period for developing ASD occurs before birth.

Autism statistics in the U.S. Centers for Disease Control and Prevention (CDC) in 2012 said that around 1in 68 American children are diagnosed as on the autism spectrum, shown in Figure 2.1. Careful research also says that this increase is only partly explained by improved diagnosis and awareness. Other research also shows that boys with autism are common more than girls with a ratio five to one. An estimated 1 among 42 boys and 1 in 189 girls are autism patients in the United States, and autism is reported to occur in all racial and ethnic groups [17][26].

Prevalence of Autism Spectrum Disorder (ASD) in 8-year Olds (2012)		About 1 in every "x" children
	Overall	1 in 68
Sex	Boys	1 in 42
	Girls	1 in 189
Race	White	1 in 65
	Black	1 in 76
	Asian/Pacific Islander	1 in 88
	Hispanic	1 in 99

Figure 2-1: Prevalence of Autism Spectrum Disorder [17]

2.2 Types of Autism Spectrum Disorder and Common Symptoms

Autism can be classified in one of the three main groups: classic autism, Asperger's syndrome, and pervasive developmental disorder or atypical autism. Each diagnosis expresses in a different way [24].

2.2.1 Classic Autism

A child is diagnosed with classic autism if he or she has some symptoms before the age of three: lack of eye-contact, expresses mismatched emotions, exhibits challenges with verbal communication, and show repetitive behaviors [24].

2.2.2 Asperger's Syndrome

Children diagnosed with Asperger's syndrome also known as 'high-functioning autism', have difficulties with social interaction and communication, and may show repetitive behaviors. On the other hand, children with Asperger's syndrome usually have normal to exceptional intelligence and language skills and causes the diagnosis of Asperger's syndrome to be given later than classic autism (e.g., after three years old) [24].

2.2.3 Pervasive Developmental Disorder or Atypical Autism

Children who are between the previous two types of symptoms are given the third diagnosis, which is pervasive developmental disorder or atypical autism. In other words, children with pervasive developmental disorder do not meet the full symptoms or criteria for the first two types of autisms (classic autism or Asperger's syndrome). But they also could have some social interaction and communication challenges, and/or have repetitive behaviors [24].

2.3 Diagnosis

Autism has an impact on patient behaviors and the ability to communicate with others. It's very important for parents who have a child with these symptoms to take him or her to specialized doctors because early intervention leads to better outcomes in spite of the diagnosis of autism a child has [24].

2.4 ASD Therapy

Unfortunately, there are no medications thus far specialized to treat or cure ASD entirely or treat the core symptoms for ASD. However, there are some available medications which can help some people with ASD to avoid some side effects for ASD in order to function better. Some of these medications are helpful in such ways as to manage high energy levels for patients diagnosed with ASD, inability to focus, depression, and seizures [17]. These medications might affect each child differently. As part of ASD treatment, it is very important also to stand and work with an experienced health care professional in the field. Both ASD patient families and their therapists should closely working together monitoring the child's progress and know his or her alterations for the given treatment to ensure that that specific treatment do not exceed the main goal which is helping the child instead of harming them [17].

Many researches and studies show that diagnosing ASD children early and starting treatment plans can significantly improve their development and lead to better results [27][28]. Starting early intervention services means starting their treatment from birth up to three years old (36 months) in order to help them to earn all required skills. These early interventions consist of multiple therapy sessions to develop the patient speech, walk, and communication with others. Therefore, it is very important for every parent to keep touch with their child's doctor immediately if they see some of ASD symptoms in their child [17].

There are other types of non-medicine treatments that are helpful for patients diagnosed with ASD, including "auditory training, discrete trial training, vitamin therapy, anti-yeast

therapy, facilitated communication, music therapy, occupational therapy, physical therapy, and sensory integration" [17].

Therapists classify these treatments into the following four main categories:

- Traditional Approaches for Behavior and Communication Therapy

- Dietary Approaches

- Medication

- Complementary and Alternative Medicine

2.4.1 Traditional Approaches for Behavior and Communication Therapy for Children Diagnosed with ASD

Many behavior and communication approaches are reported by the American Academy of Pediatrics and the National Research Council, " those approaches that provide structure, direction, and organization for the child in addition to family participation. " [17]. Applied behavior analysis (ABA), Floortime, TEACCH, occupational therapy, sensory integration therapy, speech therapy, and the picture exchange communication system (PECS) are considered as important approaches that can be used as part of effective solution for children who diagnosed with an autism [17].

Applied Behavior Analysis (ABA):

Applied behavior analysis (ABA) is defined as notable treatment approaches for patients diagnosed with ASD. ABA has become widely used by many professional health care providers, therapists, and schools around the world. ABA mainly supports reacting to usual and normal behaviors and avoiding bad behaviors, in order to improve different skills for patients diagnosed with ASD, and their progress is watched in order to achieve this goal.

There are several different approaches and types of ABA and here are some of these types [17]:

1. Discrete Trial Training (DTT):

DTT is an education method which follows a series of trials, in order to teach them all the required steps for having desired positive behaviors or responses. DTT consists of a series of lessons, which are divided into small parts and varieties of rewards are augmented with right answers and behaviors and incorrect answers are discarded.

2. Early Intensive Behavioral Intervention (EIBI):

EIBI is another approach of ABA, which is used with young children with an ASD who are under five years old.

3. Pivotal Response Training (PRT):

PRT focuses on increasing the motivation of the children diagnosed with ASD to learn, monitor their own behaviors, and establish their correct communication. Reacting positively has common effects on other negative behaviors.

4. Verbal Behavior Intervention (VBI):

VBI is another type of ABA, which focuses on teaching children diagnosed with ASD verbal skills.

Developmental, Individual Differences, Relationship-Based Approach (DIR):

DIR is also known as "Floortime", which mainly focuses on developing emotions and relationships for patients diagnosed with ASD (e.g., feelings, relationships with caretakers). Floortime is also focused on how the child responses with surrounding things [17].

Treatment and Education of Autistic and related Communication-handicapped CHildren (TEACCH):

TEAACH improves a child's skills through using visible cues to teach them. For example, using flashcards can help teach a child how to wear glasses by showing information through multiple steps [17].

Occupational Therapy:

Occupational therapy focusses on teaching patients diagnosed with ASD the necessary skills, which help them to increase their independence as possible. These skills could include: greeting, eating, playing, and reacting with people skills [17].

Sensory Integration Therapy:

Sensory integration therapy helps the person deal with sensory information, like sights, sounds, and smells. Sensory integration therapy could help a child who is bothered by certain sounds or does not like to be touched [17].

Speech Therapy

Speech therapy aims to enhance and develop the patient's communication skills. Usually, children are able to learn different verbal communication skills easily, but this depends on their gestures and exposure to picture boards showing events happening with other children [17].

The Picture Exchange Communication System (PECS):

PECS uses visual pictures and symbols to develop patients' communication skills. The patients here are taught to use pictures and symbols for asking and answering questions and communicating with other [17].

2.4.2 Dietary Approaches

There are some unproven dietary treatments which have been suggested by reliable therapists which might help one child with ASD, but may not be effective for another. Most of these types of treatments, unfortunately, do not have the powerful scientific support which make it available for widespread use.

A lot of biomedical scientists call for modifying a diet by avoiding some types of foods and supplementing with required vitamins or mineral supplements, instead of the removed foods. The idea of dietary treatments is based on food allergies, or the premise that certain vitamins and minerals could cause some symptoms of ASD. Some parents see some positive differences in their children after applying this type of treatment, but it is very important to talk with a child's doctor first, prior to changing his or her diet to make certain that they get all of their required vitamins and minerals [17].

2.4.3 Medication

At present, there are no specific medications that can be used to treat ASD, specifically, or to treat its symptoms. On the other hand, there are some helpful medications that can be used with some people to reduce or avoid ASD symptoms. For instance, there are some medications which might be used to manage high energy levels, or to avoid or reduce the inability to focus, depression, or seizures [17].

2.4.4 Complementary and Alternative Medicine (CAM)

Complementary and alternative treatments (CAM) are treatments which are considered to be outside of what is typically used by the therapists. CAM is used by some parents and health care professionals, in order to reduce the symptoms of ASD. They use it in a certain

way, and they may add special diets, chelation, biologicals (e.g., secretin), or body-based systems, such as deep pressure stimulation [29].

Complementary and alternative treatments (CAM) are very debatable, nowadays. Research shows an important statistic, which says "that one third of parents of children with an ASD may have tried complementary or alternative medicine treatments, and up to 10% may be using a potentially dangerous treatment" [30]. But, each one must talk to his or her child's doctor before using these types of treatments [17].

CHAPTER 3: RELATED WORK

Many technologies have designed to assist children with autism and work on their social, communication, and adaption skills. Research has proven that using technology are efficient tools which teaching varieties of skills to patients with ASD [11]. Those technologies can be divided in general into the following two main categories according to the type of involvement end users: static and dynamic applications. Static applications are those that contain static materials provided for the users such as flashcards and DVDs. On the other hand, dynamic applications are interactive applications which change their contents based on each user input, so they adapt the applications according to different user's abilities. For example, the system can adjust the difficulty level based on the user progress.

In the following sections, we discuss and classify some representative existing technologies, as shown in Table 3.1, based on the three main targeted skills that correspond to the contributions of this thesis: verbal communication, social communication and emotions recognition, and adaption.

Table 3-1: Existing Technology for Children with ASD. Static Applications (Blue), Dynamic Applications (Green), Application Area (Gray), and Method Used (Right Column)

Type of Involvement	Application	Application Area			Method Used
		Verbal Communication	Social Communication and Emotions Recognition	Adaption	
Static Applications	Vast Autism	✓			VAST
	The Transporters		✓		Trains animated with human faces
	Talking Tom Cat 2	✓			"Tom" Cat
	Zac Browser			✓	Provides access to games, music, and other activities specialized for ASD

	The Virtual Pink Dolphin Project			✓	Virtual Dolphin
Dynamic Applications	Proloquo2Go	✓	✓		Symbol-based communication, text-to-speech, predicting word, a customizable vocabulary and interface
	Mind Reading		✓		Video clips
	FaceSay		✓		Eye contact
	First Then Visual HD			✓	Schedules
	AustiMate			✓	Makes senses through patients' pictures and videos

| | HANDS | | | ✓ | Teachers and parents contribute to improve social and life behavior of children diagnosed with ASD |

3.1 Technology to Enhance Verbal Communication Skills in Children Diagnosed with ASD

3.2.1 Proloquo2go
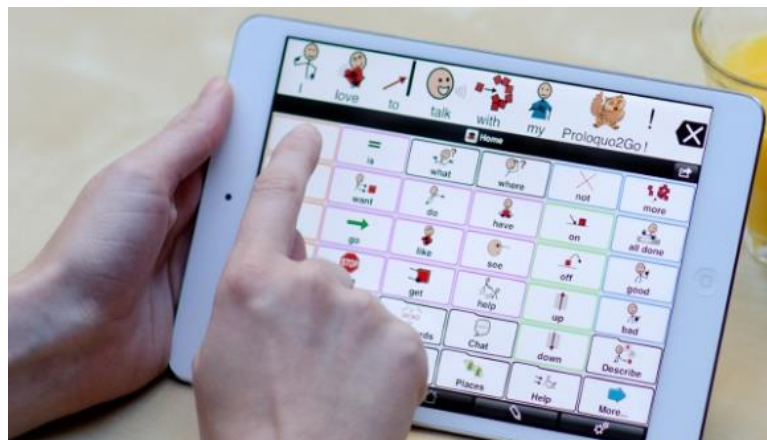
Figure 3-1: Proloquo2go Application Focus on Verbal Skills Through Symbols and Pictures

Proloquo2Go is a Symbol-supported communication application which helps and assists children to development their language and grow communication skills through using symbols and pictures as shown in Figures 3.1 and 3.2. Proloquo2Go is one of the efficient

Augmentative and Alternative Communication AAC apps that runs exclusively on iOS devices to increase students' communication skills which has been proven by several studies [31]. Half of its users are Autism Spectrum Disorder patients with wide a variety of diagnoses and ages. Proloquo2Go application has many helpful features, such as text-to-speech, predicting word, and a customizable vocabulary and interface. It also facilitates communication through symbol using the SymbolStix symbols for its users who cannot read, and it also allows users to typing with an ability to predict the written words for educated users. It augmented by natural sounding text-to-speech voices, and its users can use Proloquo2Go to practice and pronounce vocabulary and express their feeling [21][32]. Proloquo2Go has been designed to be a dynamic application that adapts itself according to each user needs. However, users are limited to images provided by the app, and it only available for iOS devices.

Figure 3-2: Proloquo2go Overview

3.2.2 Vast Autism

Vast Autism 1 Core, shown in Figure 3.3 and 3.4, is another application that uses VAST aims to help autism patients with speech difficulties. This application is designed as a video technology, which facilitates and improves communication abilities for speech-impaired individuals [33]. Vast Autism helps its users to acquire relevant words, phrases and sentences by combining the concept of video modeling with written words and auditory

28

cues which has proven its effectiveness, but its patients must have strong visual skills to developing their speech [34][35].

Figure 3-3: Vast Autism 1 Core Home Page (on the Left) and its Modeling Video (on the Right)

Many researches show that students are highly interested with this application, and they immediately attempt to move their lip or touch their mouths in response to the application. Following a close-up video of mouth movements allows users to become able to speak full sentences [33]. Many patients how use this application who were essentially nonverbal begin saying word approximations and attempting words more easily after a few weeks. Videos are categorized under one of the following five categories : "syllable repetition, single syllable words, multi-syllabic words, phrases, and sentences" [34].

Each video gives a spoken target word with its written word, phrase, or sentence. Each word, phrase, and sentence has meaning that can be practiced in their daily life in order not to be forgotten, and showing the written word enhances acquisition the correct language and increases its efficiency.

Figure 3-4: Video Types for Vast Autism

3.2 Technology to Enhance Social Communication and Emotions Recognition Skills in Children Diagnosed with ASD

3.2.1 Mind Reading

Mind Reading , shown in Figure 3.5, is one of the interactive commercial application which is used as a guide to help children and adults with different emotions and facial expressions [36][37]. Mind Reading is designed to teach its users who have difficulty with recognizing facial expressions and emotions in others. The main idea behind this application is that its emotion library provides descriptions of different emotions through short video clips which are presented by different people, from two genders, different age groups and ethnicities. This application also provides many quizzes and short lessons in order to then test their progress and recognition skills, based on what they learned. It has difficulty levels a series of collectable rewards in order to motivate its users and to provide an incentive to use the application [22][38].

Figure 3-5: Mind Reading' Video Clips for Happiness Emotion

A research has shown the efficiency of this application after children with autism used Mind Reading software who improved their ability to recognize emotions from faces and voices clearly over the course of ten to fifteen weeks compared to their initial assessment [38]. On the other hand, Mind Reading seems limited to faces utilized in this application as there seems to be poor as well.

