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An application to improve emotional skills in children with Autism Spectrum Disorder

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ABSTRACT

This dissertation presents a project developed with the aim of promoting emotional skills in children with Autism Spectrum Disorders (ASD). The project involves a serious game and a playware object, which is a physical component that acts as the game controller and allows the user to interactively play the serious game. The playware object has six pressure buttons, each one showing an emoji with a specific facial expression and communicates wirelessly via Bluetooth with the serious game app installed in an Android device. The facial expressions used are: happiness, sadness, fear, anger, surprise and neutral/normal. They were applied to the three game activities (imitation, recognition and storytelling). The chain of tests started with an online questionnaire to validate the avatars created to represent the previously mentioned facial expressions in the game (with 114 answers and a mean success rate of 96.2%), which was followed by a usability test of the application (serious game and playware object) with six typically developing children (with 94.4% answer accuracy). Finally, the three game activities were tested with six children with ASD in three/four sessions. Due to the small group test and the short number of sessions, the goal was to test the acceptance of the game rather than the users´ improvement in the activity. It is worth referring that both the serious game and the playware object had a high level of approval from the children and they expressed their interest during the activities. With this project it was intended to contribute to the development of pedagogical resources to be used by professionals and families in the support of children with ASD.

Keywords: Autism Spectrum Disorder, Emotions, Social Interaction, Human Computer Interaction

RESUMO

Esta dissertação apresenta um projeto desenvolvido com o objetivo de promover capacidades emocionais em crianças com Perturbação do Espectro do Autismo. Este projeto envolve um jogo sério e um objeto *playware*, que é um componente físico que funciona como controlador de jogo e permite que o utilizador jogue o jogo sério de uma forma interativa. O objeto *playware* tem seis botões de pressão, cada um com um *emoji* com uma expressão facial específica, e comunica sem fios por Bluetooth com a aplicação do jogo sério instalada no dispositivo Android. As expressões faciais usadas são: felicidade, tristeza, medo, raiva, surpresa e neutro/normal. Estas foram aplicadas às três diferentes atividades de jogo (imitar, reconhecer e contar histórias). A cadeia de testes começou com um questionário *online* para validar os avatares criados para representar as expressões faciais previamente mencionadas no jogo (com 114 submissões e uma taxa média de sucesso de 96,2%), seguido de um teste de usabilidade da aplicação (jogo sério e objeto *playware*) com seis crianças tipicamente desenvolvidas (com 94,4% de respostas corretas). Por fim, as três atividades de jogo foram testadas com seis crianças com Perturbação do Espectro do Autismo durante 3 a 4 sessões. Devido à pequena dimensão do grupo de teste e ao baixo número de sessões, o objetivo foi testar a aceitação do jogo em vez da evolução das capacidades dos utilizadores na atividade. É importante referir que tanto o jogo sério como o objeto *playware* tiveram um alto nível de aprovação por parte das crianças que expressaram o seu interesse durante as atividades. Este projeto pretende contribuir para o desenvolvimento de recursos pedagógicos a serem usados por profissionais e famílias no apoio a crianças com Perturbação do Espectro do Autismo.

Palavras chave: Perturbações do Espectro Autista, Emoções, Interação Social, Interação Humano - Computador

CONTENTS

List of Figures

LIST OF TABLES

ABBREVIATIONS

AR	**A**ugmented **R**eality
ASD	**A**utism **S**pectrum **D**isorder
GUI	**G**raphic **U**ser **I**nterface
ITO	**I**ndium **T**in **O**xide
PIQ	**P**erformance **I**ntelligence **Q**uotient
TDC	**T**ypically **D**eveloping **C**hildren
VIQ	**V**erbal **I**ntelligence **Q**uotient
ZECA	**Z**eno **E**ngaging **C**hildren with **A**utism

1. INTRODUCTION

Emotions play is an essential part in our everyday social interactions as human beings, reason why being capable of identifying them is so important. According to Paul Ekman, humans have six basic emotions: happiness, anger, surprise, sadness, fear and disgust (Ekman et al., 1987) – and the ability to understand and express them start developing from birth.

Children with Autism Spectrum Disorder (ASD) have difficulties to identify and replicate emotions, as well as interpreting and controlling them. Opposite to the vast majority of babies who can understand these facial expressions by 12 months of age, these individuals have impairments in developing emotional responses and only by 5-7 years of age they are able to recognize happy and sad emotions. This difficulty is present in their life even as adults (Begeer, Koot, Rieffe, Meerum Terwogt, & Stegge, 2008).

The recognition of emotions improves the social relation between children with and without ASD (Kasari, Rotheram-Fuller, Locke, & Gulsrud, 2012; Salomone, Bulgarelli, Thommen, & Rossini, 2018; Sivaratnam, Cornish, Gray, Howlin, & Rinehart, 2012). Tanaka et al. reinforce this position, explaining that ASD is characterized by difficulty in terms of socio emotional reciprocity and that success in social interactions goes through the ability to recognize and interpret facial emotions in social context (Tanaka et al., 2012).

Mobile applications have already proved to be a successful aid for therapists and teachers in a learning environment, by facilitating the intake of information by individuals with ASD. Many studies using serious games have already been done, exploring different purposes such as education and therapy (Noor, Shahbodin, & Pee, 2012).

Serious games is the term associated with games that move beyond entertainment to deliver engaging interactive media to support learning (Noor et al., 2012). Their focus is to facilitate the learning of important topics by making the entire process more appealing and fun. This way, the user is willingly engaged in an activity that they enjoy, and the assimilation of knowledge is not so much a burden but more something that happens naturally.

Another very used concept in this dissertation is Playware. Playware is the term attributed to the use of intelligent technology that aims at producing playful experiences by combining the use of both hardware and software (Lund, Klitbo, & Jessen, 2005).

Serious games and Playware objects have been utilized in studies with children with ASD as a target group, but despite all the current efforts there is still much space to grow and improve (specially the more conventional methods which aim to facilitate the integration of these children in the day-to-day society).

1.1 Problem and Motivation

Humans are social by nature. Every interaction is emphasized by the participants' emotions, which are constantly present during their lives. Being unable to "read" the emotional state of their peers is a very significant deficit for anyone. This is the situation in which children with Autism Spectrum Disorder (ASD) usually find themselves in, since they struggle with emotions interpretation, replication and control (Tanaka et al., 2012). This fact is present throughout their lives but may have a reduced effect if the subject undergoes behavioural intervention and/or receives specialized education.

There are a few factors motivating this research, the main one being the interaction with individuals with ASD and the hopeful success in improving their development of emotional skills, contributing this way to positively impact their lives and facilitate their interaction with the surrounding social environment.

Other motivations existed on a more personal level regarding the learning opportunity associated with the utilization of unfamiliar tools and materials.

1.2 Goals

The objective of this dissertation is the development of a mobile application and a playware object that by working together can improve/promote the socio-emotional skills of children with ASD.

With this in mind, the main goals of this research project are:

1) to develop a mobile software application (serious game) designed to improve emotional skills in children with ASD;

2) to create an appellative and interactive playware object to act as the game controller for the serious game;

3) to assess the usability and acceptance of the system (serious game and playware object) by the target group (children with ASD).

