CodaRoutine: A Serious Game for Introducing Sequential Programming Concepts to Children with Autism

Menna Elshahawy  
Department of Computer Science,  
The German University in Cairo  
Cairo, Egypt  
menna.elshahawy@guc.edu.eg

Khaled Aboelnaga  
Department of Computer Science  
The German University in Cairo  
Cairo, Egypt  
khaled.aboelnaga@student.guc.edu.eg

Nada Sharaf  
Department of Computer Science  
The German University in Cairo  
Cairo, Egypt  
nada.hamed@guc.edu.eg

Abstract—Problem solving, analyzing the validity of a solution and spotting patterns in data are all substantial skills needed in the workplace nowadays not only in the programming field. Solving and generating multiple solutions to a problem is quite challenging for children with autism spectrum disorders. As a solution, the work in this paper presents the design, implementation and the evaluation of a serious game that focuses on the sequential programming concepts. The presented game aims to teach problem solving skills to children with autism. A user-study was conducted to evaluate the game with children who have autism. According to the evaluation carried out in this research, the game was proven to be engaging, which indicates that the serious game is promising for teaching sequential programming concepts to children with autism.

Index Terms—Problem solving, Children, Serious games (SG), Autism Spectrum Disorders (ASD), Computational thinking (CT), Sequential Programming

I. INTRODUCTION

Computational thinking (CT) is a term which was introduced first by Seymour Papert in 1980 [1] and readdressed by Wing in 2006 [2], can be defined as a set of problem solving processes. CT is not only about using computer science or typing lines of code, it is a way of thinking in which one can solve problems by breaking down the problem and performing several steps. CT is considered deeply essential as a method to approach complex problems in a systematic and effective way [3]. CT is also argued to be a crucial skill for this century in the workplace as well as in educational settings [4]. Thus, CT should be integrated in our educational systems and taught to everyone, including people with special needs such as autism spectrum disorders (ASD).

Often students with ASD lack problem solving skills, which can severely affect their interactions with others [5]. Thus, teaching children with ASD problem solving skills could help them resolve conflicts that may happen in their everyday life. Effective problem solving skill is critical for academic and social success in their lives.

Computer-based interventions for children with ASD have proven to be useful and effective for educational as well as therapeutic purposes [6]. This is due to several reasons, first of all, considering that social interactions might be overwhelming for children with ASD [7], they are drawn more to computing which is free from social demands [8]. Second, one of the key benefits of software development is that it provides a controlled environment with immediate feedback and no surprises, which is suitable for children with ASD. In addition, one of the reasons why they might be attracted more to computer programming specifically is that it is consistent and logical [8].

Serious games (SG), also recently named as game-based learning [9], have proven to have a positive impact on the learning gain and motivation for normally developed children in general [10]. They were also proven to be more effective than other methods in teaching skills and concepts [11]. SG are considered to be important tools for education. The use of well-designed SG can provide students a more enjoyable way to learn concepts in general and in the context of programming education in specific [12].

In the past several years a lot of SG were designed for educational purposes for normally developed children, as well as for children with ASD. ASD are a variety of disorders that mainly affect social, language, communication skills and learning abilities. Children with ASD also have difficulty in solving social problems and in generating solutions to problems they face everyday [13]. Henceforth, the majority of SG designed for people with ASD either have therapeutic, educational purposes or aimed at improving their social communication skills [14]. The use of SG, is accepted by people with intellectual disabilities in general, because of several reasons. First, they feel comfortable exploring the virtual world which does not include the pressure existing in the real world. Second, since computers are considered as an important tool nowadays, people with intellectual disabilities feel proud to be using it [15].

Children with ASD are often believed to be visual thinkers [16] [17]. This means that whenever there are more pictures or animations in the framework or application they use, they tend to be engaged more [18] [17]. Thus an application designed specially for children with ASD should depend mainly on
visual input, for instance more images and animations for the children to be able to learn concepts in an effective way. In addition for a child with ASD, language should be simple and straightforward, which applies for computer programming and coding in general [19].

This paper is organized as follows. Section 2 reviews the published work related to this paper. Section 3 introduces the flow of the proposed serious game as well as its features. Section 4 describes the experimental phase “CodaRoutine” passed through. Section 5 then presents the results that were obtained from the evaluation carried out. Finally, Section 6 presents our conclusions and suggested future work.