3.2.2 FaceSay
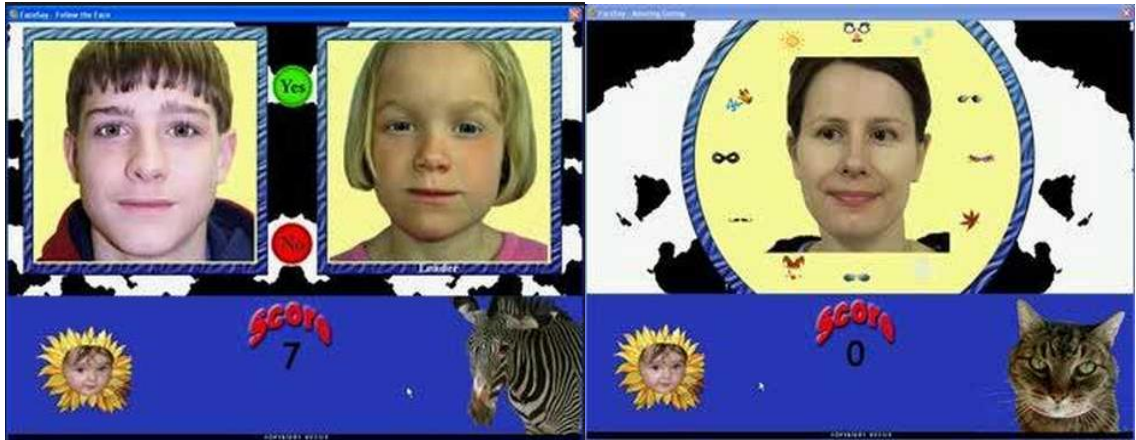
Figure 3-6: FaceSay Application's Games: Follow The Face Game (on the Left) Asks User to Copy the Avatar's Emotion, and Eye Gaze Game (on the Right) Asks User to Click on the Object which the Avatar Looks at it

The FaceSay is one of the computer applications which aims to help and teach autism children to understand different facial expressions and use eye contact correctly during communications with other [37][39]. The FaceSay application, shown in Figure 3.6, included several interactive games which make children become more familiar with using and understanding eye gaze and facial expressions in order to let them to have better communication with other. One of its games shows two animated images and asks the users to confirm when these two images have the same emotion. Another an interactive game which focuses on eye gazing shows many objects surrounded by a face in the middle which look at one of these objects; and asks user to select which object the face is looking at it. Many researches have shown that autism patients who used this application have become much better in recognizing different emotions, facial expressions, and eye gaze in their social life [20].

3.2.3 The Transporters

Figure 3-7: The Transporters Show Animated Human Faces on Different Trains with Different Emotions

The Transporters is classified as a Static DVD, which consists of an animated series available on DVD that designed to help children who diagnosed with ASD to understand and know different emotions in a social context. It basically shows animated human faces on different vehicles, shown in Figure 3.7, which are trains in this system, and it uses characters similar to "Thomas the Tank Engine" [37][40]. A study has done by the Autism Research Center has shown its efficiency and children diagnosed with ASD improved their comprehension and twenty-seven recognitions of emotions significantly after using the Transporters DVD over a four weeks period. [41]. This type of technology is focusing on teaching and understanding different emotions through a series of animated faces on trains encourages the children to look at these faces which can test later. On the other hand, The transporters' faces in this way laminate their view comparing to the real human emotions and faces and sometime intimidate some children. [21][22]

3.2.4 Training Faces
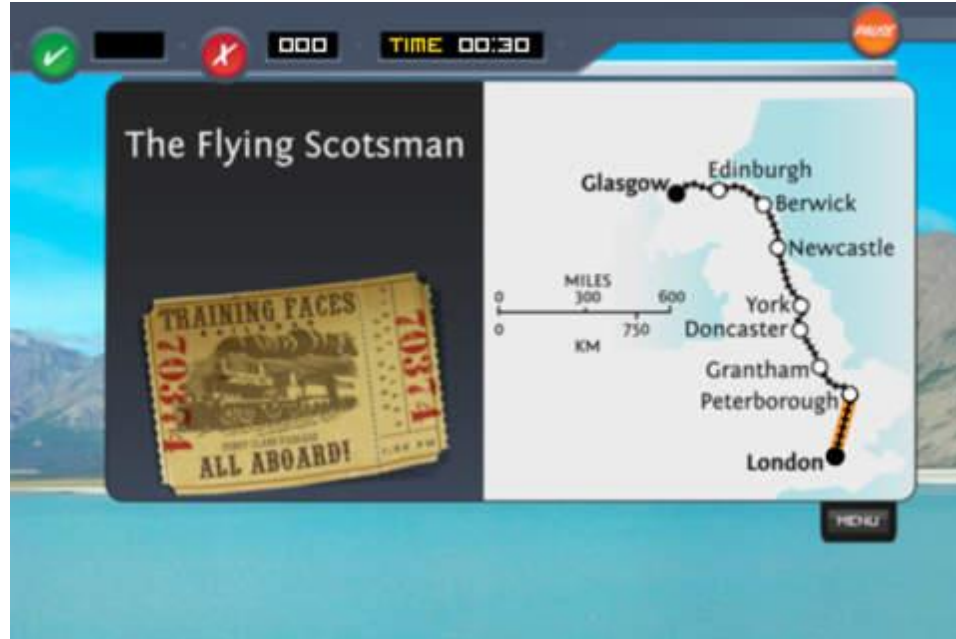
Figure 3-8: Training Faces Home Page

Training faces is another game, shown in Figure 3.8 and 3.9, that is designed, especially

for Asperger's Disorder patients in order to teach them emotion recognition skills. Its idea

is to enforces the users to choose the correct emotion in order to move on to the next stage

to reach their final destination [35]. The game encompasses with nine different emotions,

which are happy, sad, excited, afraid, angry, sick, tired, confused and silly. The player has

to selects an emotion at the beginning to start. Then, each train route is assigned to one of

nine different emotions, and the train route then displayed to the player, and the player is

told where the train is going after selecting an emotion. After that, two train cars display

five people on each train of them, and the user must identify and tap the correct pictures of

the characters, which show the selected emotion in the beginning, in order to move to the

next station and to reach to the final destination. In order to be more efficient, this game

has speedup recognition and becomes more difficult for its users after each round [21].

Figure 3-9: Training Faces Process for Emotion Recognition Which Enforces Users to Choose the Correct Emotion, in Order to Move on to the Next Stage to Reach the Final Destination

This type of fun game encourages autistic children to keep attention to facial expressions and understand different emotions, in order to reach to the final destination and win, but the game could become uninteresting to them sometime. Cheering children after identifying emotions correctly, let the game to acquire emotion recognition skills.

3.2.5 Talking Tom Cat 2

Figure 3-10: Talking Tom' Cat Repeats What the Users Say to Him

Talking Tom Cat 2, shown in Figure 3.10, is a popular game has gained positive feedback from the autism community in spite of was not designed at the beginning for helping

children diagnosed with ASD. Talking Tom Cat repeats what the users say to him with a funny and high-quality voice. This game also responds to gestures and commands from the users, such as it purrs if stroked, cries if hit, and it jumps when scared [42]. Talking Tom Cat 2 is one of the useful applications to make social adapting for patients diagnosed with ASD less intimidating and comfortable since Tom Cat is friendly to most users. The main con of using this app to in purpose to help ASD is that Tom limited and just repeats what the users says[21].

3.2.6 Clown Zapo

J.Lozano, J. Ballesta and S.Alcaraz Murcia [43] introduced a project in 2011 to teach and help patients diagnosed with ASD with different social and emotional skills. This project, shown in Figure 3.11, consists of multiple teaching levels of emotions, from basic to complex, through a controlled environment by contacting with the main character called (Clown Zapo). It also tries to teach children diagnosed with ASD to predict the actions of people from their true or false beliefs. A study [10] has shown its efficiently through the results noticed by their teachers and families, and this game emphases that such educational application can help patients diagnosed with ASD to perform different tasks, based on their understanding of different emotional skills, and to encourage them to work in pairs and interact with the other people.

Figure 3-11: Emotion Recognition through Drawings (on the Lift), and Emotion Recognition through Images (on the Right)

3.3 Technology to Enhance Adaptation Skills of Children Diagnosed with ASD

3.3.1 First Then Visual Schedule HD4

Research has shown the effectiveness of using visual schedules for patients diagnosed with ASD to manage their time, encourage them to do different tasks, and to avoid their anxiety [44]. It can be clearly seen that patients diagnosed with ASD have greater challenges dealing with unstructured time than other people, and they also sometime have inappropriate behaviors. Schedules can help children diagnosed with ASD in many ways, such as improving their communication skills by giving them visual images for their requirements. Schedules can also help the patient to behave calm and avoid their inappropriate behavior by showing pictures of routines for them, so they know what are happening now and what will they do later [21].
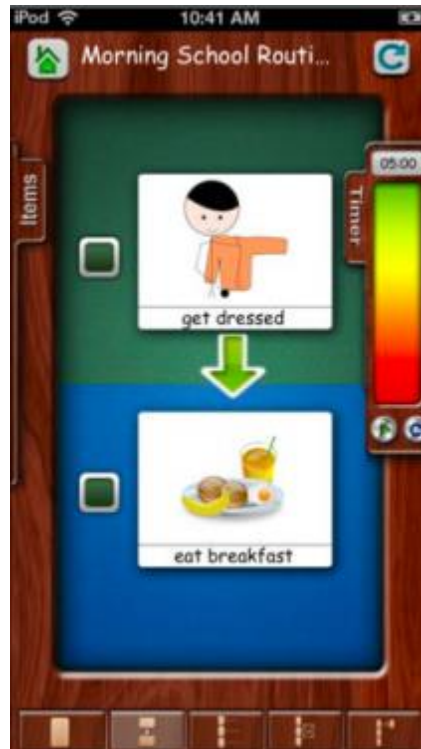
Figure 3-12: First Then Visual HD Allows Users to Check Off Completed Tasks

The First Then Visual Schedule HD achieves the previous discussed goals for using schedules, which helps patients diagnosed with ASD to organizes the time of them, develops their independence, and increases their self-esteem. It allows them to check off completed tasks. Schedule events associated with a timer, which is appropriate to the of the individual with unique needs. Users can view those schedules in multiple views, which make Human-Computer Interaction more effective. Schedules are also can be created from different image sources, such as the web, and daily events can be created in more detail and set up as a reminder, which described in the Figure 3.12 and 3.13 [45].

Figure 3-13: Events Schedules (on the Left) and Show Events Steps (on the Right)

3.3.2 AustiMacte

AustiMate is an Augmentative Alternative Communication application (AAC), shown in Figure 3.14, that lets autism children to construct sentences. AustiMate is considered as a dynamic application, which allows its users to load their pictures, videos as well as add voice recordings, in order to create different scenes, which promote social skills and communication in children with ASD [46]. This feature makes AustiMacte different than Proloquo2Go application, which we discussed previously. AustiMate application is helpful tool also for children diagnosed with ASD to encourage them to do their daily routines, as well as building sentences. The scenario for using their own pictures to create scenes begins by taking photos by a caretaker of rooms in their home to use them to make interactive scenarios for its users. Later, those scenes can be accessed by children diagnosed with ASD, in order to assist them to complete their basic tasks. Utilizing and dealing with their own pictures makes patients diagnosed with ASD more comfortable, and makes AutisMate application more efficient [21].
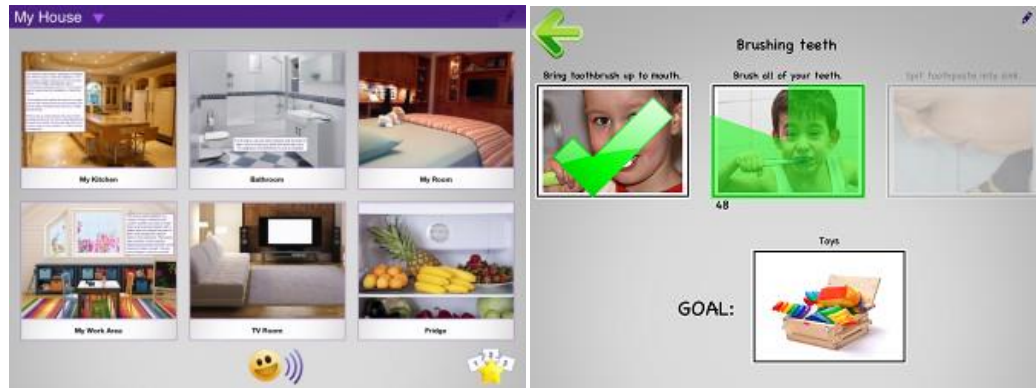
Figure 3-14: AustiMacte Uses Users' Own Pictures to Do Their Daily Tasks

Earning readers' choice award for About.com 2013 in the favorite special-needs application category shows the efficiency for AustiMacte for many reasons. Some of the main reasons which show its efficiency are because this application works on the lives of children with ASD to make it easier, cognitive weakness, and speech delays and difficulties. Many features will be added in the next version for this application, such as providing different rewards for completing all tasks visual schedules, and adopting text to speech keyboard for the children to enable them to type [46].

3.3.3 Zac Browser

Figure 3-15: Zac Browser Homepage

Zac Browser, shown in Figure 3.15, considered the first web browser, which designed for children diagnosed with ASD in particular. Zac Browser main objective is to enable low, medium and high functioning autism children diagnosed with ASD to browse easily without overwhelm them [47]. As we know that it is hard for patients diagnosed with ASD to focus on one particular task, and having many websites and sounds nowadays can confuses children diagnosed with ASD [21] [48].

Figure 3-16: YouTube Window in Zac Browser [9]

ZAC, shown in Figure 3.16, homepage basically has a full-screen interface which allows users to access to games, music and other activities, which promotes children social interaction, develops their communication, and avoiding their repetitive behavior. This kind of website which takes over the computer and reduces the controls available. By making this kind of website, which towards, especially to ADS, it opens varieties of new possibilities for children with ASD [47][48].

3.3.4 The Virtual Pink Dolphin Project

The Virtual Pink Dolphin Project, is one of the virtual reality (VR) applications which aims to improve ASD children' prediction and their daily living quality. The main idea of this application is having a learning game with VR dolphins augmented within it and enforces children diagnosed with ASD to follow instructions shown visually in order to guide the dolphins by having certain movements [10][49].

The Virtual Pink Dolphin Project has three different levels of difficulty by performing specific antics through the dolphins, which will be controlled by users to achieve that. Rewards provided to the users after successfully achieving each level, and a tutorial are available to the beginners. The Virtual Pink Dolphin Project owner is looking in further VR research that will force on teaching communication, improving social communication and daily life skills for children with ASD [10][49].