1.3 Ethical Considerations

The work presents studies involving typically developing children and children with ASD. Therefore, the following measures were taken to meet the ethical concerns:

- Protocols: A protocol was formed between the elementary school that participated in the studies and the University where the research was developed. A prior meeting took place in the school to explain the research and what would their role be in it, as well as to clarify any other questions.
- Parents' consent: The parents/tutors of the children that participated in the studies signed an informed consent, allowing their children to participate in the research. The consent was accompanied by another document detailing the objectives, risks and benefits of the research, as well as the full freedom to withdraw their child at any point.
- Privacy: The anonymity of the participants was ensured, as their personal data is enclosed, and all private information gathered during the studies is confidential and dealt to meet the rules on data and private life. Only the people directly involved in the research have knowledge of this data.

1.4 Results of the Developed Scientific Activity

Two papers detailing the work developed in this dissertation were submitted and accepted for oral presentation in international conferences:

- José Azevedo, Vinicius Silva, Filomena Soares, João Sena Esteves, Ana Paula Pereira, Serious games assisted by playware as a way to improve socio-emotional skills in children with autism spectrum disorder, SENSORDEVICES 2018 - The Nineth International Conference on Sensor Device Technologies and Applications, Venice, Italy, 16-20 September, 2018.
- José Azevedo, Vinicius Silva, Filomena Soares, Ana Paula Pereira, João Sena Esteves, An Application to Promote Emotional Skills in Children with Autism Spectrum Disorders, SGDA 2018 - Joint Conference on Serious Games - 9th Int. Conf. on Serious Games Development & Applications, 8th GameDays Int. Conference (GameDays 2018), Darmstadt, Germany, 7-8 November 2018.

1.5 Structure of the Dissertation

The dissertation is divided in five Chapters and Bibliography and Appendixes with the following structure:

- Chapter 2 addresses the state of the art. Focused and divided on three main topics of emotional processes, serious games and playware, it presents different studies and work developed for each, involving individuals with ASD.
- Chapter 3 presents the application. With the title of "System Development", it starts with considerations regarding the hardware and software utilized. In here, both the playware object and the game engine, Unity, are explained. The system architecture is also a component of this section and here is where the serious game is explicated, giving detailed information regarding the available game activities.
- Chapter 4 provides information about the different tests performed with the application and the results obtained from them. It starts with the validation of the avatars created, following with the assessment done with typically developing children (TDC) and it closes with the data gathered form the different sessions with children with ASD.
- Chapter 5 presents the conclusions of the work developed and suggests several approaches for future work.

2. STATE OF THE ART

Currently there are several projects that were or are being developed to improve the quality of life of individuals with ASD. This section is divided in three sub-sections, where the first is dedicated to studies regarding emotional process and ASD, and the other two present the work that has been done in this field, related to this dissertation, following the topics of serious games and playware, respectively.

2.1 Emotional Process and Autism Spectrum Disorders

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder, involving differences in brain growth, organization and function (Tanaka et al., 2012). Individuals affected by ASD display social deficits such as difficulties in understanding facial expressions (and by association, emotional states) of others during interactions, leaving them at a disadvantage in social exchanges.

ASD being associated with an impairment of basic automatic social-emotion process was the conclusion from a study that examined automatic and voluntary mimicry of facial expressions (McIntosh, Reichmann-Decker, Winkielman, & Wilbarger, 2006). The participants for this study were 14 high-functioning adolescents and adults with ASD (can speak, read, write, handle basic life skills and may live independently) and 14 typically developing individuals, matched in gender with the first group (three females and 11 males), chronological age and verbal ability. They performed two activities, being first evaluated in automatic mimicry (where they were asked to look at some pictures) and then evaluated in voluntary mimicry (where they were prompted to mimic an expression), while the activity of their brow and cheek muscle regions was monitored with electromyography. The facial expressions they were presented with were limited to happiness and anger. The participants with ASD did not automatically mimic facial expressions where the typically developing participants did, despite both groups being able to perform successful voluntary mimicry.

A 2012 study involving twelve children with ASD and the same number of typically developing children with ages around seven years old conducted several tests with the aim of evaluating how each group performed and comparing the results (Sivaratnam et al., 2012). Verbal Intelligence Quotient (VIQ) and Performance Intelligence Quotient (PIQ) were also considered, with values very similar between both groups for the PIQ and a deficit of 11.34 regarding the VIQ of the children with ASD. The conclusions

extracted revealed that the children with ASD performed more poorly than their typically developing counterparts, demonstrating more intention-understanding difficulties.

Also from that year, J. Tanaka conducted tests with identical objectives, but with a larger number of participants (Tanaka et al., 2012). The ASD group had a mean age of 11.58 years old (85 individuals) and 11.96 years old for the group with typically developing children (130 individuals). Sub groups were created, matching individuals on chronological age and IQ. From the gathered test data was possible to notice that the ASD group displayed worst results when compared with the other group, regarding their ability to generalize facial emotions across different facial identities (Tanaka et al., 2012).

Another study evaluated the effectiveness of a 7-month cognitive behavioral intervention for the facilitation of social-emotional understanding and social interaction of 15 high-functioning children with ASD (Nirit Bauminger, 2002). The participants (with ages between 8 and 17 years old) were measured before and after the intervention regarding interpersonal problem solving, emotional understanding, teacher-rated social and social interaction. When the intervention was concluded, the participants showed improvements in eye-contact and were more likely to initiate positive social interactions. They also provided more relevant solutions regarding problem solving and in emotional knowledge provided more examples of complex emotions.

Emotion processing was investigated in study with a group of 23 adults with ASD and 23 age and gender matched individuals (Philip et al., 2010). Recognition of basic emotions (sadness, happiness, anger, disgust and fear) was assessed from facial, body movement and vocal stimuli, as well as the ability to make social judgements from facial stimuli. The participants were asked to select a textual label to express the emotion they were present with for a duration of 5 seconds over the course of ten trials without any type of feedback on their choice. They were after presented the same test but with Japanese and Caucasian facial expressions over the course of 7 trials. The final activity regarding facial tasks revolved around matching the target stimuli to another picture of a face. For the body movement task, they were presented with short movie clips without visible facial emotions, where the user would have to label the emotion that was being expressed. For the voice task, the participants were required to label the emotion in the vocal stimuli, which consisted of male and female actors saying strings of numbers in an emotional tone. The final test was regarding social judgment, where the user's ability to make a range of social judgements from faces was tested. Over the course of 40 images they were asked to make a decision, choosing one of two options, relating to age (set 1), trustworthiness (set 2), attractiveness (set 3), intelligence (set 4), approachability (set 5), distinctiveness (set 6).

The results showed that the ASD group had significant deficits in emotion recognition compared to the control group across all stimulus domains and all range of emotions. They also demonstrated impairments in making social judgements.

2.2 Serious Games

Serious games is the term associated with games that move beyond entertainment to deliver engaging interactive media to support learning (Noor et al., 2012). Their focus is to facilitate the learning of important topics by making the entire process more appealing and fun. This way, the user is willingly engaged in an activity that they enjoy, and the assimilation of knowledge is not so much a burden but more something that happens naturally.