II. RELATED WORK

Teaching computer programming has been evolving in the past few years. A lot of tools and applications have been developed and designed with the purpose of teaching programming languages, such as, Scratch. Scratch is a block-based programming environment developed by a research group in the MIT Media Lab (http://scratch.mit.edu). Scratch allows users to create interactive stories and animations by dragging and dropping blocks of code.

A lot of researches evaluated Scratch and tested its effectiveness on the skills of children. A research evaluated using Scratch in introducing programming for engineering students [20]. They found that Scratch makes programming more enjoyable, visual and it helps in increasing creativity of users. However, another study tested the effectiveness of using Scratch program on problem solving skills of fifth grade students in Turkey using pre and post tests [21]. The research found no significant difference in their problem solving skills.

Code.org (https://code.org/) is another non-profit platform that aims to expand participation in computer science by encouraging people, specifically, school students, to learn computer science. The goal of Code.org is to demystify the meaning of code and prove that anyone can know the basics of programming, including children [22]. The findings of the study in [22], show that after the participants tried the tutorials on Code.org, they became much more interested in programming. However, Code.org’s interface might have a complicated design to children with autism, who need to have simple interfaces in the applications they use as mentioned in [23].

Computer-based approaches for educational and therapeutic purposes for children with ASD have got attention in the previous several years, and have been proven to be effective in teaching concepts and skills. Tsikinas [24] showed that the majority of studies performed on the effects of serious games for people with ASD had a positive impact. This is quite promising for teaching children with ASD computational thinking through a serious game intervention.

A study performed to spot the communication patterns of two students with ASD learning how to code within two different settings: a normal classroom and a computer lab. The mentioned study showed that Alex, a child with autism who participated in this study, made a lot more interactions with peers and his teacher in the computer lab [25]. Although the results of this research cannot be generalized for several reasons, this might be an optimistic indication that using computers can have a positive impact on the communication skills of children with ASD which is quite promising.

In the past several years, a lot of games were designed and developed to teach different skills for children with autism. A serious game was designed for children with autism to teach them the concept of money. The game was based on digital story-telling. It also aimed at teaching them the proper behaviour they may follow while shopping. The game had positive impact upon children which indicates that with proper design and training, serious games may have a positive effect on children skills [26].

Another research [27] presented a computer serious game that uses human virtual characters to reinforce problem solving and emotion recognition for both normally developing children and children with ASD. The game had mainly two parts, a playable introduction and a coding interface resembling Scratch which focuses on teaching children with ASD programming logic. But the application was in development stage and the study have not shown the effect of using this program with children yet.

III. SYSTEM OVERVIEW

The primary goal of “CodaRoutine” is to introduce programming concepts for children with intellectual disabilities, specifically children with autism. The proposed serious game focuses on sequential programming concepts.

A. Game Flow Description

“CodaRoutine” targets children with autism spectrum disorders. Considering the special targeted user group, it was crucial to know the characteristics of this group first, by research and meetings with experts from specialised centers, as will be shown in section IV. It was stated that the symptoms of autism involve having problems mainly in the following areas: Communication skills, social skills, and restrictive, repetitive, and stereotyped behaviour. As per communication and social skills, children with autism:

- may have a rigid understanding of words, therefore words have to be simple and straightforward [28].
- may have difficulties sharing emotions, understanding how others think and feel [29]. Therefore it is believed they find dealing with computers less overwhelming.
- may have difficulty with imaginative/pretend play.
- may have difficulty in solving social problems and generating solutions for them [13].

According to the meetings conducted with community experts from “Caritas Egypt” as will be shown in section IV, the main idea of the game is to include tasks from everyday life in a program-like structure. The proposed framework uses:

- simple verbal prompts which are available in English and Arabic.
- prompts are presented in audible and visualized forms.
• a storyboard that contains the tasks that need to be completed by the child was used. The storyboard shows the tasks with some visual aids such as images of each object needed in that particular task, to guarantee that the game is suitable for children with learning deficiencies.
• a virtual character to guide the child throughout the game using simple verbal prompts.
• a home was chosen to be the scenery of the game to be as familiar to the children as possible.