3.3.5 Hands
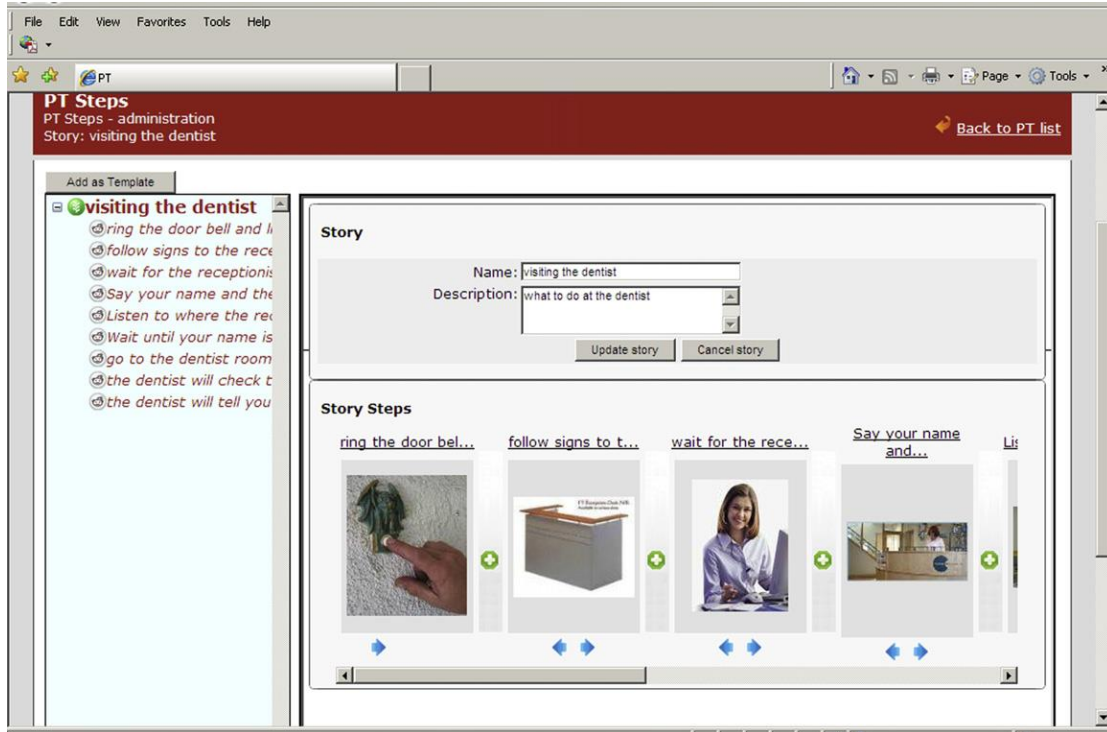
Figure 3-17: The HANDS Server for Teacher Set Up Functions [50]

HANDS is a smartphone application designed to improve social behaviors for children with ASD, based on their teachers and parent's participations. Teachers play a big role through intervening in their daily life through the application by a web-based toolkit, shown in Figure 3.17 and 3.18, so this method reflects an efficient computer – human interaction between teachers and children' interaction, in order to help children in every moment of their own life. Parents are also another big part involved to use this application They give teachers the required information and feedback about their children's preferences and progress. These records are most likely to be taken under consideration in the future, in order to get better results from using this application [10] [50] .

J. Mintz [51] conducted a study in 2012 on HANDS application and its important successful factors, such as "credibility and Kairos". The results show the efficiency for this

application and emphasis some of those factors for designing success interactive systems, according to Fogg.
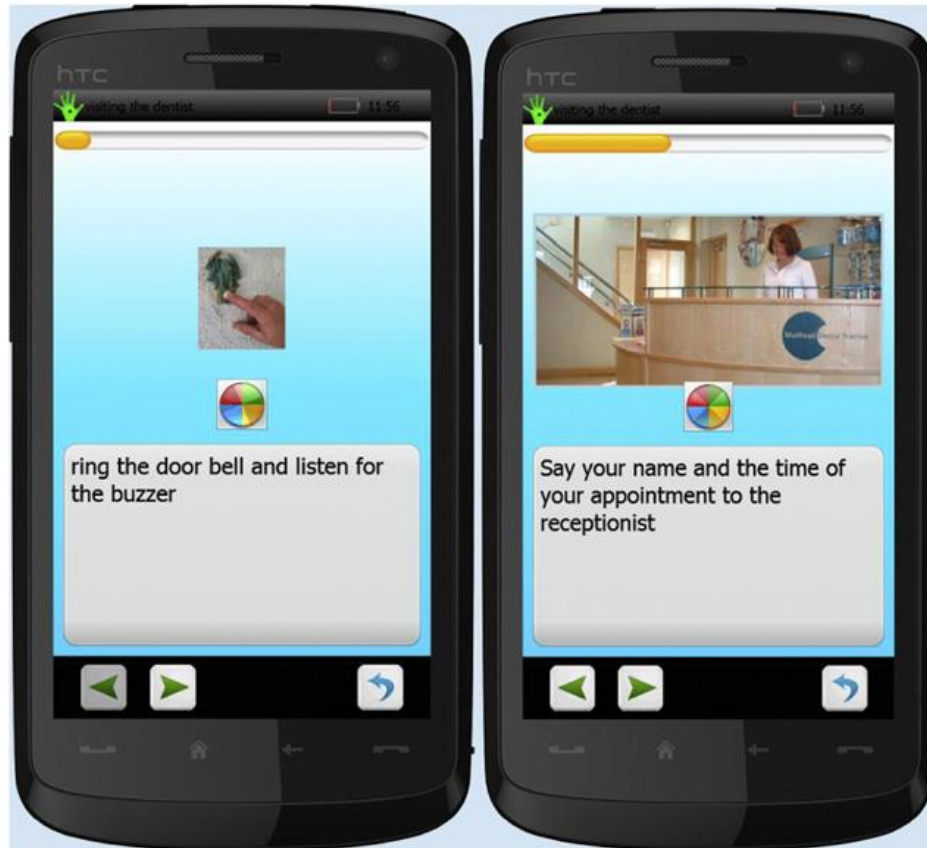
Figure 3-18: The Client Application for HANDS [50]

CHAPTER 4:RESEARCH FOCUS

As we know, communication development for children with ASD happens differently and more slowly than other non-autistic children [52]. As discussed previously, most patients diagnosed with ASD have language difficulties, deficits to developing peer relationships and emotional recognition (e.g., social communication), and lack of engagement with peers (e.g., adaptation) [8]. This study focuses on developing their verbal communication skills, training them to practice social communication and emotional recognition by themselves, and developing their adaptation skills with other people.

4.1 Developing Verbal Communication

As we know, most children who are diagnosed with ASD have difficulties previously discussed in Chapter 2, and developing their language skills is one of the main difficulties. Children with ASD are also facing another challenge to understand what others say to them. The verbal communication of children with ASD differs from patient to patient, which mainly depends on their intellectual, as well as, their social development. Some patients with ASD have poor communication skills and may not be able to communicate using speech or language, while others may have very limited communicate skills. On the other hand, some of them may have rich vocabularies and be able to talk about multiple subjects with more detail [53]. These difficulties, which affect the ability of children with ASD, are the main motivations behind this research, which is intended to help them to have better verbal communication skills. Multiple activities, such as Flashcards and Spell It, are augmented with varieties of approaches, which reinforce their verbal communications.

4.2 Training Children with ASD Social Communication and Emotions Recognition on Themselves

Patients with ASD are often self-absorbed, so they seem to exist in a private world in which they have some communication limitations to successfully understanding and interacting with others. Communicating nonverbally is also another difficulty, which most of children with ASD have. Interpreting and understanding hand gestures, eye contact, and facial expressions are considered as the important nonverbal limitations upon which most of the therapist focus. Another important symptom that we explained earlier is that most of them have issues with the meaning and rhythm of words and sentences. Children with ASD also have difficulty with understanding body language and to get the meanings of our different vocal tones [29]. Because of that reason, Ying was developed, to work on these issues in order to have better lives. This research aims to train, learn, and reinforce children with ASD varieties in social communication skills and emotions recognition by themselves through multiple activities, such as Show Me Faces and Eye Gaze, which will be explained in more detail later.

4.3 Developing Adaptation Skills for Children Diagnosed with ASD

Because children with ASD have multiple difficulties, they seem to exist in their own world, which makes them self-absorbed. Unexpected situations, such as having a new food or going new places such as pediatrics, makes them feel stress and increases their anxiety. These situations also affect their parents, which makes them also feel stress and anxiety. Therefore, developing adaptation skills for children with ASD is a substantial goal for this study to control their environment and help them to be comfortable and familiar with different situations. Movie Time is one of the developed activities which shows multiple

educatable videos, which is designed especially for that reason. Varieties of videos have

different topics, such as going to the dentists, how to dress, sharing toys with friends and

are available for Ying users in order to develop their adaptation skills.

CHAPTER 5: YING SYSTEM ARCHITECTURE

5.1 Objective

During the design of application Ying, firstly, the required factors which reinforces different skills of those with ASD (social, verbal, and emotion recondition) were determined, based on scientific literature in order to create an augmented and effective system which stands besides different behavior and communication treatment approaches. Health care professionals and treatment clinics also are the big and main resource of system design considerations in order to provide us with the necessary required information of all the needs of patients diagnosed with ASD and guide us to produce an effective system. Ying, includes the most necessary target functions to achieve our goals.

Secondly, we looked through different behavior and communication treatment approaches and different types in more detail which used to avoid some side effects for ASD (e.g., "Applied behavior analysis (ABA), Floortime, TEACCH, occupational therapy, sensory integration therapy, speech therapy, and the picture exchange communication system (PECS)" [17]). The purpose of this essential step is to figure out the efficient features which could be added to our target augmented system, Ying, in order to develop a powerful, helpful, and effective system apply the necessary human computer interaction features to help children diagnosed with ASD.

The following section describes the requirements of Ying after identifying different features and characteristics of the existing effective applications which discussed in the related work section. To get better effective results, the implementation of Ying includes

new features such as emotion recognition as well as some effective features (for example, speech recognition) from other effective applications. To sum up, the main goal of this study is to provide an effective system augmented with interesting and effective features that stands with therapists in order to help patients diagnosed with ASD.

5.2 Approach

Figure 5-1: Logo of Ying

This version of Ying is a mobile application, which will be available for free for 87% of people around the world who have Android phones. Ying incorporates varieties of effective features, which have been proven valuable by HCI researches. Ying promotes verbal skills, as well as social communication skills for children diagnosed with ASD, through a group of fun activities. Ying also stands hand-by-hand with therapists and caretakers through Ying, based on the Evaluation page, which will be explained later. Therapists or caretakers have the power to schedule educational activities for a child. To sum up, Ying is as a helpful system which is considered as a link between patients diagnosed with ASD, their parents, and their caretakers, in order to reach better results. Figure 5.1 shows logo of Ying.

Figure 5-2: Six Modules for Ying (Ying Home Page)

To reach our goal for this study, the new era of Ying consists of six modules, as shown in Figure 5.2:

1. Learn: Users in this module, as shown in Figure 5.3, provided by varieties of basic information, in order to increase their knowledge and reinforce their skills, which will be tested later in the Fun Time module.

2. Fun Time: This module contains multiple educable games, which promise to obtain the targeted skills provided through Learn module.

3. Schedule: Children can see and check up off their completed daily main activities, which encourages them to do it and organize themselves, as well as to increase the ASD patient's independence.

4. Rewards: In this module, a list of the rewards is shown to users, based on their progress.

5. Progress: Parents and their child's caretakers can see the progress of a patient, based on his or her activities and solutions.

6. Evaluation: This module is considered as a link between the caretakers, the patient's family and the programmer, which allows them to contact each other, in order to develop this application to meet the needs of a child, based on his or her progress. This module contains a brief questionnaire, which is collected to be used in the evaluation of this system across the users.

5.2.1 Learn
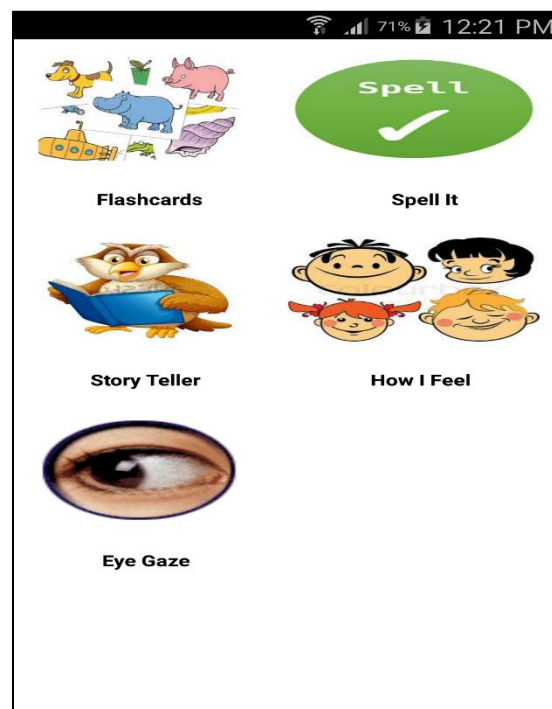
Figure 5-3: Learn Module Activities

Learn Activity 1: Virtual Flashcards

This activity is the same activity that existed in the previous version of this application, consists of virtual flashcards for words and phrases, but we added more categories in this version and increased more flashcards. The reason behind keeping this activity in this new

version, is its efficacy, which helps children diagnosed with ASD to build their verbal communication skills. Learning and acquiring vocabulary is the key for proper communication. We can define communication as the way by which we interact with and understand each other, and how information is exchanged. Listening to others and interpreting their gestures is the first step toward learning language. Many tools can be used in order to develop language, such as photo language cards and digital flashcards. These visual tools are considered as a helpful to language development, which increases vocabulary and leads to having stronger communication' skills, especially with children diagnosed with ASD [54].

Ying has the ability to develop verbal communication skills for patients diagnosed with ASD through the activity Virtual Flashcards, by allowing the child to hear the pronunciation of words, see related pictures, and see the spelling at the same time. This activity provides virtual flashcards for words (animals, emotions, colors, vehicles, and fruits) and phrases (pronouns, and verbs). The Fun Time module consists of games related to the Flashcards activity, which aims to examine what users learned in this module, Learn [21].