Baldassarri developed a study that utilized two videogames to promote communication and attention in children with ASD (Baldassarri, Passerino, Ramis, Riquelme, & Perales, 2018). One application allowed the students to work with seven basic emotions (happiness, sadness, fear, disgust, anger, surprise and neutral) throughout a difficulty range of 10 levels, while the other, with 20 difficulty levels, was intended to provoke reactions and capture the player's facial expressions. This study counted with 10 participants, 5 being for the control group (ages between 5 and 10 years old) and 5 being individuals with ASD (ages between 14 and 18 years old). The authors concluded that most users with ASD replicated correctly happiness, fear, anger and surprise being the remaining three the most difficult emotions to reproduce.

Toon-char is the name of an application developed by Cheng Zheng. It is a video chat system that makes use of cartoon masks to help children with ASD to improve their communication and comprehension skills (Zheng et al., 2017). The study counted with 10 children with autism that were asked to participate in a 20-minute session. The professionals that accompanied the participants indicated that despite the children completing the tasks or not, their concentration, participation and frequency of eye contact had increased with the assistance of the application.

"Invasion of the Wrong Planet" is the title of a serious game developed for behavioral therapy (Marwecki, Rädle, & Reiterer, 2013). This application has the therapeutic goal of enhancing social interaction and communication. The game encourages collaboration through the means of team work, which rewards the players with extra points.Following the lines of the collaboration, another game worth mentioning is the Collaborative Puzzle Game. This application is a tabletop activity that is designed to foster collaboration in children with ASD (Battocchi et al., 2009). To do so, in order to move the puzzle pieces, they must be touched and dragged simultaneously by two players (enforced collaboration). To test the

effects of enforced collaboration, this study tested the application with 70 typically developing children and 16 children with ASD, concluding that it has a positive impact on collaboration.

ECHOES is a serious game that aims to help children with ASD to practice and acquire social communications skills. The children interact with a virtual character in the context of social situations through a multitouch LCD display equipped with eye-gaze tracking and with scenarios structured around twelve learning activities intended for the day-to-day use as part of the children's routine (Bernardini, Porayska-Pomsta, & Smith, 2014). The test group included 29 children with ages between 4 to 14 years old and, although no significant transfer of increased social responsiveness was observed, there was evidence of some of these children having benefited from exposure to the serious game (Bernardini et al., 2014).

A serious game dedicated to teaching children how to produce facial expressions was created by Arnaud Dapogny (Dapogny et al., 2018). This work involved feeding a machine learning algorithm with several labeled frames from a database of videos depicting typical children's facial expressions to train the model. The study involved 157 participants with ages between six and eleven years old, and approached four facial expressions: neutral, happiness, anger and sadness. Two tasks were presented to the children, the first being producing a facial expression after it being requested by audio and the second consisted in the imitation of the facial expression that an avatar was displaying.

Focused on a target group of adults with ASD, "JeStiMulE" aims at investigating its effect with social cognition disorders concerning emotion recognition (Antonini et al., 2017). 30 participants (with a mean age of 24.6 years) were divided in two groups with fifteen people each, one where the members would play the game until completion and the other, the control group, where they would play a commercial platform video game without any social cognition dimension. The game "JeStiMulE" presents its users with a series of different scenarios where the user plays in a virtual environment and circulates in five different areas of life (square, theatre, restaurant, garden and store), where they have to recognize the emotions of the avatar in various situations (Boucenna et al., 2014). The gathered results showed a significant improvement of fear recognition after the intervention but no notable difference regarding the other emotions (joy, sadness, disgust, anger and surprise).

"Tobias in the Zoo" is a serious game based on Augmented Reality (AR) (Carvalho, Brandão, Cunha, Vasconcelos, & Soares, 2015). It has a book style (GameBook) and aims to assist children with ASD with social interaction and communication skills, as well as promoting the recognition of emotions. The GameBook contains a story of Tobias's adventure in a zoo park, divided in five scenarios (one for each

emotion that it addresses) that can be presented through text or audio. The user interacts with these scenarios by playing with one 3D AR avatar and matching the correct facial expression to the situation presented.

2.3 Playware

Ishi and Ullmer concluded that Graphic User Interfaces (GUI) are very limited where it comes with interacting with the physical world, and so they developed the concept of Tangible Interface. Tangible interfaces combine the interaction of both physical and virtual worlds, through objects provided with ubiquitous computing (Ishii & Ullmer, 1997).
Resnick proposed the concept of Digital Manipulatives, i.e., physical objects imbued with computational properties that children can use to manipulate digital information (Resnick et al., 1998).

However, the focus of this sub-section will rest on a very identical concept to the ones that were mentioned in both previous paragraphs. The use of intelligent technology associated to playful activities and experiences is designated as playware technology. One example are the tangible tiles (Figure 1), i.e., modular blocks that can be placed both on the ground and on a wall where each contains multiple LEDs to display information to the user, a microcontroller ATmega 128 and a force-sensitive resistor to read when someone steps on that tile (Lund et al., 2005).

Figure 1: Children playing games on the tangible tiles (Lund et al., 2005)

A study (Yannakakis, M, Hallam, & Lund, 2006) was developed associated with this playware technology with the goal to determine the best way to create a fun experience to the user by focusing on the game

opponent's behavior contributions to the real-time entertainment value of the game. A Bug-Smasher game was utilized to acquire data of human judgement on entertainment, being played by twenty eight children with ages between 8 and 10 years old (Yannakakis et al., 2006).

Although none of the two previously mentioned studies involved children with autism, one of the games (colour mix) developed in the project (Lund & Marti, 2009) was actually performed with a therapist and seven children with autism.

Due to the wide variety of applications, this type of playware technology can be applied to different therapies (e.g., cardiac patients, individuals with autism, physiotherapy) (Lund, Jensen, Ssessanga, Cataldo, & Yahya-Malima, 2015). Their feedback methods (light and sound) and their interactiveness makes these tiles very appropriate to explore cognitive development in children with autism (Figure 2).

Figure 2: Children with autism playing with modular tiles (Lund, Dam Pedersen, & Beck, 2009)

Other work was also developed in the area of the biofeedback technology using social playware (Figure 3), utilizing the wireless signal strength and the measures posture and orientation to estimate the 2-dimensional relative positions (Suzuki, 2014). Seven children with autism with ages between 7 and 13 years old participated in this study. The time periods that each child spent in groups, holding or throwing a ball was also recorded and increased when the bibs were lighted.

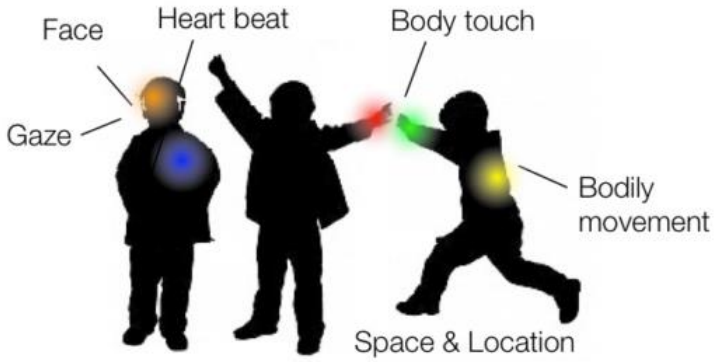

Figure 3: Social Playware: Cyber-physical system (Suzuki, 2014)

Other devices were also developed in this study, e.g., Que ball, the spherical object COLOLO, and a robot pet interface PEPITA (Figure 4), which aimed to integrate cyber and physical spaces and to help people develop their social ability.