The game consists of three levels, each with a required task to be accomplished by performing simple sub-tasks. The levels are increasing gradually in their difficulty level. Each Level consists of a virtual character who mentions steps to be followed in order to achieve the mentioned goal. The storyboard contains the sub-tasks along with visual aids. Visual aids are mainly images for the object to be used to perform the task. The three levels focus on sequential programming concepts. Every right action from the child’s side is associated with celebrating sound effects as a rewarding mechanism and the tick appears beside the successfully accomplished task on the storyboard. “CodaRoutine” aims for teaching children the sequential programming concepts as well as introducing simple lines of code in the process in an attempt to familiarize the children with how code could be written. Below is a detailed description of each level:

Level 1. Consists of a living room scene. This level has three main tasks to be accomplished. Each task consists of three sub-tasks.

• Task 1: a guide character asks the child to turn on the TV placed in the scene. The child performs the task by following the sub-tasks found on the storyboard in order as shown in Fig.1a. After performing each sub-task successfully, a tick appears beside the task to denote that this sub-task was accomplished as depicted in Fig. 1b and Fig. 1c.

• Task 2: task is to turn on the air conditioner found in scene. The player again has to follow the sub-tasks in order.

• Task 3: last task in this level is to turn on the light. The storyboard of this task has pieces of pseudo code. This was to familiarize the children with how the code should be written. This task can be shown in Fig. 1c.

Level 2. Consists of a Kitchen scene which has two main tasks.

• Task 1: is to prepare a plate of fruit. The child performs this task by placing the fruits on the plate by a drag and drop technique. The child has to place the fruits with the right order and also in the right place on the plate as shown in Fig,2a.

• Task 2: is to prepare banana juice by placing a banana and a cup of milk in the blender. The child performs the task by a drag and drop technique of the elements.

Level 3. This level was added upon the request of experts, as will be shown in section IV. This level consists of a Bedroom scene. This level simulates preparing for the next day in school for a child. This level aims to teach children sequential programming concepts along with some everyday tasks in an attempt to be able to transform this into real life actions later on. The guide character asks the child to prepare his/her by placing tools and books inside the bag in a specific order. This level has two tasks.

• Task 1: is to place the tools in the bag. The child performs this task by a dragging tools and dropping the tools in the bag. This task is presented in 3a.
• **Task 2**: is to drag the books in the right order according to the schedule found on table. Every right action is associated with sound effects and the tick appears beside the successfully accomplished task as shown in Fig. 3b.

**B. Game Features**

"CodaRoutine" serious game has some features in order to make sure it is suitable for children with autism. The game is available in two languages, English and Arabic. The game has visual aids, such as, written texts on the storyboard and images of the object used to perform a task, which should be easier and more effective for children with autism as mentioned by [17] and experts from Caritas team. The guide character can be a male or female. Researchers found that many people with intellectual disabilities face difficulties in recognizing themselves in programs and games [30], so any attempt to help them in recognizing themselves in the game should be effective. According to the choice of the player’s gender in the beginning of the game, the character and audio aids change. The home presented in the game can be customized, to create a safe environment for each child, resembling their own home. Those settings can be chosen at the beginning of the game from the menu presented in Fig4.

**IV. EXPERIMENTAL PHASE**

To make sure that the game is well suited for its target group a number of focus groups were held in different phases. Our group is collaborating with Caritas Organization. "Caritas Egypt" is a local centre whose mission is to provide adequate services to people with disabilities and focuses on intellectual and related disabilities, including ASD.

**A. Collaborative Design of “CodaRoutine”**

As a first step, it was decided to conduct a meeting with community experts to guide us through developing our SG. A focus group was held with "Caritas Egypt" to discuss the
meaning of computational thinking and its effectiveness and importance. The members of the focus group were: the head of the center, the head of the training section and the head of instructors. A meeting of two sessions was organised with them.

The first was a brainstorming session, where our ideas were discussed with feedback and modifications from their side. Caritas team were then shown some existing tools to teach children programming and computational thinking. As a result of the discussions, it was decided to start working on a tool that focuses on sequential thinking since according to their expertise, children with ASD in their sessions prefer to have an ordered list of tasks. Thus, the aim was decided to make them apply the same concept in different contexts and to understand the importance of doing things in a specific order. More of their advised points for our serious game are presented below:

- to use clear, direct and simple local Arabic dialect for any verbal prompts throughout the game.
- to add visual and auditory input to each level in our game.
- the game interface should be simple [23].
- to use a rewarding mechanism in our game after each successful task done by the player.
- to add a storyboard to the game to guide the player throughout the game, as children with ASD in their sessions prefer to have an ordered list of tasks.
- to make the goal and objective of each task clear from the beginning.
- The game should be designed according to the cultural environment of the player. This was also backed-up with the research performed in [15].
- to make the game theme related to things the child would face in their every day life.
- every correct action should have immediate feedback, and this feedback should be used as a consistent rewarding mechanism throughout the game [31] [15].