Learn Activity 2: Story Teller

Story Teller activity uses voices, different facial expressions, and body movements to make a list of meaningful that are better, and therefore, come alive. Some researchers suggest this way of better understanding through showing children with ASD the facial expressions and other verbal and nonverbal communications of the storyteller [55]. The activity, Story Teller, is only focused on helping emotion recognition skills for children with ASD. It was focused on teaching them about the seven basic emotions, through a limited number of

social stories (anger, fear, disgust, contempt, joy, sadness, and surprise) [56]. In this era of Ying, more helpful stories are added, based on suggestions from Autism Parenting Magazine [57]. These stories are carefully-selected, not just for emotion recognition, but also have varieties of benefits, such as teaching them the basic daily life essentials, such as dressing, greeting, and eating.

Learn Activity 3: Eye Gaze

Children with ASD have difficulties with keeping eye contact while they communicate with others, and they usually focus at the mouth [58]. Because of that reason, they miss social cues and have difficulties with understanding others. In this Ying, the Eye Gaze activity is added from the previous version of Ying, because it is an important contribution to reduce some of the significant symptoms of autism (e.g., missing eye contact) [21][22]. This activity was limited within one level that mainly asks the child to follow the eyes of the avatar and select the object at which the avatar is looking [21]. On the other hand, this activity was totally changed to be composed of multiple levels, based on real video clips shown in the middle surrounded by multiple pictures, instead, of an avatar. From a human computer interaction point of view, showing real video clips is more efficient than showing a cartoon avatar. The first level aims to test the children on what they have learned in the Flashcards activity, a short video clip plays, containing a person who looks to a certain direction, and the user is supposed to select the object at which the person is looking. The next level shows an emotion (anger, disgust, contempt, fear, joy, surprise, and sadness) and asks the user to identify the correct emotion that is shown by the video clip's actor. The difficulty level increases as the user goes through the following levels.

Learn Activity 4: Spell It

Students with learning disabilities in reading usually have spelling problems, and spelling problems increase with patients diagnosed with ASD, especially if they have mantel disabilities [59]. Spelling difficulties sometimes continues in individuals with reading disabilities, sometimes even after their reading has been improved. The important thing is to address this issue with our children, in order to work on it, because poor spelling leads to a hampering in writing, even when the content of the writing is of excellent quality. Because of the importance of teaching spelling, Ying gives its users the chance to learn and practice the spelling of what they learned in the Flashcards activity, by asking them to spell what they see and hear from Ying.

Learn Activity 5: How I Feel

Children with ASD have evidence of difficulties in interpreting social cues and understanding the different emotions of others. How I Feel is a new activity which focuses on developing emotions and making connections with relatives for patients diagnosed with ASD. The children can choose a picture from their gallery to be processed by Ying to determine their emotions. Eight emotions can be determined through the How I Feel activity, which are happiness, anger, fear, contempt, disgust, sadness, surprise, and neutral. This activity tries to use parameters from ASD childrens' own lives (e.g., their own pictures) to help them to understand different emotions. How I Feel is augmented with an emotions recognition approach that uses the childrens' own pictures, instead of using cartoons or video clips, in order to improve their social behavior.

5.2.2 Fun Time

Figure 5-4: Fun Time Module Games

Fun Time module promises achieving Ying objectives, in order to improve the verbal communication skills for patients with ASD. Four effective games, shown in Figure 5.4, were developed and added under this module, which mainly focuses an emphasis on what they learned in the previous module (Learn module).

Fun Time Activity 1: Say My Name

This game is the same one that existed in the previous version, which mainly teaches users the correct pronunciation of the Flashcards words. The Say My Name game challenges the users to pronounce the showing display picture correctly, in order to earn more points to get more rewards. The difficulty increases as long as the patient goes to the next stages.

Fun Time Activity 2: Exception Identification

Exception Identification is also one of the games that places an emphasis on increasing abilities for children with ASD in interpreting social cues and understanding the different emotions of the other. Some autistic children could not differentiate between different emotions, so the Exception Identification game comes in to reduce this difficulty. This game shows six different images, which have different emotions, and asks the children to choose the emotion that is not the same. The children have to know eight emotions (happiness, anger, fear, contempt, disgust, sadness, surprise, and neutral), in order to determine which image has a different emotion than the rest. Exception Identification game plays a big role in reflecting their progress, based on their answers, and more rewards become available for the children as they accelerate through each section.

Fun Time Activity 3: Matching Emotions

Matching Emotions game works also on improving children with ASD abilities to distinguish between varieties of emotions in a different way. The Matching Emotions game was developed in Ying to test the differences in knowledge of different emotions in patients with ASD, by using their own images. The contribution behind this game is to work on one of the evidenced difficulties for children with ASD, which is to interpret social cues and understand different emotions in other people. This game promises to make children with ASD able to differentiate emotions through their own images. The Matching Emotions game asks children to choose an image for themselves that copies the shown emotion (happiness, sadness, fear, anger, surprise, neutral, disgust or contempt). Then, Ying analyzes this image to determine their occupied emotions, regardless of whether they are correct or not. These eight different emotions are calculated and determined, cross-

culturally, and at the same time, universally, through the same basic known facial expressions, which are determined by Emotion API [60].

Fun Time Activity 4: Show Me Faces

Show Me Faces Activity is considered to be the core activity in Ying for teaching patients with ASD different emotions through their own images. As we discussed previously, patients diagnosed with ASD have evidenced difficulties in interpreting social cues and understanding different emotions for the other people; therefore, this game comes to avoid and reduce this symptom. Unlike other studies, and based on scientific literature, this game promises to yield highly-efficient benefits that lead users to practice and express their different emotions through their phones' cameras. The Show Me Faces game depends on the Microsoft Emotion API packages, which takes an image as an input, and analyzes this image to specify their emotions. The set of emotions which can be detected through these packages are happiness, sadness, fear, anger, surprise, neutral, disgust or contempt. These eight different emotions are calculated and determined, cross-culturally, and at the same time, universally, through the same basic known facial expressions, which are determined by the Emotion API [60].

5.2.3 Schedule

The Schedule module aims to increase ASD patients' independence and enhance their ability to manage their anxiety. Using visual schedules with individuals with ASD provides many benefits, which have been proven by many researches and studies, such as preventing them from acting out and doing unexpected things [44]. Ying consists of a set of the main daily life activities that are divided into three categories (morning, afternoon, and evening routine). These activities can be assigned, and change according to therapist

or caretaker feedback, which can be taken through the Evaluation module. Patients can check off the completed activities, which leads to earning more points, in order to get rewards. This module plays a big role, which affects their progress and will be explained later in the Progress module.

5.2.4 Rewards

This module has been changed, completely, to consist of a variety of rewards, which encourages patients with ASD to be more active with the system. Three types of rewards are available for users, which are Movie Time, Music Time, and Drawing Time. Instead of encouraging them to eat a chocolate, which could be unhealthy, or just telling them to play without giving them some actual toys, which may be unavailable to some families, this version of Ying carefully-selected varieties of rewards, which have proven its efficiency in many studies [61][62]. "Music therapy is a health profession in which a music therapist uses music and its facets – physical, emotional, mental, social, aesthetic, and spiritual, to help patients improve and maintain their health" [63]. Art therapy has proven its efficiency as a beneficial treatment approach that is used with patients who have been diagnosed with Autism Spectrum Disorder [64], and because of that reason, the Drawing activity was added within this module, in order to reach the goals of this study. This module is connected and related to all other activities, which depend on the users' progress, so more rewards become available to them when their progress improves. Multiple music and short movies have been selected to serve these goals.

5.2.5 Progress

Figure 5-5: Progress Module

This module was suggested to be in the previous version, but did not apply because of the time limitation. Now, the Progress Module, as shown in Figure 5.5, has been applied and shows the child's progress through a flowchart, based on his or her performance in the Learn Fun Time, and Schedule modules. A child earns more points when he or she practices more in the Learn module, plays the Fun Time module' games, and completes his or her daily life activities in the Schedule module. The important thing is that this module information can be available for therapists and caretakers, in order to keep track of a patient's progress.

5.2.6 Evaluation

The Evaluation Module was suggested as future work in the previous version, and has been developed here to be a brief questionnaire collected from the users. The Evaluation Module contains a brief questionnaire that is to be used to rate the application and evolve this system in the future. This module has another significant purpose, which is used as a contact tool between the patients and their therapists, in order to adjust this system's

contents, by adding or removing features from the system, in order to reach the highest benefits for this system.

CHAPTER 6: YING SYSTEM IMPLEMENTATION

The implementation of this version of the system is going to be discussed in this section in more detail. Therefore, this section focuses on the detailed architectural overview of the Ying system, the main features and components used within this system, and an analysis of the collected data and related methods.

6.1 Implementation
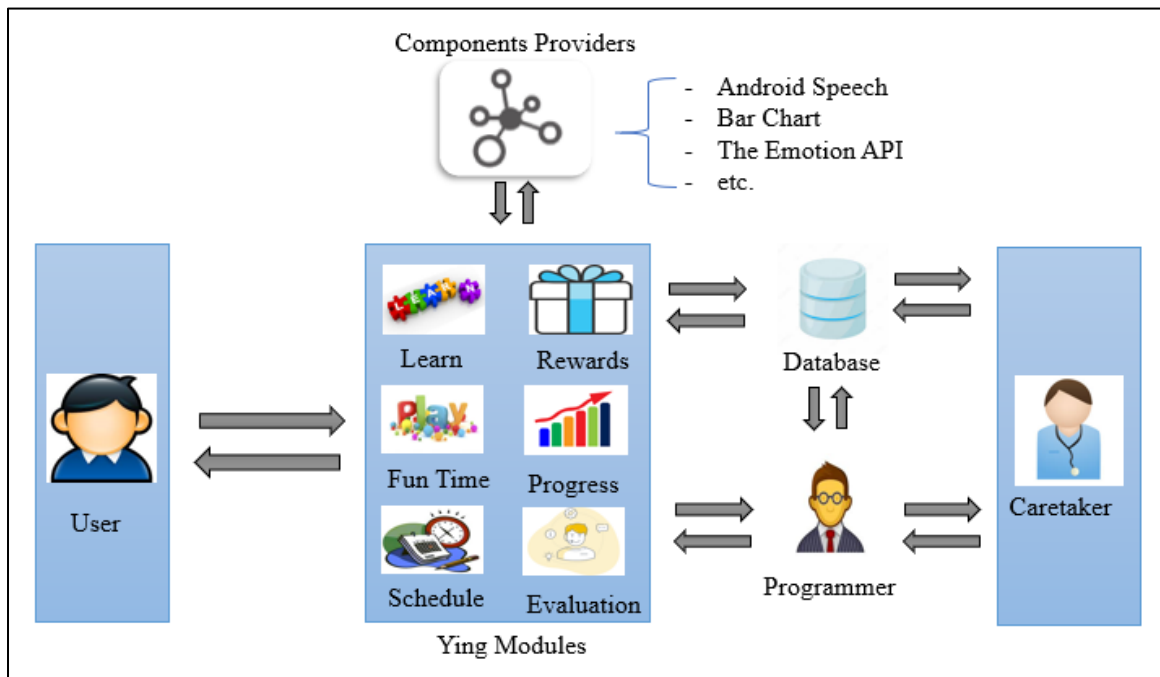
Figure 6-1: A High-Level Overview of the Ying System Showing the Implementation and System Modules (in the Middle) Supplied by Different Components (such as Android Speech), Caretakers' (e.g., Therapists) Progress Monitoring, and How the Programmer Develops and Sets Up the System, based on Caretakers' Feedback and Collected Evaluations

Figure 6.1 shows a high-level architectural overview of the new version of Ying system.

This Figure explains the conceptual model of Ying that defines its structure, behavior, and

more general views of the system. The user (e.g., a child) utilizes the Ying application, which is composed of six modules supported by a variety of components and services, such as Microsoft Cognitive Emotion API and Android Speech, that provide its functionalities, which will be explained in the next sections in more detail. Ying's programmer and users' caretakers stand hand-by-hand through the Evaluation module, in order to keep tracking their patients' progress and to evolve the system. Ying is supported by a local SQLite database to easily store and retrieve the users' information on their Android devices, which uses the SQLite.NET library. Ying's system has been developed to be a free mobile application, available on Google Play store for any person who has an Android smartphone.

6.2 Main Components

6.2.1 Android Speech

Developing an application that interprets the user's speech and pronounces what is being typed (e.g., Speech to Text and Text to Speech) is a new era within mobile development, as requests for programs which provide these services rise. There are many useful applications where having a component that converts a text into speech or speech into text, is considered as a very helpful feature to incorporate into our mobile applications. For example, speech recognition technology comes to decrease the total number of accidents, which are caused by texting while driving, so it helps drivers to be hands free while driving [65]. In our case here with Ying, this component has been used to enable the children diagnosed with ASD to improve their verbal skills in multiple activities, such as Flashcards and Story Teller, which will be explained in more detail in the following sections.

Ying's system is augmented by a set of APIs in the "Android.Speech" namespace, as shown in Figure 6.2, that are supplied by Google, which enables Ying to understand most

instances of making a device "speech aware". The namespace has the feature that enables

text to be translated into speech, by using "Android.Speech.Tts", control within the engine,

which is used to give the correct translation, and it also has a number of

"RecognizerIntents" that convert speech to text. On the other hand, the translation process

provided by this component has some limitations, based on the hardware used. This

component will be mentioned within the modules which they use and are based upon [65].
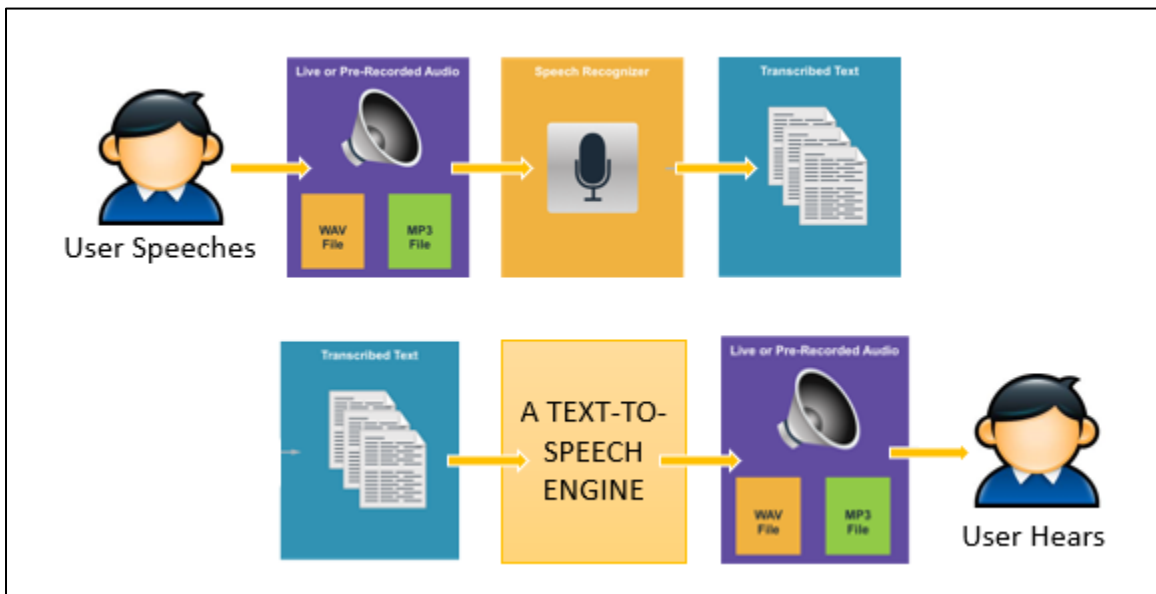
Figure 6-2: Android Speech Component Process which Enables Text To Be Translated
Into Speech or Speech to Text [65]

6.2.2 Bar Chart

Figure 6-3: Progress Module Shows Users' Progress on an Interactive Bar Chart

This important component, which is shown in Figure 6.3, has been used in the Progress

module that enables Ying's users to easily display their progress on an interactive bar chart.