Figure 4: PEPITA: the robot pet for promoting human-human interaction (Suzuki, 2014)

Focusing on communication skills, J. Lobo developed two playware objects incorporating two major early language learning areas: vocalization training and breath control training (Lobo & Suzuki, 2018). The first is dedicated to vocal sounds and its social usage, while the second aims at improving speech timing and voice quality. Both devices can provide real-time feedback and still are in a prototyping phase.

HoloLearn is a Mixed Reality application that was implemented using HoloLens technology and is designed to work with people who have Neuro-Developmental Disorders (Aruanno & Vona, 2018). The focus of the project is to improve the autonomy of these individuals in performing simple domestic tasks.

The application counts with a virtual assistant to capture the user's attention and guide him through the several tasks. The study had 20 participants with Neuro-Developmental Disorders during an exploratory test phase to assess the application's usability and acceptability, which allowed to conclude that it was well accepted and the activities were enjoyable.

According to the various results obtained in different studies with both serious games and playware objects, interlinking these two would prove an interesting experience. The work developed by A. Barajas does exactly that. He created a serious game which utilizes a playware object similar to Lego-like building blocks augmented with electronic modules (Barajas, Osman, & Shirmohammadi, 2017). The intended goal is to be used as a therapy tool to improve social and cognitive skill in children with ASD. An experiment was conducted with nine children with ASD (ages between 6 and 15 years old) that volunteered to participate, where they would play the game with a computer and without one. It was possible to determine from the gathered data that the participants spent less solitary play time in the computer game and the collaborative play time was increased. Their performance in the computer game was also significantly better.

Despite the several existing works that focus on children with ASD as a target group, there is still room to grow and develop tools that can impactfully affect their lives. As all these studies show, people with ASD have difficulties in social interaction, social behavior and specially in identifying and producing emotional states.

The joint interaction with both serious games and playware objects is a good example, since it allows the user to physically interact with the virtual world. This dissertation project intended to explore exactly this mechanic due to how powerful it can be. There are also very few projects that make use of both serious games and playware objects, which allows this work to be fairly unique and to constitute a step towards a greater goal that is common to all of the studies previously mentioned (i.e., to improve the quality of life of individuals with ASD).

3. SYSTEM DEVELOPMENT

This section presents a breakdown of the utilized hardware and software. The former will be focused on the playware object and its components, while the later will address the chosen IDE for developing the serious game and the game's architecture. In the following, the developed system is detailed.

3.1 System Overview

The application is composed of a serious game and a playware object (Figure 5). The goal was creating a serious game to deliver the information in a "funny" and interesting way. A playware object was added with the aim of making the game even more attractive and interactive, allowing the user to influence a virtual object through the use of a physical one.

Figure 5: The application developed

The entire system was designed with the focus of exploring emotions with children with ASD, that follows the work done by Sandra Costa (Costa, Soares, Pereira, Santos, & Hiolle, 2014) where a robot was utilized as a mediator and some activities that are replicated in the serious game were tested.

The serious game focus on three separate game activities: imitation, recognition and storytelling. A flowchart of the application is presented in figure 6 detailing its working process. Each of the game modes will be separately described in chapter 3.2, with a closer look at its respective flowchart.

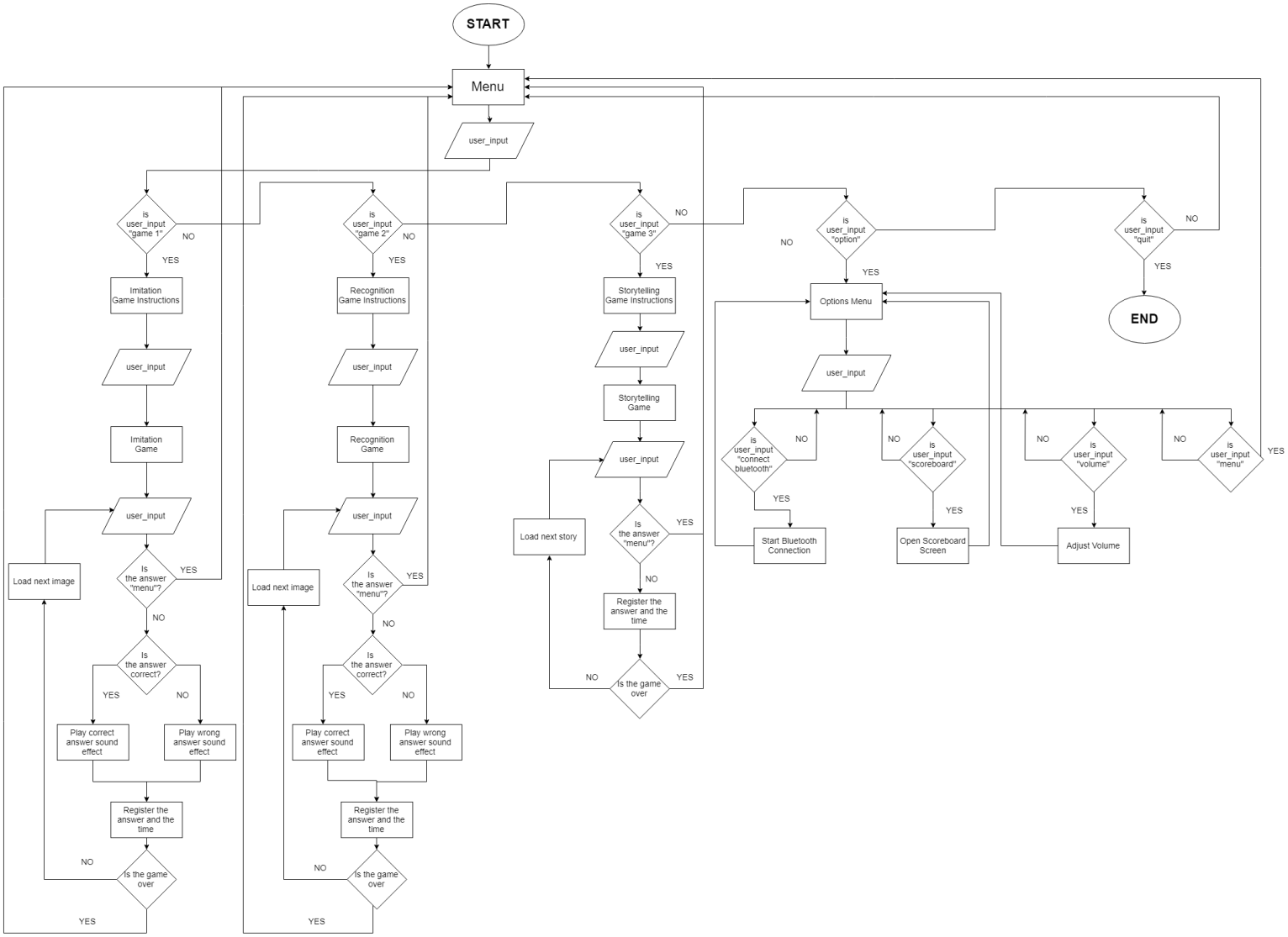

Figure 6: Flowchart of the application

3.2 Activities designed

In each game mode, the user works with six emotions/facial expressions: happiness, anger, surprise, sadness, fear and neutral/normal, at least once.