The second meeting was conducted after developing a preliminary prototype, which had the first two levels only. A focus group was held with the Caritas team. Their comments were to increase levels that relate to problems parents face with children. Thus, a level related to the preparation of the school bag was added (Level 3). In addition, Caritas members mentioned that it is crucial to have more audio directions which was also modified.

B. Prototype

After developing a prototype that met the requirements of the experts that deal with children with ASD on a daily basis, it was decided to also see what children in general think of the game. A group of 8 children in the age range 8-11 (with average age of 9.5 years) were asked to play the game. They were asked to play the games with all of its levels which appear consecutively. The minimum duration for the session was 15 minutes and the maximum duration was 40 minutes. At the end, children were asked to give their feedback about the game.

C. Testing Phase

To make sure that our framework will be effective in teaching computational thinking skills to children with autism, our sample for the study consisted of four users, they were all autistic but with different computer skills. A presentation of the skills and age for our participants from Caritas association is presented in Table I. The participants age mean for our study is 10.25 years. Participants are of slightly different age groups because autism is always associated with learning disabilities.

<table>
<thead>
<tr>
<th>ID</th>
<th>Gender</th>
<th>Age</th>
<th>Computer skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Male</td>
<td>14</td>
<td>High</td>
</tr>
<tr>
<td>P2</td>
<td>Female</td>
<td>12</td>
<td>Low</td>
</tr>
<tr>
<td>P3</td>
<td>Male</td>
<td>8</td>
<td>High</td>
</tr>
<tr>
<td>P4</td>
<td>Male</td>
<td>7</td>
<td>Low</td>
</tr>
</tbody>
</table>

The engagement study was a one session test for each of the four participants. Each participant was asked to play the game from the first level till the end of the game. Each session lasted about 30-40 minutes. Each child had his/her instructor to guide them through the game and help them with the controls if required. After each session each instructor asked the child some questions to test their engagement.

V. RESULTS

For the first group of normally developed children, participants commented that they enjoyed the game. However, it was noticed that children with a higher age tend to finish it very quickly. This might imply that although the game is interesting to children without learning problems and special abilities, levels might need to be tuned to be more challenging for them. This phase was beneficial to make sure that the graphics and the layout is appealing to children in general before trying it with children with ASD.

For the second group, most of the participants had no difficulties in playing the game. All of the participants played the game till the final level. When they were asked about their feedback, they stated that they enjoyed the game. The observations for some of the participants are presented below:

**P1:** The participant did not face any difficulties playing the game, and finished the game with minimal assistance from his instructor.

**P2:** The participant struggled in controlling the main character at first, and with guidance, she finished the first level. When she started playing levels that required drag-and-drop mechanism, she did much better with almost no assistance.

**P3:** The participant did not face any difficulties controlling the main player in the first level, but faced some difficulty controlling the mouse in the levels that required drag-and-drop mechanism. With proper assistance, he finished the game smoothly.

**P4:** The participant struggled in controlling the main character, and could finish the first level with a lot of guidance, but when it came to the levels that required drag-and-drop mechanism, he started interacting more with the game, and with some help he could finish the tasks.
VI. CONCLUSION & FUTURE WORK

The motivation behind the work presented in this paper was to develop a serious game to introduce sequential programming concepts for children with autism. To achieve our objective, a focus group was held with Caritas organization. The game is then developed using concepts and directions from experts to make sure it is well suited to the target group. Some focus groups then were held to gather opinions and discuss the existing prototype.

The next experimental phase is planned to be held with more children with ASD. The aim is to test the effectiveness of the game in teaching them computational skills after being exposed to the game for a proper time. In the future, the game should be extended to account for other concepts such as loops and conditionals. In addition, the game is to be more configurable to make it more suitable for each child.

REFERENCES