The Database is considered to be the information source for the Bar Chart component,

which reflects the progress of the users. For the Learn, Fun Time, and Schedule modules,

points collected from each activity will be based upon multiple factors, such as consumed

time, number of attempts, and correct answers, which are stored in Database, and are then

reflected on the bar chart within the Progress module.

6.2.3 The Emotion API

The Microsoft Emotion API is what Ying mainly depends on. The Emotion API allows us

to build this effective system through Microsoft's cloud-based emotion recognition

algorithm. The Microsoft Emotion API packages as we explained previously in Chapter 5

take an image as an input (a child' picture in Ying), and analyze this image to specify the

emotions for the face in the image. The set of emotions that can be detected through these

packages are happiness, contempt, surprise, disgust, fear, sadness, anger or neutral, and the

returned results from this component for us is shown in Figure 6.4. These eight different emotions are determined, cross-culturally, and universally through the same known facial expressions, which is determined by its algorithms [60] [66].

As we know, patients diagnosed with ASD have multiple difficulties. One of these difficulties is interpreting social cues and understanding different emotions. Unlike other systems that are used in this industry, the new era of Ying has allowed patients diagnosed with ASD to practice these different emotions on their own pictures instead of showing videos clips or avatars. Practicing different emotions on their own pictures increases the efficiency of Ying's systems.

Figure 6-4: The Set of Emotions which Can Be Detected by The Emotion API [66]

6.3 Modules

This version of Ying is composed of 6 modules. These modules are Learn, Fun Time, Progress, Rewards, Schedule, and Evaluation. Learn and Fun Time modules are considered the core of this system. The other 4 modules (Progress, Rewards, Schedule, and Evaluation) depend on the core. Each one of these modules consists of multiple activities, which cooperates to achieve this system goals. The modules mainly enhance verbal and social

communication skills for patients diagnosed with ASD. The implementation for each module will be explained in the following section.

6.3.1 Learn

Figure 6-5: Learn Module Activities (in The Middle) Supplied by Different Components (such as Android Speech), Caretakers (e.g., Therapists) Progress Monitoring, and How the Programmer Develops and Sets Up the System, Based on Caretakers' Feedback and Collected Evaluations

Children diagnosed with ASD are provided the necessary knowledge through this module that will be tested later in the Fun Time module. This module consists of five different activities, shown in Figure 6.5, which are Flashcards, Story Teller, Eye Gaze, Spell it, and How I Feel. The Learn Module aims to enhance the verbal and communication skills for children diagnosed with ASD. Each one of these activities has goals in order to achieve the objectives of this system.

The Flashcards activity allows users to hear the pronunciation of the shown word stored in the system, see its related picture, and see the correct spelling at the same time. This activity

depends on the Android Speech component, which was described earlier in this chapter. Moreover, Story Teller activity consists of multiple stories that use voice, different facial expressions, and body movements to make these stories more meaningful stories and come alive. Android Speech is one of the main required components to implement the Story Teller activity. Because children with ASD have difficulties with keeping eye contact, Eye Gaze activity comes to reduce how often the child's eyes wander while focusing on an activity. Users face multiple levels of difficulties within this activity to earn more points to get rewards. The shown videos in Eye Gaze are stored in the Database and shown through their URI. The Spell It activity is another activity in this module that gives users the chance to learn the spelling of what they learned in the Flashcards activity, by asking them to spell the shown pictures and hear from Ying. How I Feel is an important activity augmented with an emotions recognition approach that uses children's own pictures, instead, of using cartoons or video clips, in order to teach them different emotions.

The programmer of this system and caretakers or therapists keep watching the progress of the children, based on earned points, which are stored in the database. Based on collected evaluations through the Evaluation and therapist' feedback, the Learn module could be adjusted and changed into future versions available for users.
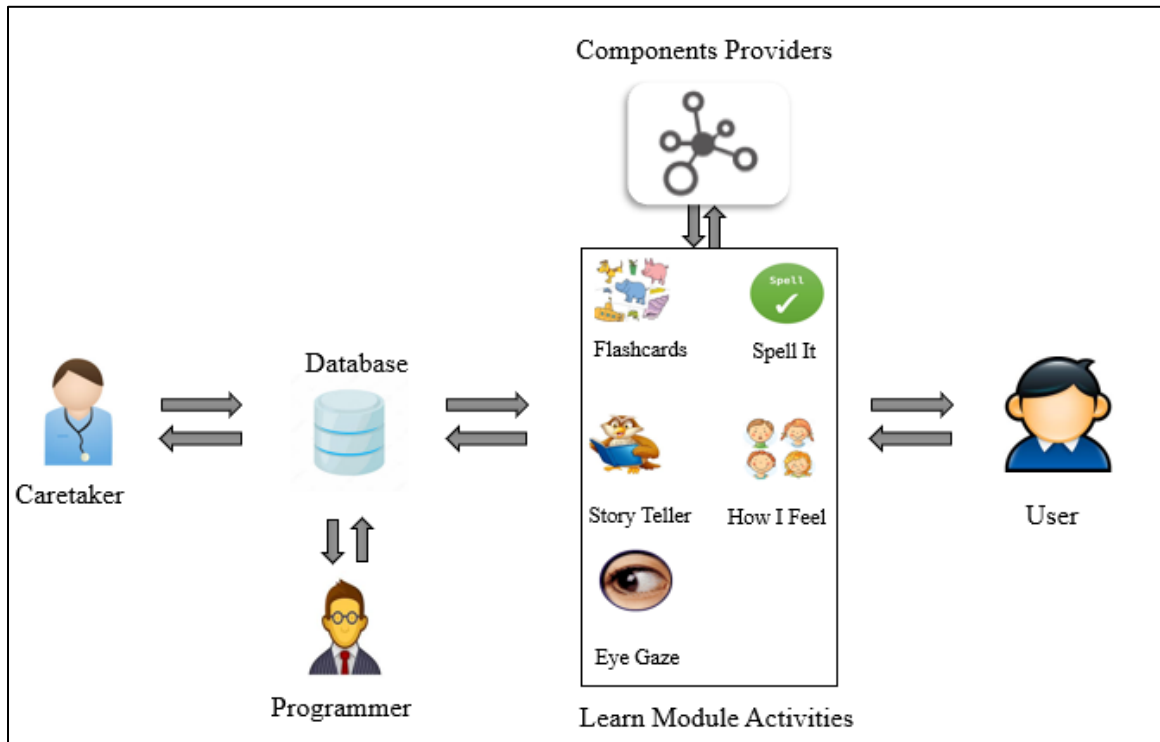
6.3.2 Fun Time
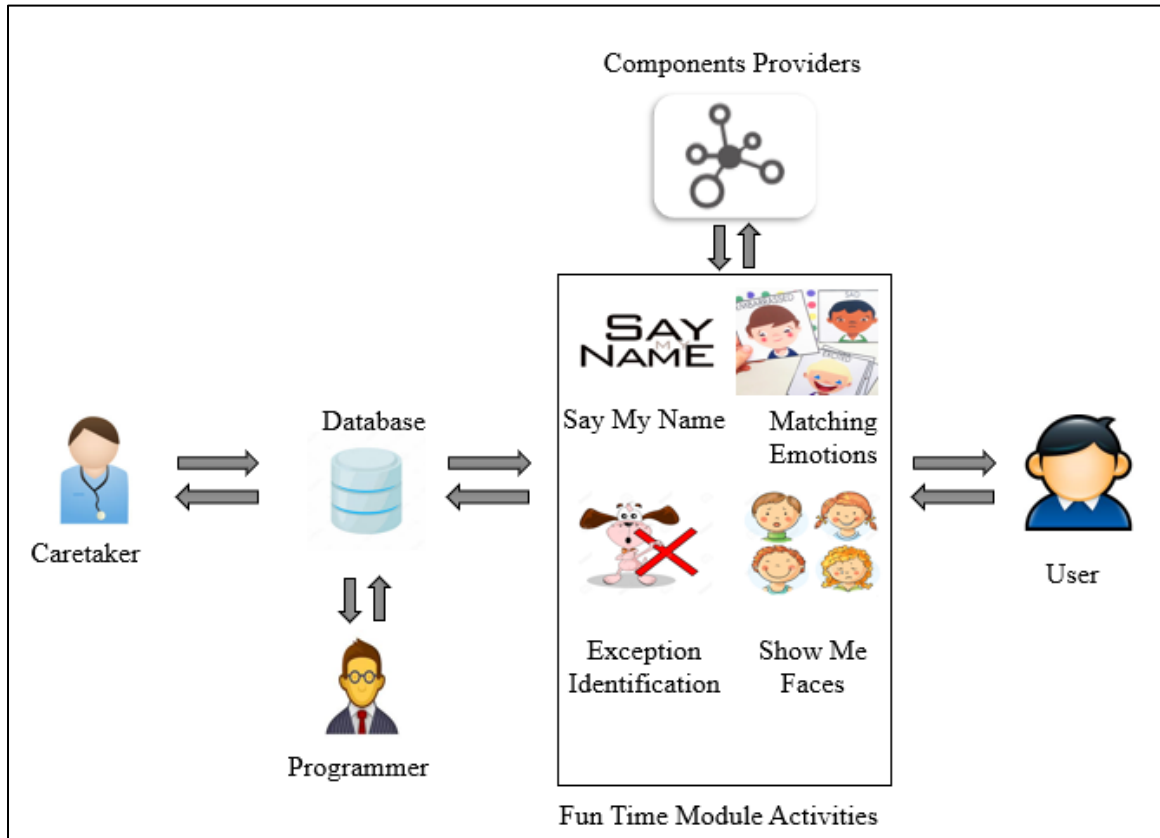
Figure 6-6: Fun Time Module Activities (in the middle) Supplied by Different
Components (such as Android Speech), Caretakers' (e.g., Therapists) Progress
Monitoring, and How the Programmer Develops and Sets Up the System, Based on
Caretakers' Feedback and Collected Evaluations

Multiple educable games, shown in Figure 6.6, are available in this module for children

diagnosed with ASD, which makes sure to obtain the targeted skills provided through the

Learn module. It mainly tests the verbal and the communication skills for the children, and

measures their progress through four games, which are Say My Name, Exception

Identification, Matching Emotions, and Show Me Faces.

Say My Name teaches the users Flashcard's pronunciations and challenges them to

pronounce the display images correctly, in order to earn more points to get rewards.

Android Speech is the core component that is used to implement this game. The Exception

Identification game emphasizes increasing abilities for children with ASD to interpret social cues and differentiate emotions of the other. Matching Emotions is another game that promises one of the main contributions for this study, which improves the skills of children with Autism Spectrum Disorders. Show Me Faces focuses on enhancing the communication skills of the patients, through teaching them different emotions through their own images, so they practice the different emotions on themselves. The Microsoft Emotion API component is what is relied on to develop this game that asks the children to take a picture for themselves or for their families members for a certain emotion, such as happiness, surprise, sadness, anger, disgust, contempt, fear or neutral.

More games and additional contents and levels can be applied by the programmer of this system and can be based on caretakers or therapists' suggestions, in order to provide better and useful games for users. The database stores users' points, which are earned after playing these games and reflect their progress in Progress module.

6.3.3 Schedule
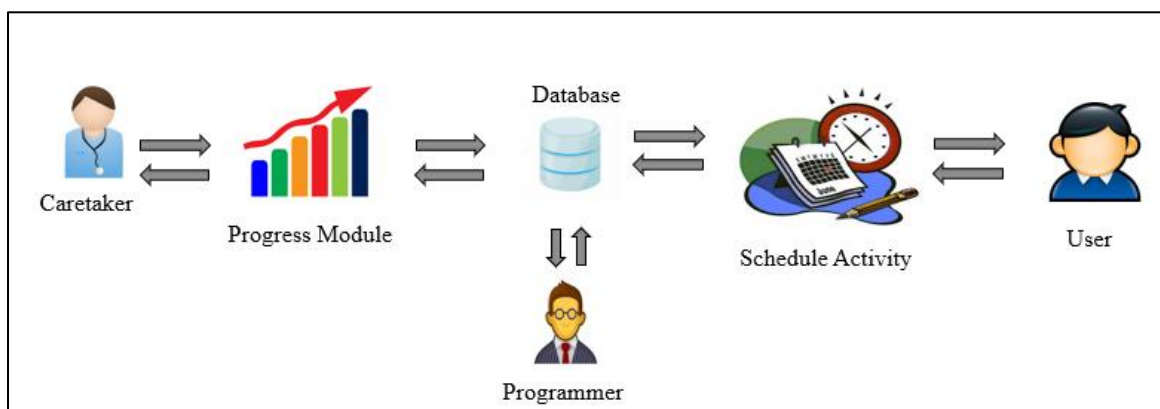
Figure 6-7: Schedule Module Contains Morning, Afternoon, and Evening Routine; Users Can Check Off Completed Tasks which Reflect Their Progress that Can be Seen By

69

Their Caretakers, The Programmer Changes Different Tasks According To Caretakers' Feedbacks

The Schedule module helps patients with ASD to increase their independence, manage their anxiety, organize themselves, and reduce their unexpected behaviors. In this module, children can see and check off their completed daily main activities, which encourages them to do it and organize themselves. This module consists of a set of some main daily life activities, which are divided into three categories, shown in Figure 6.8, which are morning, afternoon, and evening routine. The user can check off the completed activities and five points will be earned upon completing each activity, which lets them to get more rewards. This module plays a big role to in showing the Progress module, which will be explained later in this chapter.
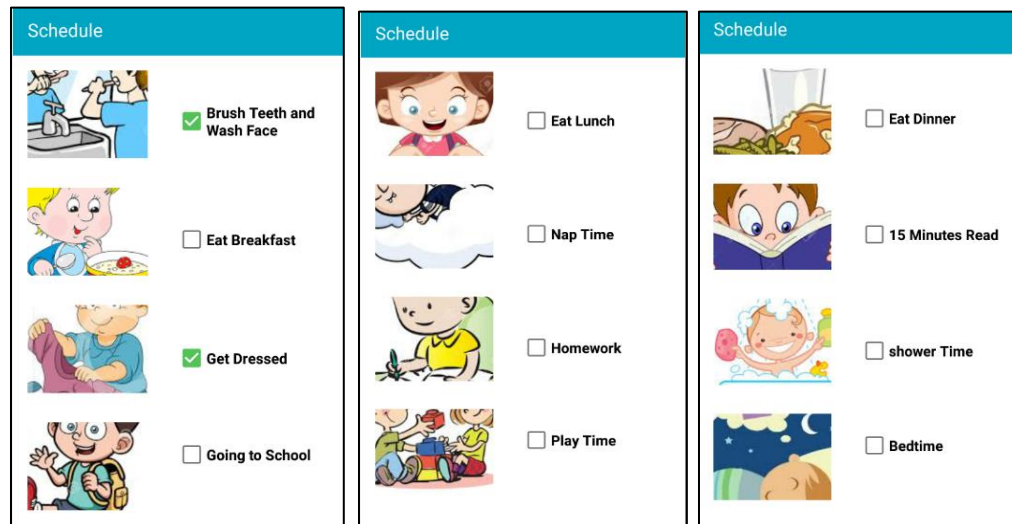
Figure 6-8: Morning (on the Left), Afternoon (on the Middle), And Evening Routine Activities (on the Right)

These activities, shown in Figure 6.7, can be modified by the programmer according to therapist or caretaker's feedback, which can be taken through the Evaluation module. The therapist can specify the appropriate activities in this module for each user, which will be programmed by this system's programmer later. Patients also can share in this process, by

suggesting the required activities to be added that might be difficult for their children to do, so adding it encourages them to do it.