These activities are focused on working skills such as identifying and demonstrating emotions by associating facial expressions to specific emotional states as well as understanding unique situations and determining how they affect someone's emotions.

3.2.1 Imitation game mode

This activity revolves around the user's capabilities to see a facial expression and successfully replicating it him/herself. For that purpose, the six avatars created (one for each emotion) are presented to the user, one at a time.

The game is played side by side with a therapist/teacher that acts as a reinforcement to motivate the user to show the facial expression that matches each emotion. This agent has also the role of evaluating if the correct facial expression is replicated and sending the respective feedback to the serious game.

Following the flowchart (Figure 8), upon the selection of the activity, a set of instructions is given to the user in a pre-game screen, designed for this purpose. Once any input is sent to the mobile application, the game starts, displaying the first avatar (Figure 7, as an example).

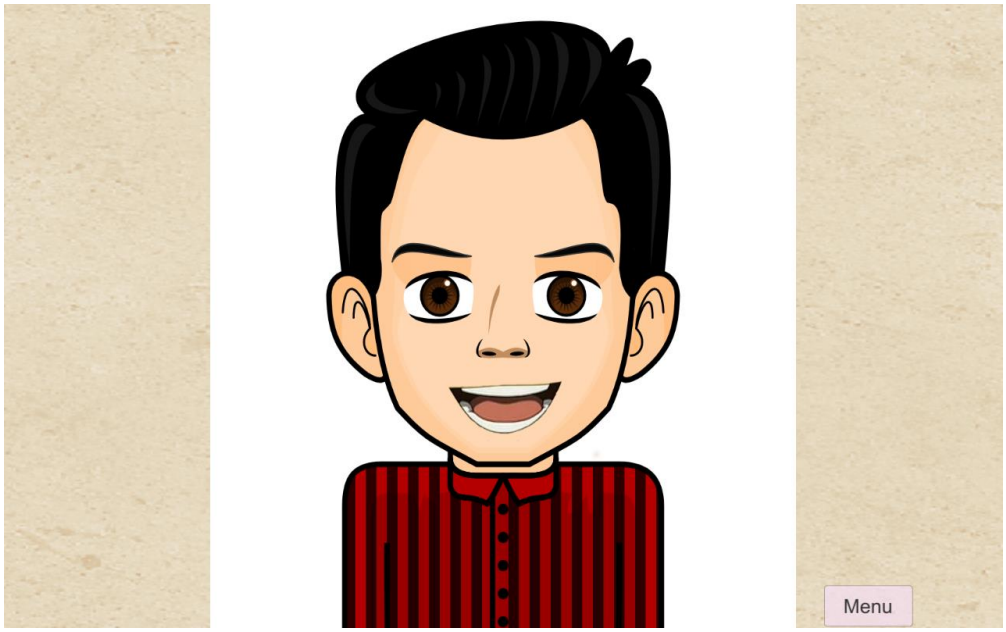

Figure 7: Screenshot of the serious game during the imitation game mode

At this point, the user performs the task of stating which emotion is being represented and imitates it, which the therapist/teacher will then verify and send the input with that emotion to the serious game, through the playware object. A sound is then played, accordingly to the correctness of the answer provided. The time necessary to perform this task and the emoji selected (button pressed on the playware object, section 3.3) are logged. This process repeats itself five more times, covering each facial expression that is worked in this project. Once the user went through all six facial expressions the game is over and the serious game returns to the main screen. Note that this action can also occur if at any time during the activity the “Menu” button is pressed in the mobile application.

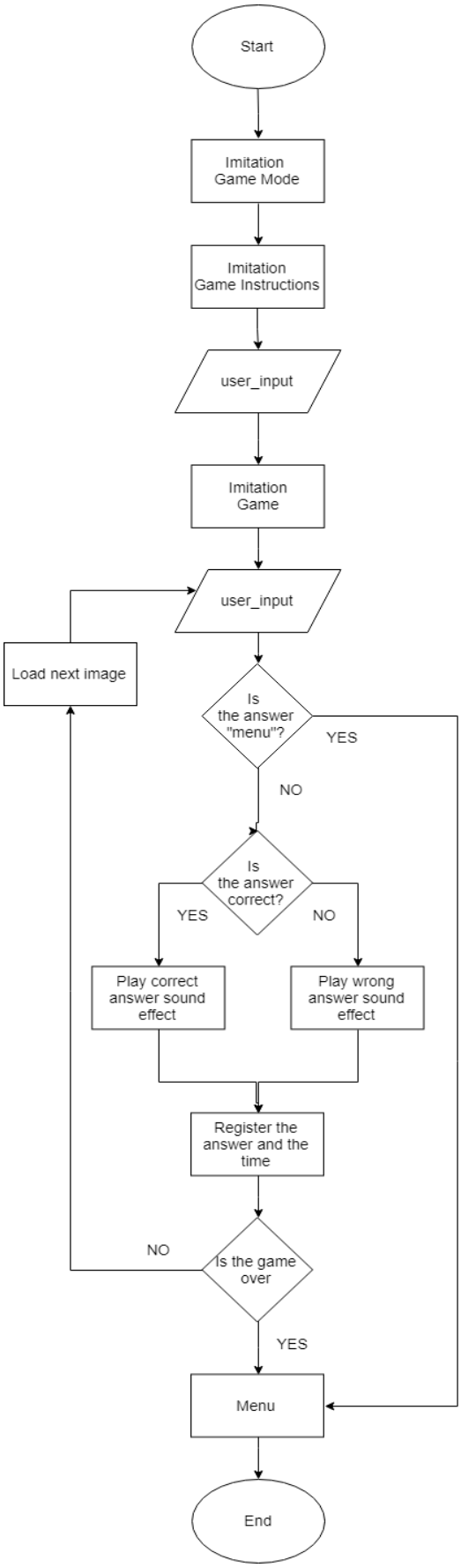

Figure 8: Flowchart of the imitation game mode

3.2.2 Recognition game mode

This activity only differs from the first game mode due to changes in how the user plays the game. The same avatars are utilized and from the serious game perspective the process is identical (Figure 10).

In the same way, the user is presented with the instruction screen that tells him/her how he/she should play the game and any input afterwards will start the activity. Once this happens, a cycle begins where an avatar is displayed (Figure 9), the user states what emotion is being portrayed and then, after analyzing the different emojis on the playware object, chooses the one that is also conveying that emotion. The serious game verifies if the answer provided is the right one or not and plays the respective sound. The data saved is the same as in the imitation game mode.

When this sequence concludes, or if the "Menu" button is pressed in the mobile application, the user is returned to the main screen.