6.3.4 Rewards
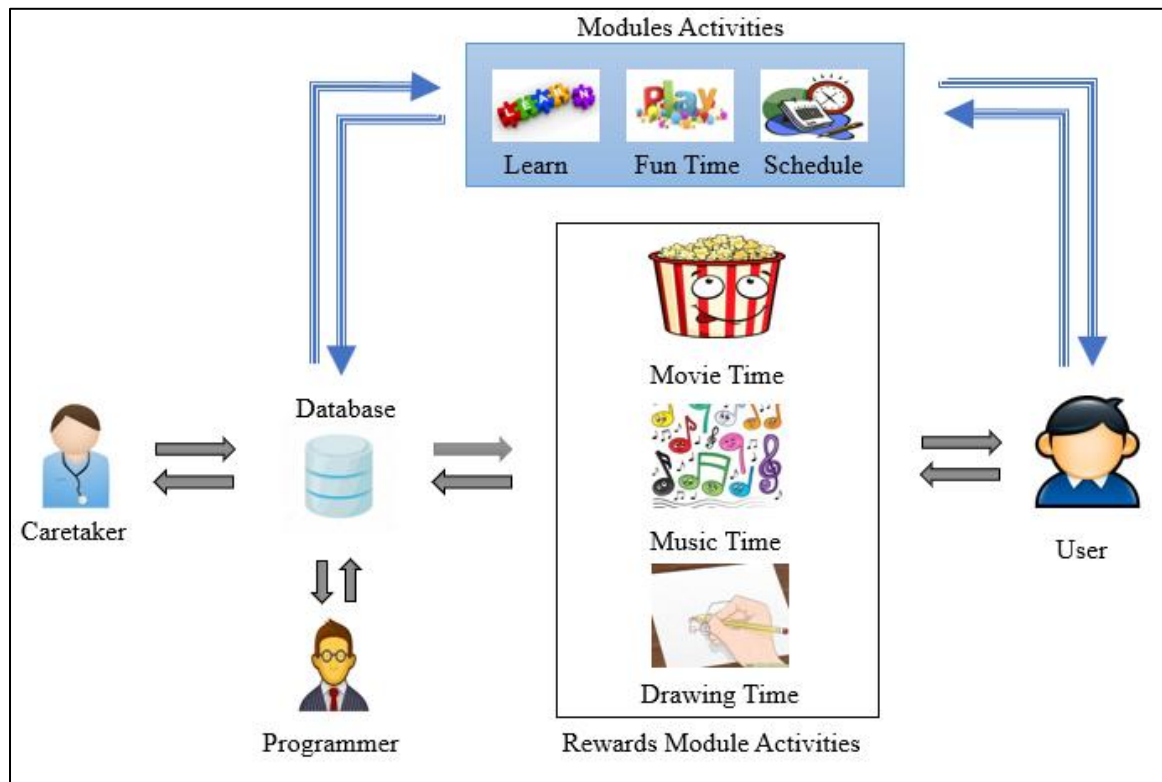
Figure 6-9: Rewards Activities (in the middle) Available to Users Based on their Progress in Learn, Fun Time, and Schedule Modules; Caretakers with the Programmer Set up This Module Contents

Based on the patients' progress, a list of the rewards shown to them in this module, which encourages patients with ASD to be more active with the system. As shown in Figure 6.9, three types of rewards are available for the patients, which are Movie Time, Music Time, and Drawing Time. As we discussed in chapter five, the contents of this module selected, based on many studies, which have proven its efficiency [61][62]. Music therapy and Art therapy have proven their efficiency as a beneficial treatments approach, which used with patients who diagnosed with autism spectrum disorder [63][64].

The other five modules (Learn, Fun Time, Schedule, Progress, and Evaluation) determine how long users can enjoy these rewards, and become enabled or disenabled, so collecting more points and having high progress keeps these rewards remains available for them with more music and movies. Multiple music and short movies have been selected to serve this module's goals. Therapists' and users' evaluations can determine future contents of this module by the programmer.

6.3.5 Progress
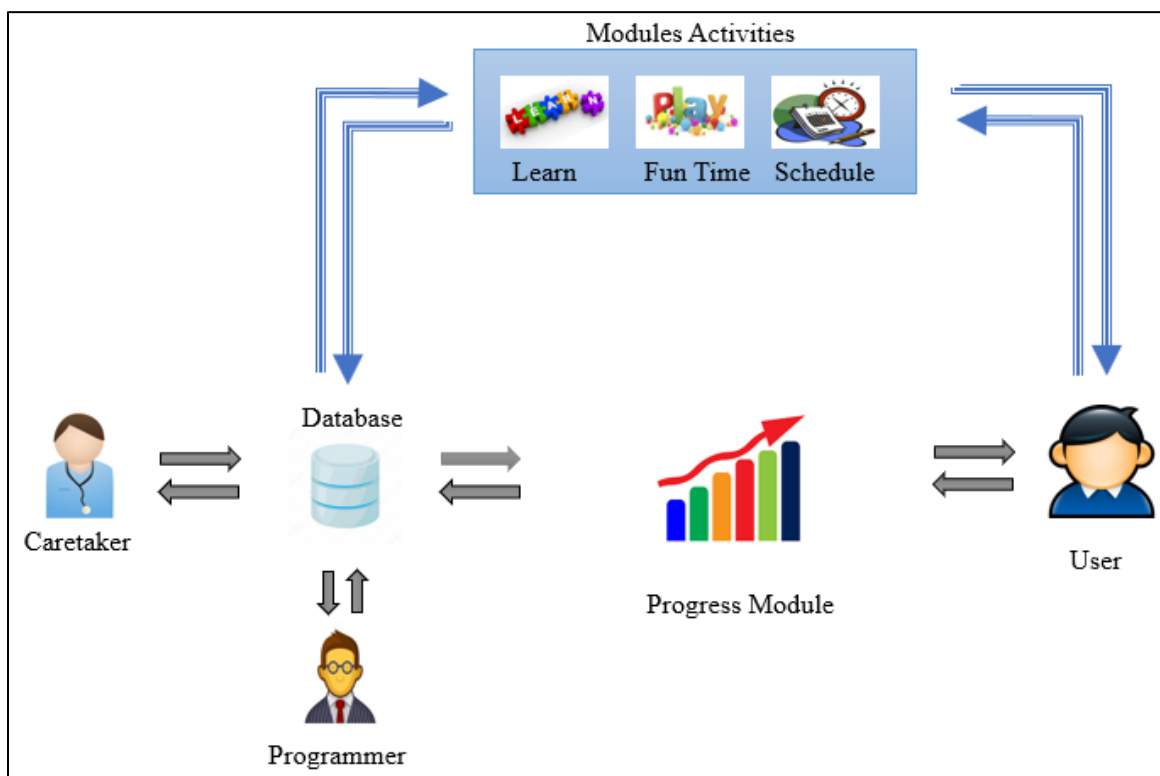
Figure 6-10: Progress Module Reflects Patients' Progress Based on the Activities of Learn, Fun Time, and Schedule Modules

The progress of the patients shown in this module, is based on multiple factors determined by therapists and the programmer. Parents and their children's caretakers, as shown in Figure 6.11, can see the progress based their activities in Learn, Fun Time modules, and Schedule, and having better progress can happen when:

- Practices more in Learn module.

- Plays more Fun Time module's games.

- Answers correctly in the activities.

- Quickly responding in different activities.

- Completing the daily life activities in the Schedule module.

- Getting more points.
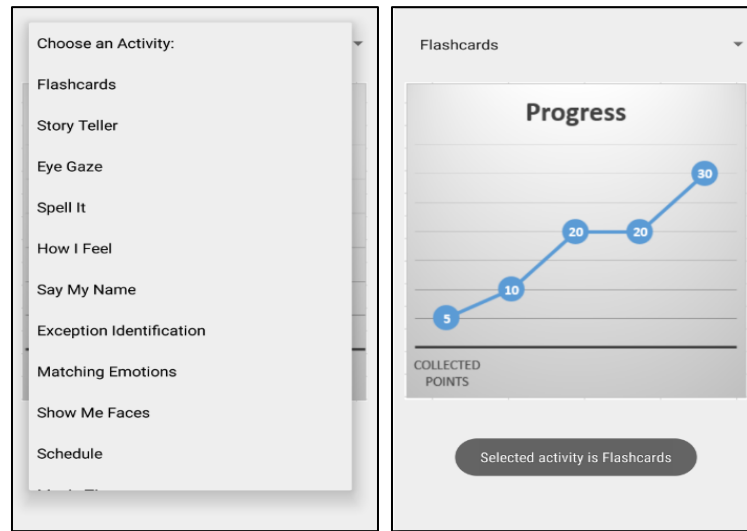
Figure 6-11: Parents and Their Children's Caretakers Can See the Progress for Their Patients Based on Collected Points

The Progress Module has been implemented by using the Bar Chart component, which is explained in the previous chapter. This module's information, shown in Figure 6.10, is stored in the database that can be available for therapists and caretakers, in order to keep track of a patient's progress.

6.3.6 Evaluation
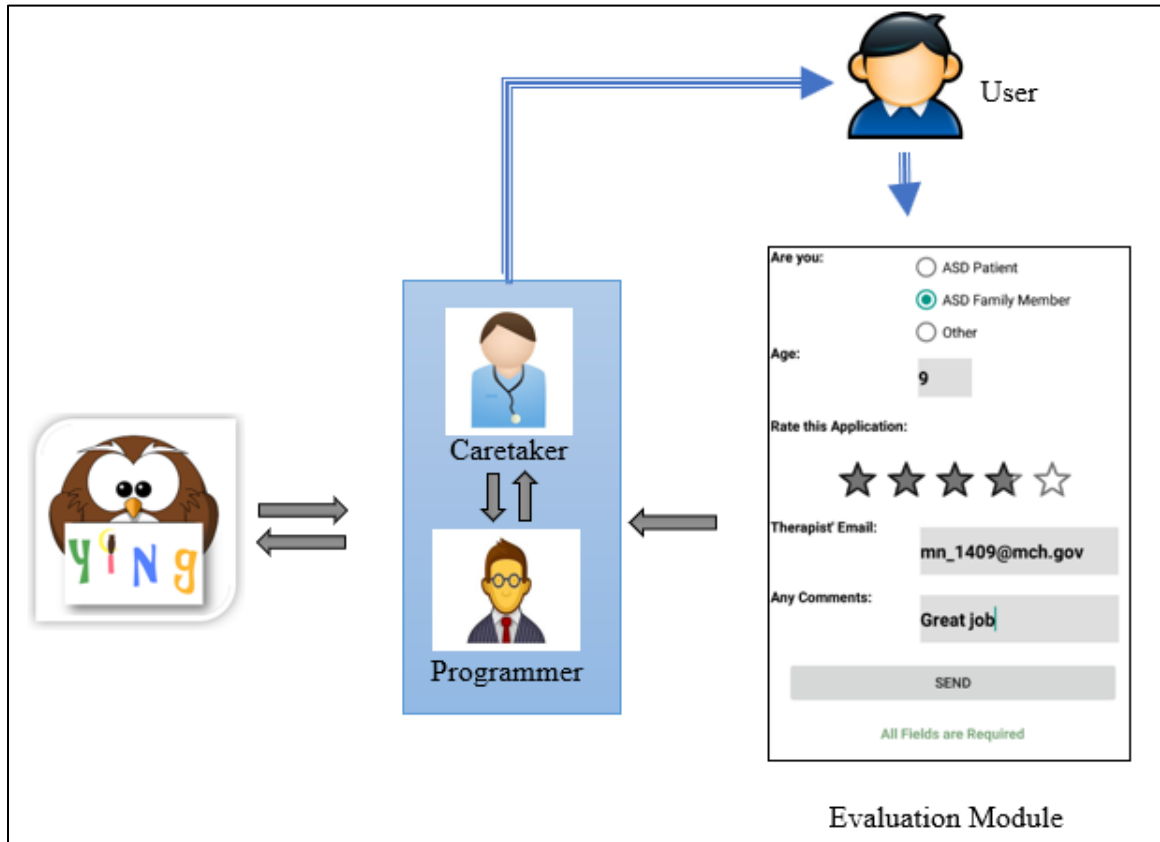
Figure 6-12: Evaluation Module Collects Questionnaires from Users' Parents for Evaluate the System, and Sends its Contents to the Caretakers and the Programmer

The Evaluation Module, shown in Figure 6.12, is considered as a way that is used to communicate between the caretakers, the patients' families, and the programmer. Moreover, this module allows users to evaluate the system, in order to evolve this application to meet the needs of children, based on their progress and needs. This module contains a brief questionnaire, collected by parents and sent to the programmer and caretakers, to achieve its goals.

This module classifies the users: whether they are patients diagnosed with ASD, ASD family's members, or other users, which is used for statistical studies by therapies, and the users age is also collected for the same purpose. The Rating bar is another important component which is contained within this module to reflect the users' rating about this

system. The users are required to type their therapist's email, in order to send a copy for these questionnaires, and any comments could be sent from the users to their caretakers and the programmer. Adjusting and modifying the system's contents can be done through the Evaluation module.