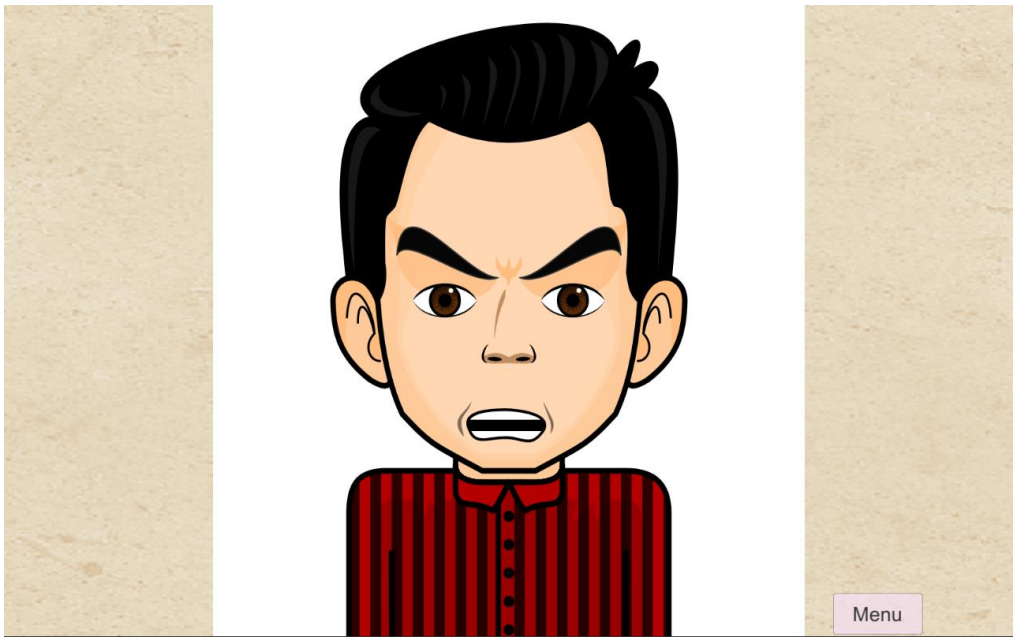

Figure 9: Screenshot of the serious game during the recognition game mode

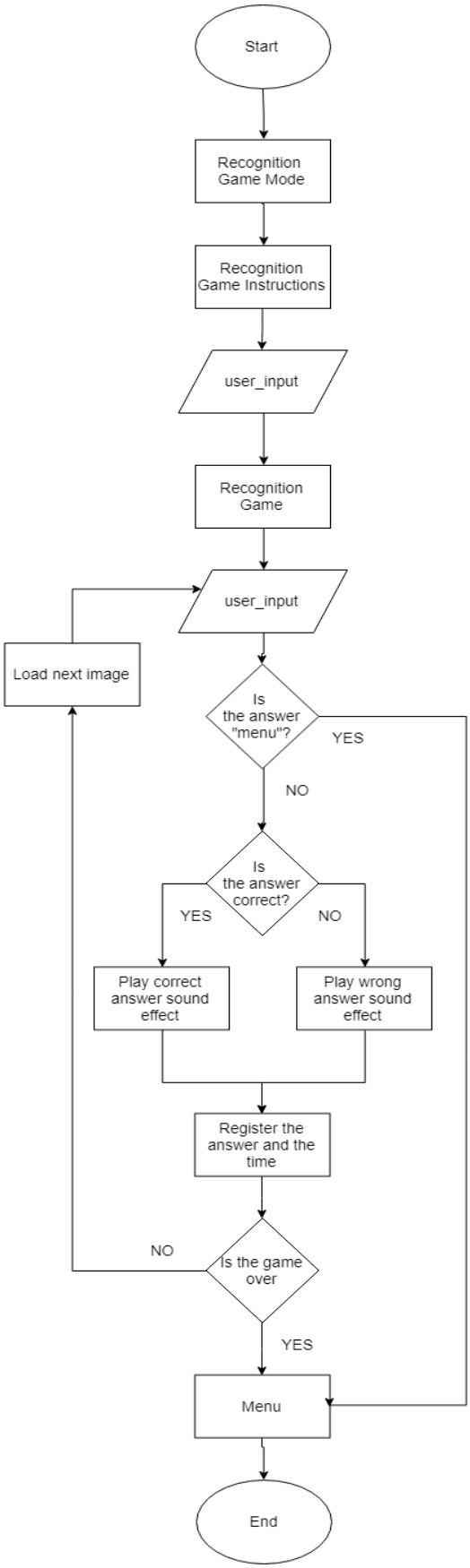

Figure 10: Flowchart of the recognition ga38me mode

3.2.3 Storytelling game mode

This is the hardest of all three game activities. A set of 15 different scenarios where created to match the existing narratives which were already validated by the work developed by Sandra Costa(Costa et al., 2014). These stories where recorded with the use of a text-to-speech software with the sound identical to that of a child.

This activity plays out accordingly to the process represented in figure 12. Upon its selection, the user is presented with the necessary information to play the game, which starts when any input is sent to the application. For the length of 15 stories, and for each of them, the user listens to the narrative and at the end is asked to understand what emotion the main character of that story was feeling (Figure 11). The answer is given with the use of the playware object and it is logged, alongside the time necessary to provide one. Like in the previous game modes, upon the end of the activity or if the "Menu" button is pressed, the user returns to the main menu.

It is important to note that due to the possibility of multiple emotions being correct for some stories, it was decided not to play any right or wrong sound after the answer being provided.

An example of the narratives utilized during the storytelling activity and the emotions associated with them is presented in the following table (Table 1). All fifteen stories and scenarios created are present in the appendixes section of this dissertation.

Table 1: Examples of the narratives utilized in the storytelling activity and the emotions associated with them

Narratives	Emotions
"My sister's name is Alice. Alice plays with me in the playground. Today, when we were playing, Alice took my ball. I hate when Alice does that. How did I feel?"	Sadness/Anger
"After dinner I go to my room. When I'm laying in bed, ready to fall asleep, my mother turns of the light. Then, I see shadows on the wall and can't sleep. How do I feel?"	Fear
"Every day I go to school. I like to play with my friends. My teacher says that I did a good work. It is so good to be able to do what we like. How did I feel?"	Happiness
"When I was playing during playtime, while I was running, I fell. My arm and my leg were hurting a lot. I had a big scratch and I couldn't stop crying. How did I feel?"	Sadness

Figure 11: Screenshot of the serious game during the storytelling game mode

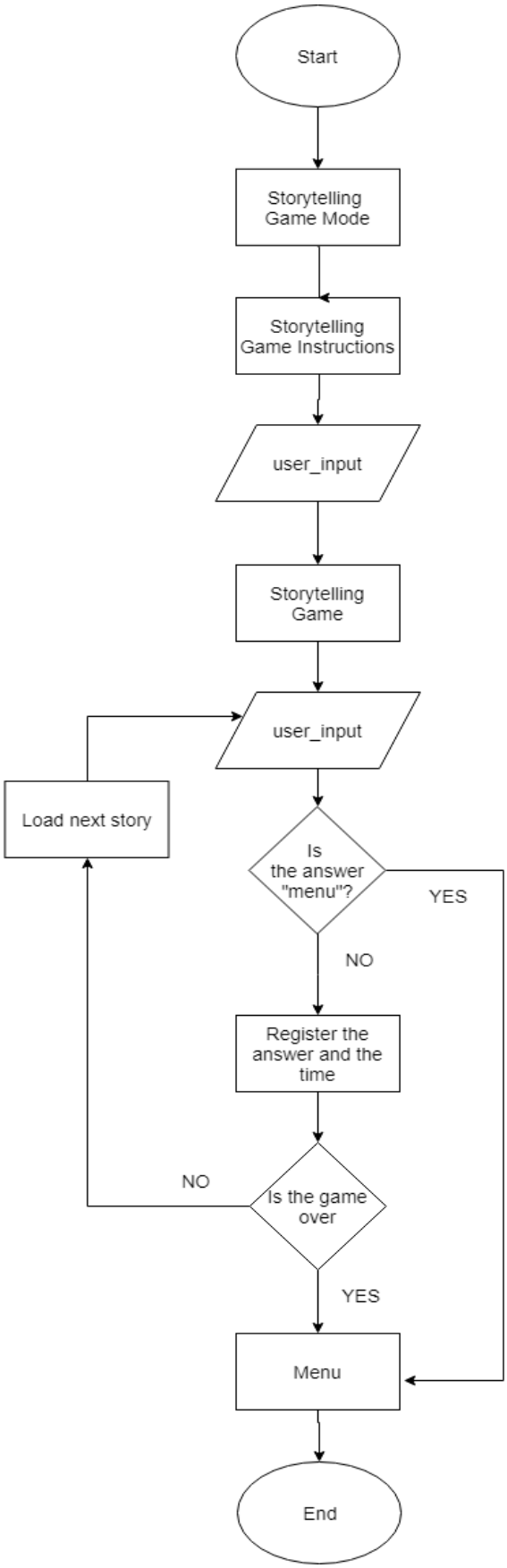

Figure 12: Flowchart of the storytelling game mode

3.3 Playware

The playware object was created from scratch. Originally there were three designs to choose from: a parallelepipedal box with the semblance of a panel filled with six buttons on top (each with an emoji) – figure 13, an object with the structure of a cube where each side would have an emoji – figure 14, and the last one was a small box to store only the microcontroller and other essential components, where the objects that the user interacted with would be indium tin oxide (ITO) coated glass rectangles – figure 15.

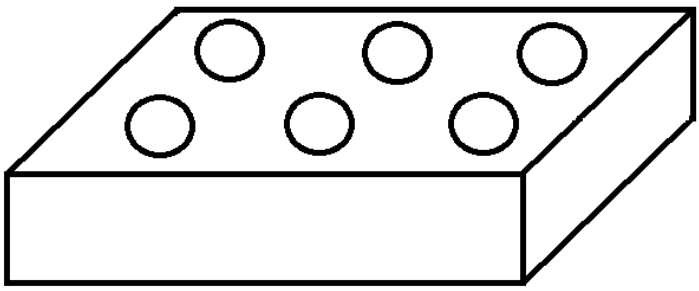

Figure 13: Sketch of the option number 1

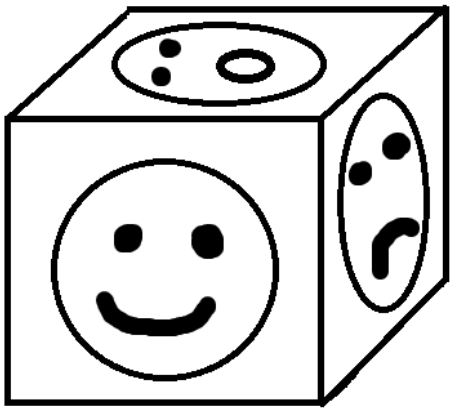

Figure 14: Sketch of the option number 2

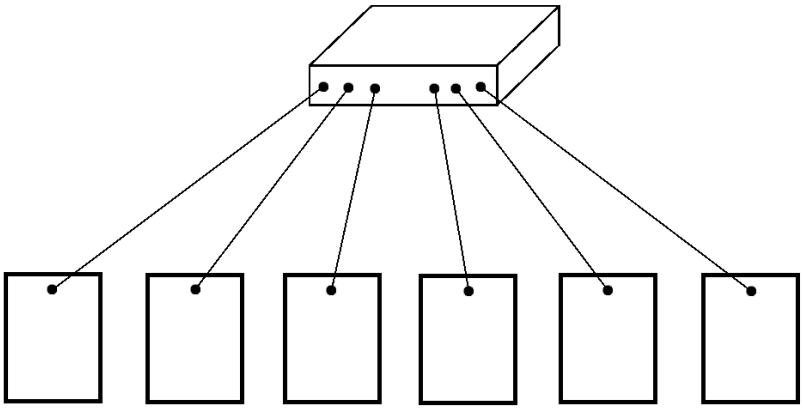

Figure 15: Sketch of the option number 3

The first option (Figure 16) was deemed to be the best, due to its simplicity. This trait is very important when dealing with children with ASD, since conveying too much information or complexity could lead to the user being overwhelmed or having difficulty understanding its usability rules (Kozima, Michalowski, & Nakagawa, 2009).

There were also other small issues regarding the alternative options. The design that utilized ITO coated glass posed a greater risk of failure due to the lack of experience in using that material. The components were also harder to find and a lot more expensive.

The cubic playware object was also explored but posed two significant problems. The user was unable to see all the options at once, forcing him/her to look for the correct emoji every time which would delay his response time. Furthermore, there was also the need to establish how to validate the answer. If button were utilized, it was highly probable that false inputs would happen derived to simply handling the box. Another option would be to use a touch screen on each face of the cube to display each emoji, but in that situation a pattern for validation would have to be implemented (like a double tap or a swipe) which would significantly increase the difficulty of using the playware object and cause a possible loss of interest in the activity.

With the chosen format, all six emojis are displayed at the same time facilitating the task of going through the facial expressions available to choose from and decide upon the one that the user finds more appropriate.

The action of pressing the button is also rewarding due to the "clicking" sound and tactile effects.

The choice to utilize emojis was not made without consideration. Emojis are something that is present in everyone's life and it is very likely that the user will be familiarized with them. The option was using human

faces instead of emojis was theoretically explored but posed a very particular problem. While the emojis are neutral and constant images showing different facial expressions, humans are different from each other and one's facial expressions may vary (even so slightly) from the one of its peers. This could be a factor leading to confusion, so the appropriate path was to use emojis, that also present simplistic features, making it significantly easier to understand.

Figure 16: The playware object that acts as the game controller

Inside the box are present all the necessary components for the playware to be able to interact with the serious game (Figure 17). It integrates a microcontroller (Arduino atmega2560), a Bluetooth module (HC-05), six buttons with 6mm of diameter, fourteen resistors, a power supply for the Arduino and a power supply for the buttons (which work at 12V).