6.4 Platform

Ying can be downloaded from Google Play on any Android phone. Being that Android dominates the market with a whopping 87%, Android is one of the most popular and accessible operating systems in the world [23]. Ying has been designed by using the Xamarin platform, which is a Google-owned, and Microsoft Visual Studio 2017, used also beside Xamarin to develop Ying. This platform was chosen, because it can be used by developers with a C#-shared codebase to develop applications with different platforms, such as Android, iOS, and Windows, which all use native user interfaces, which could be used across multiple platforms, including Windows and macOS. In the future, this system can be easily converted to be an iOS application and more patients would have access and benefit from Ying.

6.5 Ying Activities

The new version of Ying consists of ten different activities, which have varieties of goals, which will discuss its implementation in this section. Four of those activities existed in the previous version (Flashcards, Eye Gaze, Story Teller, and Say My Name), but it has been developed and augmented with more effective approaches and contents. The other six new activities are Spell It, How I Feel, Exception Identification, Matching Emotions, Show Me Faces, and Drawing Time.

6.5.1 Virtual Flashcards

This activity, shown in Figure 6.13, is one of the important Learn Module's activities that provides the children with some necessary vocabulary, in order to build their verbal and communication skills. There were just two main categories after clicking on the Flashcards icon, which are Words, and Phrases. The Words category had limited number of subcategories user can choose from, which are Animals (cat, dog), Emotions (happy, sad), Colors (red, blue), Vehicles (car, bus), and Fruits (orange, banana). Sports flashcards added as a new sixth subcategory under the Words classification (swimming, climbing). The Phrases had two subcategories, which are Pronounce (I, You, He, She, It, We, You, and They) and Verbs (jumping, eating). Gestures flashcards are added as a third subcategory, besides Words and Phrases (Showing Hello, Call Me, Great Job, Me?).

Figure 6-13: Flashcards Activity Main Categories (on the Left), Words Categories (in the Middle), and Phrases Categories (on the Right)

Ying develops and builds verbal communication skills for patients diagnosed with ASD through this activity, by allowing the child to hear the pronunciation of those flashcards

and see its pictures, also. Android Speech component has been used to implement this activity, which allows the system to pronounce flashcards. The children can also learn the spelling of these flashcards at the same time. Five points will be earned each time the users browse flashcards, which reflect their progress. To make sure the efficiency for using this activity, the Fun module's games, such as Say My Name and Show Me Faces examine them what they have learned here in this activity [21]. The therapists can determine new flashcards and categories through the Evaluation module.

6.5.2 Story Teller

This activity, shown in Figure 6.14, belongs to Learn module that voices, different facial expressions, and body movements to make a list of meaningful that are better, and therefore, come alive. Showing children with ASD the facial expressions, and verbal and nonverbal communication through stories has been proven its efficiency in many studies [55]. The users can learn varieties of things through this activity' stories, such as emotions and doing some basic daily life essentials. The main emotions are focused on here are anger, fear, disgust, contempt, joy, sadness, and surprise [13][55] [56]. Varieties of stories are added, based on Autism Parenting Magazine, which are carefully-selected not just for emotion recognition, but also have varieties of benefits, such as teaching them the basic daily life essentials, such as dressing, greeting, and eating. [57]. Android Speech is the essential component that has been used to implement this activity. The users can enjoy hearing and seeing some relevant pictures for those stories, which are divided into sentences, and the users can use the Next button to move on to the next parts.
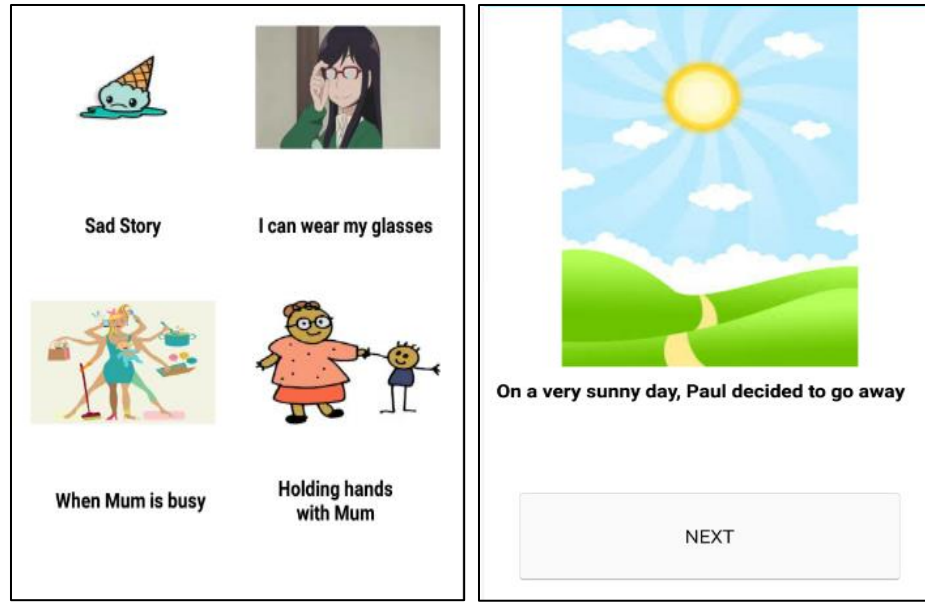
Figure 6-14: Story Teller Activity Show Varieties of Stories (on the Left), An Emotional Story Shown (on the Right)

6.5.3 Eye Gaze

As we explained previously that children with ASD have difficulties with keeping eye contact while they communicate with others and they usually focus at mouth [58]. Because of that symptom, they miss some social cues and have difficulties to understand other people. Eye Gaze activity comes to reduce this significant symptom of autism (e.g., missing eye contact) [21][22].

Figure 6-15: Eye Gaze Activity

This activity is developed to be composed of multiple levels with different levels of difficulty, based on short video clips shown in the middle surrounded by multiple objects. The users are supposed to choose one of the surrounded objects, based on that video, as shown in Figure 6.15. The first level aims to test the children vocabulary, which learned in the Flashcards activity, and user is supposed to select the object at which the person is looking. The next level shows a certain emotion (disgust, fear, anger, contempt, surprise, sadness, and joy), and the user has to select the correct emotion within the four images that reflects the actor's emotion. The difficulty level increases as the user goes to through the following levels.

6.5.4 Spell It

Spell It activity has developed as a new activity to help users with learning disabilities to make their spelling better. The important thing is that to address this issue with our children, in order to work on it, that because poor spelling leads to a hampering in writing, the content of the writing is excellent. Ying, as shown in Figure 6.16, gives the users the

chance to learn the right spelling of what learned in the other activities, such as Flashcards activity, by asking them to spell what they see and hear from Ying. The system compares the users answers with what are stored in the database, and tells the users whether their spelling is correct or not. The users can collect five points when they type the correct answers in the first attempt, or the collected points are decreased each time the spelling is wrong. This activity considered as an important activity that affects and reflects on the users' progress and the rewards, based on these collected points.

Figure 6-16: Spell It Activity Asks the Users to Spell what Shown, and Tells the Users if that the Correct Spelling (the left case) or they Asked to Try Again (the right case)

6.5.5 How I Feel

How I Feel activity aims to help children with ASD who have evidenced difficulties in interpreting social cues and understanding different emotions of others. How I Feel focuses on developing emotions for patients diagnosed with ASD, which asks the children to choose any picture from their gallery, for them or for their families' members, to be processed by Microsoft Emotion API packages that determine their emotions (e.g.,

happiness, anger, fear, contempt, disgust, sadness, surprise, or neutral). In this activity, as shown in Figure 6.17, Microsoft Emotion API as we explained previously tries to use ASD children' own pictures to teach them different emotions. How I Feel uses parameters from ASD children' own lives, which promises effective results.
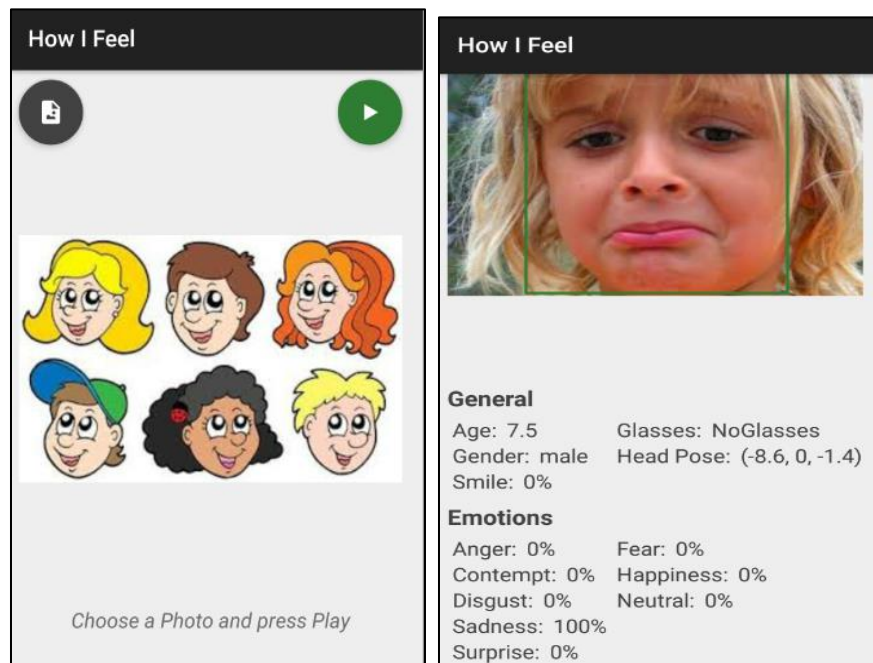
Figure 6-17: How I Feel Homepage (on the Left), and the Return Results (on the Right)

6.5.6 Say My Name

This game is similar to the previous version, which mainly focus on teaching and testing the children the correct pronunciation of the Flashcards vocabulary. This version of game, as shown in Figure 6.18, has varieties of vocabulary that have been chosen from different categories, which considered as important vocabulary to be learned. Android Speech has been used to develop Say My Name game, that challenges the users to pronounce the showing in display correctly, in order to enhance their verbal and communication skills. Android Speech recognizes the human speech and converts it to a text, which will be compared with what are stored in the database. Say My Name is also used to earn more

points to get more rewards. Saying the correct pronunciation in the first attempt leads to get more points, and pronounce the more difficult vocabulary also leads to collect more points and thus better progress.

Figure 6-18: Say My Name Activity Asks Users to Say What Shown in the Picture

6.5.7 Exception Identification

Exception Identification, shown in Figure 6.19, is a game available for children with ASD that focuses on increasing their abilities to interpret different social cues and understand different emotions of others. Exception Identification game is developed to help autistic children to differentiate between different emotions. This game tests children eight different emotions (happiness, anger, fear, contempt, disgust, sadness, surprise, and neutral) through showing five images have the same emotion, beside one image has a different emotion. The children must identify the emotion, which is not the same, in order to win this turn and move to the next level and to earn more points and rewards. Android Speech and stored images in the database are the essential components behind developing this game to retrieves a selection of images randomly each turn. The therapists and the

programmer can adjust the contents of this game, based on their progress in the Progress

module.

Figure 6-19: Exception Identification Game Tests the Children to Figure out the
Exception Emotion (Anger is the Correct Answer here)

6.5.8 Matching Emotions
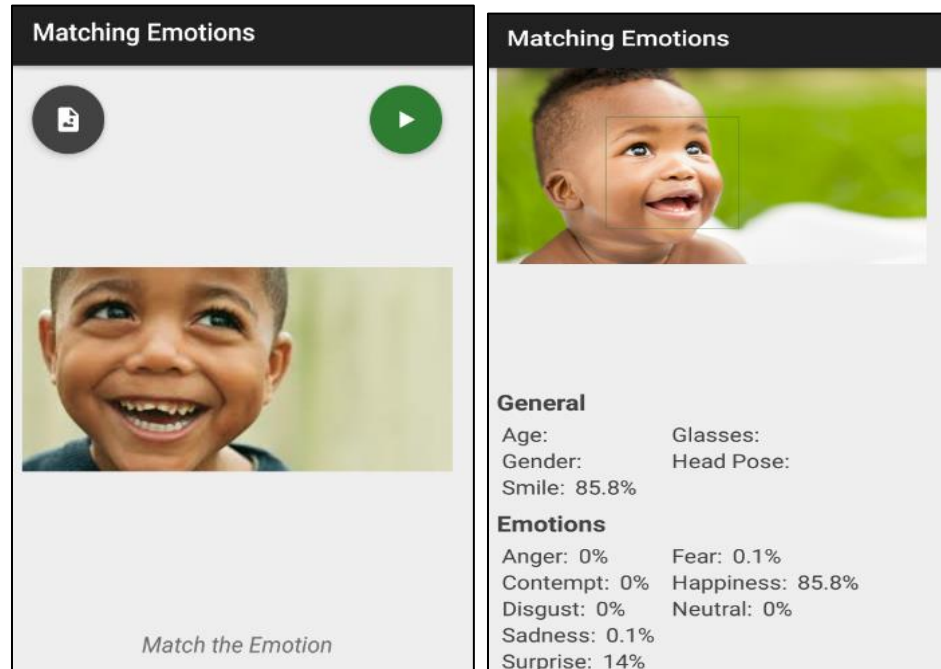
Figure 6-20: Matching Emotion Page Asks Users to Choose an Image for a Certain
Shown Emotion (on the Left), and Results for Analyzing the Image (on the Right)

Matching Emotions game has developed in Ying, as shown in Figure 6.20, in order to
improve children with ASD abilities to distinguish between varieties of emotions and test
their knowledge of different emotions, by using use parameters from ASD children' own
lives. The goal for this game is to work on one of the evidenced difficulties for children
with ASD, in order to get better social cues interpreting and understand different emotions
for the others. Children have to choose an image, for themselves or for their families'
members (from their phones' gallery), that copies the shown emotion (happiness, sadness,
fear, anger, surprise, neutral, disgust or contempt). The Microsoft Emotion API packages
takes their images as an input, and analysis these images to specify the emotions for each
face in the image. Ying then determines whether they expressed the correct emotion or not,
based on the return results of the Microsoft Emotion API. As we mentioned previously that

eight different emotions are calculated and determined, cross-culturally, by the Microsoft Emotion API.

6.5.9 Show Me Faces
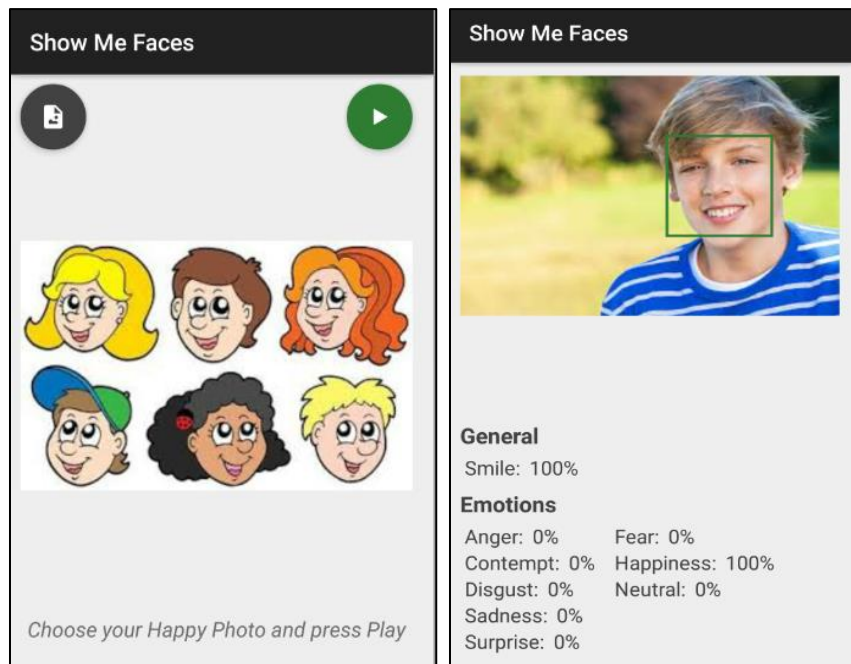
Figure 6-21: Show Me Faces Game Asks Patients to Show Each Emotion Separately

Patients diagnosed with ASD have evidenced difficulties in interpreting social cues and understanding different emotions for the other people as we explained previously in Chapter 2, therefore this game comes to avoid and reduce this particular symptom. This game considered as the core activity that was not exist previously, which teaches patients with ASD different emotions through their own images. This game promises to yield highly-efficient benefits, which lets the users to practice and express their different emotions through their own images by their phones' cameras. The scenario for this game, shown in Figure 6.22, is mainly asks the child to take a picture for his or her happy face or for one of the other emotions. Then, Show Me Faces game that depends on the Microsoft Emotion API packages, takes the image as an input, and analysis this image to specify the

emotions for each face in the image. The result returned to Ying, which consist percentages for each emotion, and Ying decides whether the child has shown the right emotion or not. The set of emotions which can be detected through this library are happiness, sadness, contempt, disgust, fear, surprise, anger or neutral, and those emotions have been explained previously in Learn module. These eight different emotions are determined, cross-culturally, and also universally through the same basic known facial expressions, which are determined by Emotion API [60]. Like the other activities, this game also affects on the progress of the users and on the available rewards.
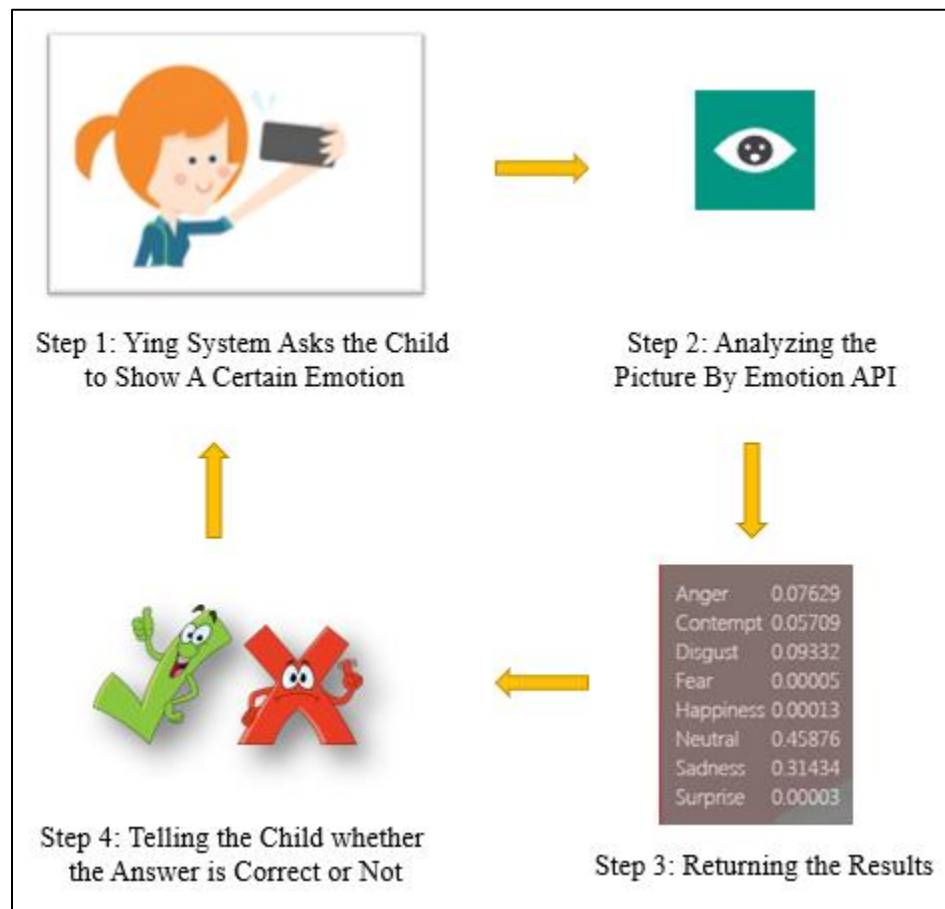
Figure 6-22: The Scenario for Show Me Faces Activity Which Consists of Four Steps

6.5.10 Drawing Time

Figure 6-23: Drawing Time Activity Incorporates Art Therapy

Drawing Time, shown in Figure 6.23, is one of the three rewards that is available to the children beside Movie and Music Time rewards. Because Art therapy has been proven its efficiency as a beneficial treatment approach, which is used with patients who diagnosed with autism spectrum disorder [64], this reward is added within Ying, in order to express themselves and thus reach the goals of this study. The users are able to choose the color and thickness to draw by their fingers, and of course they can clear the screen to start over. This game is connected and related to all other activities, which depends on the users' progress, so this reward become available to them longer when their progress is improved.

CHAPTER 7: EXPERIMENT AND ANALYSIS

7.1 Experiment

Eight children participated in a primitive experiment that was conducted to determine the value of Ying in autism therapy for children. Different aspects have been taken into consideration in the experiment including: targeted behavior, autism spectrum disorder symptoms, targeted symptoms Ying addresses, and remaining untargeted symptoms that Ying does not address.

Table 7-1: Experiment Data Showing Targeted Behavior and ASD Symptoms

Ying Activity	Participants	Targeted Behavior	Targeted ASD Symptoms
Virtual Flashcards	A 3-year old female	- Developing Verbal Communication	- Delayed language or non-lingual - Repeating words or phrases (e.g., echolalia)
Story Teller	2 male children, aged 4 and 6 years	- Social Communication and Emotions Recognition - Adaptation Skills	- Lack of interest in physical contact

			- Failure to develop friends
Eye Gaze	A 5-year old male	- Social Communication and Emotions Recognition	- Lack of interest in physical contact - Avoids making eye contact with others
Spell It	A 6-year old male	- Developing Verbal Communication	- Delayed language or non-lingual
How I Feel	4 children (3 males and 1 female), aged 3 and 4 years	- Social Communication and Emotions Recognition	- Deficits to develop peer relationships and emotional recognition
Say My Name	3 male children, aged 3 and 5 years	- Developing Verbal Communication	- Delayed language or non-lingual
Exception Identification	2 male children, aged 5 and 6 years	- Social Communication and Emotions Recognition	- Deficits with developing peer relationships and

			emotional recognition
Matching Emotions	2 male children, aged 4 years	- Social Communication and Emotions Recognition	- Deficits to develop peer relationships and emotional recognition
Show Me Faces	5 children (4 male and 1 female), aged between 3 and 5 years	- Social Communication and Emotions Recognition	- Deficits to develop peer relationships and emotional recognition
Schedule	A 6-year old female	- Adaptation Skills	- Avoiding following routines
Movie Time	4 male children aged between 3 and 6 years	- Social Communication and Emotions Recognition - Adaptation Skills	- Deficits to develop peer relationships and emotional recognition
Music Time	A 3-year old male	- Social Communication and Emotions Recognition	- Deficits to develop peer relationships and

			emotional recognition
Drawing Time	3 male children, aged between 2 and 4 years	- Social Communication and Emotions Recognition	- Expressing their needs and feels

The primitive experiment, as shown in Table 7.1, shows the efficiency of Ying, which aims to develop verbal communication skills in children diagnosed with ASD, train children with ASD social communication and emotional recognition, and develop adaptation skills for children diagnosed with ASD. Ying's system targeted avoiding and reducing varieties of ASD symptoms, including delayed language or non-lingual, repeating words or phrases (e.g., echolalia), lack of interest in physical contact, avoids making eye contact with others, failure to develop friends, avoiding following routines, inability with expressing ASD children's' needs and feelings. On the other hand, there are some ASD symptoms that are not addressed with Ying's system, such as repetitive behaviors (child demonstrates repetitive motor movements, such as rocking and hand or finger flapping), preoccupation (usually with lights, moving objects, or parts of objects), dislike for noises, and having rituals (a child may have to touch his favorite toy before going to bed).

7.2 Evaluation

To test the efficacy of Ying, we have conducted a preliminary evaluation of the system Ying among eight children between two to six years old. Seven are male and one is female.

According to [2] male-to-female ratio in autism spectrum disorder is 3:1. So we selected more boys than girls in the evaluation.

The Evaluation process consisted of two parts. The first part is collecting users' response to questionnaires (this portion is done with the help of the parents). 12 questionnaires were collected through the Evaluation module explained earlier which consist of five simple questions:

- Their categories are (Patients diagnosed with ASD, ASD family members, or neither).

- Users ages.

- Rating the application.

- Therapies' Email address for the users.

- Any comments.

The result of the questionnaires shows that the rating of the system is between 3.5 and 5 out of 5.

The second part of the evaluation is observation and monitoring of using Ying. Eight children participated in the evaluation process, seven of them are boys and one is a girl, all are under ago of seven years old. They played with the system between two to four hours. The results received through the primitive evaluation are shows in Figure 7.1. The observation shows that components of Show Me Faces, Movie Time, and Drawing activities are used more frequently than other components. More usage date will be collected upon putting the application available on the Google Play store.
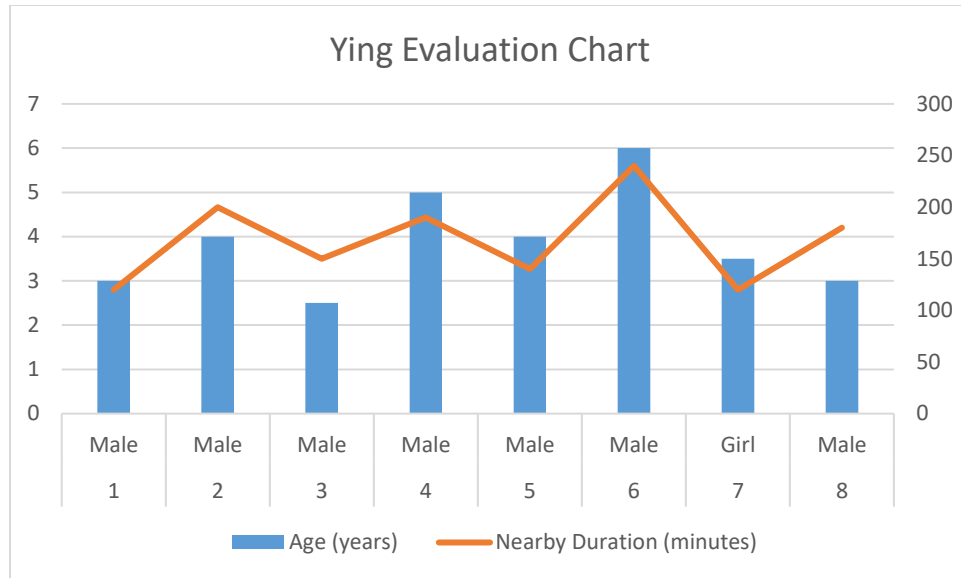
Figure 7-1: Ying Evaluation Shows Eight Participants' Genders, Duration, and Ages

CHAPTER 8:CONCLUSION AND FUTURE WORK

8.1 Summary and Research Contribution

Computer-aided technologies have shown effectiveness to enhance ASD children's behavioral and social skills. This thesis presents an interactive, dynamic, and effective application called Ying that integrates different Behavior and Communication Approaches, including facial and emotion recognition, to enhance ASD children's social communication skills and verbal skills.

Ying complements and works hand-in-hand with therapeutic procedures provided by ASD children's patients, their families, and their therapists in order to have better function. Different modules, fun games, and educational activities are added to Ying to function as additional intensive therapy for not only children with autistic in particular, but also for other children who have other difficulties such as delayed speech.

8.2 Ying Limitations

As everyone knows, having limitations encourages software developers, designers and researchers to further develop existing applications to the next level, by using the newest available approaches. Ying's system, like any other application, is also bounded by some of those limitations which will be easily avoided, solved, and further developed in the future. Recognizing the user's facial and emotional expressions through the Emotion API component limits our system's ability to process a limited number of images per month. More comprehensive studies are also needed to investigate and evaluate Ying's system to show its efficiency.

8.3 Future Areas of Development

There is massive potential of future development for this system Ying. The current version has developed for Android phones which dominate the market with a whopping 87%. Developing another version of Ying for iOS operating system is one of the main future areas to reach another 12% mobile markets [23]. Therefore, more patients and children will use this system. Another future work is to support multiple languages which enables more patients to reach Ying's contributions.

There are many ideas related to Facial and Emotion Recognition which we could use in future development. For example, identifying the users through their photos, instead, of using the traditional method to access users' accounts which based on usernames and passwords. Rating the application can be developed in the future to be taken through their photos also based on the Facial and Emotion Recognition approaches instead of using a visual rating bar. Another Emotion Recognition mechanisms which promise better Human-Computer interaction and without limitations can be used in the future. Involving eye tracking into the system is another important area which could monitors the children' eyes capture and record their eye gazes to get better Human-Computer interaction. Adding eye tracking to our system in particular can be used to guide the children in different activities such as giving them hints for the right directions which they should look at it.

More a comprehensive search of psychological and empirical studies on this thesis are also needed to demonstrate its promised contributions and show its efficiency. More systematically examining the feasibility and usefulness for this research is another important part which can be done within the future work to reach better Human-Computer interaction. More games and activities can be added to the application to incorporate more

Behavior and Communication Approaches in order to avoid more side effects for ASD and

have better functions.

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