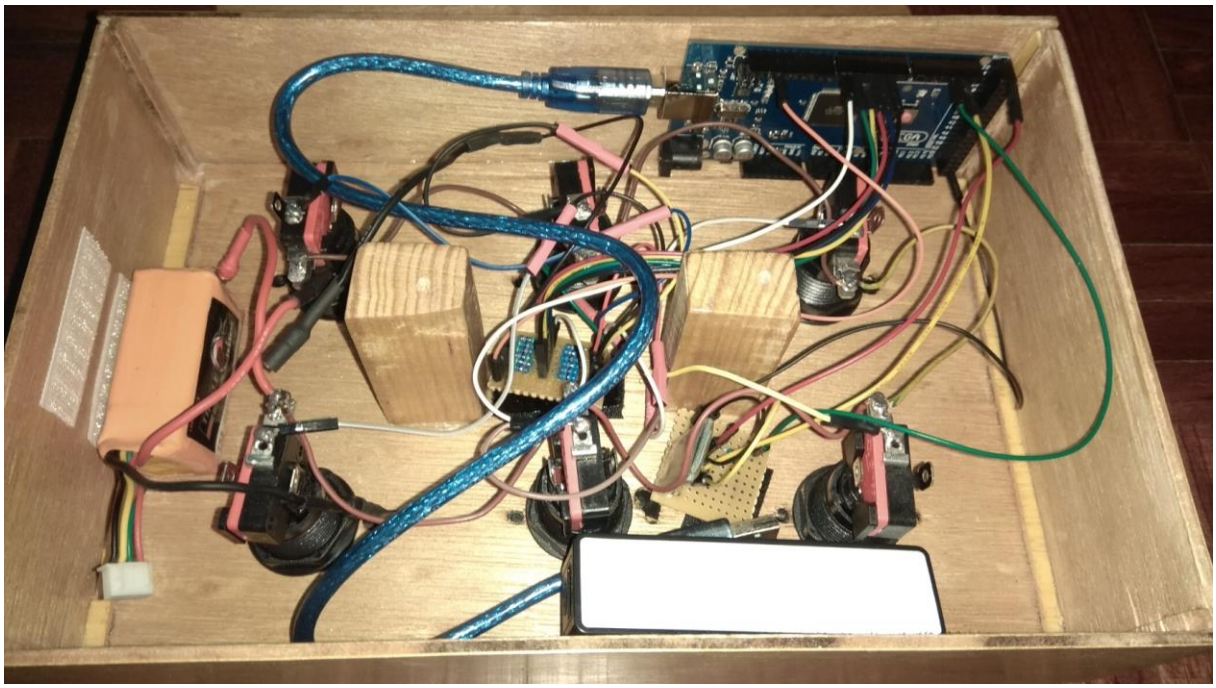

Figure 17: Inside view of the playware object

The electronic circuit containing all the mentioned components is reproduced in the diagram in Figure 18.

Resistors of 68kOhm and 47kOhm are needed to lower the voltage potential with a voltage divider from 12V to a value around 5V, which is supported by the Arduino ports (Eq. 1).

$$Vout = Vin\left(\frac{R2}{R1 + R2}\right) = 12\left(\frac{47k}{68k + 47k}\right) = 4.9 \qquad (Eq.1)$$

The 47kOhm resistors also work as pull-down resistors, ensuring that unless the button is press, the respective port will read a logic value of 0.

The Bluetooth module HC-05 is connected to the Arduino through the serial pins (Serial Port 0) and is the component that enables Bluetooth communication with the serious game, sending and receiving data between the mobile device and the microcontroller.

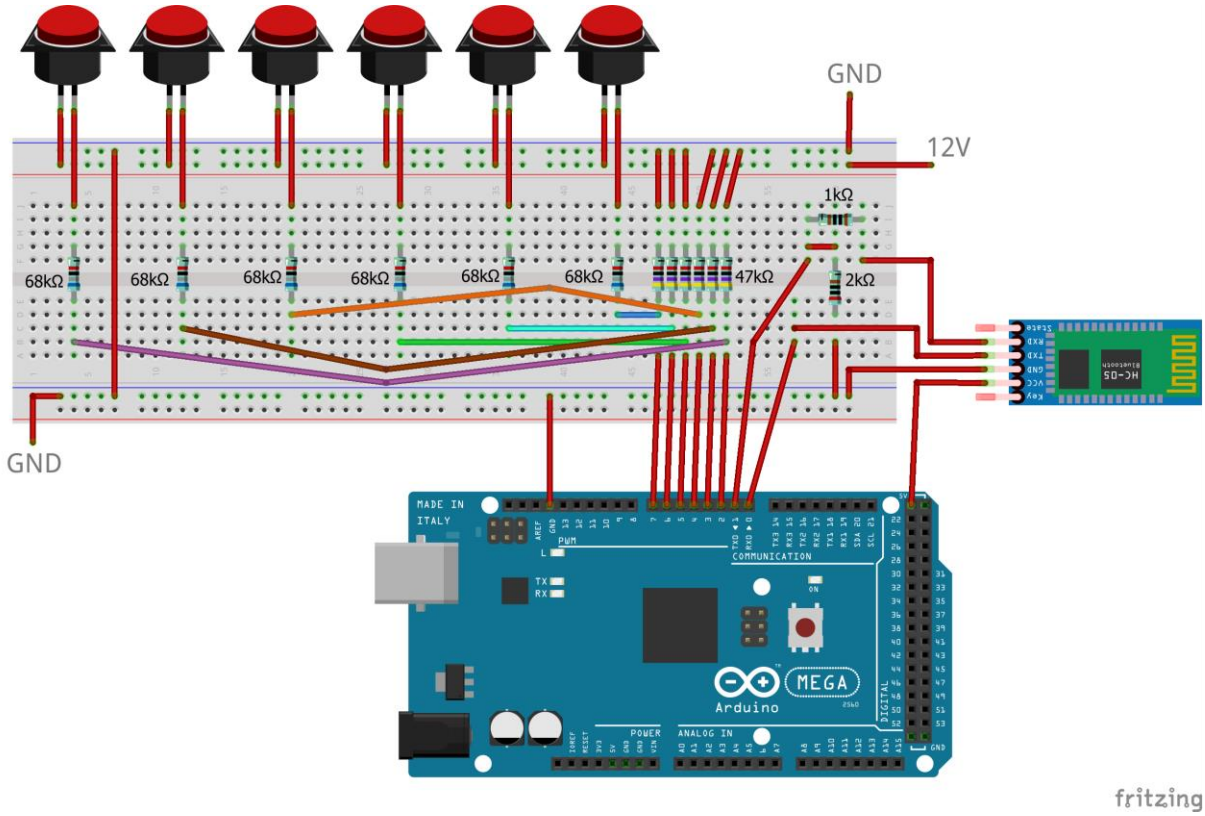

Figure 18: Schematic of the circuit utilized for the Playware object

3.4 Game Engine

During the preparation phase for the work described in this dissertation, one important decision was regarding the software to develop the mobile application. After working with Android Studio and Unity, the later ended up being the chosen program to create the serious game. This choice was not because Android Studio was unqualified for the creation of the app, but because Unity was more appropriate since it is a game engine, providing a better range of game-like functions.

Unity is a cross-platform game engine that supports both 2D and 3D development of video games for computers, consoles and mobile devices. Paired with Microsoft Visual Studio, which is used for the creation of C# scripts, Unity presents an intuitive and practical interface to develop game applications. Furthermore, it also has a free version for students and a large online community with members that are mutually helpful.

Titles such as Angry Birds 2, Plague Inc., Hearthstone: Heroes of Warcraft, Ori and the Blind Forest, Pokémon Go, Super Mario Run and Albion (between many other games) were all created with Unity.

3.5 Game Design

The serious game is the core of the application, because it is where all the information is centered. It was developed for Android and, during the test phase, it was played in an Android tablet. Upon the start, the serious game opens the main screen, i.e., the menu (Figure 19, in Portuguese). From the menu, the user can choose one of the three game modes to play (imitation, recognition or storytelling), access the options menu – figure 20 - (to adjust the volume, start the Bluetooth connection or access the scoreboard) or quit the game.

The scoreboard displays the information gathered during the user's playthrough of the game. Its displayed always in the same template form, displaying first the game mode and the avatar/scenario that is being displayed, followed by the answer provided by the user and the time necessary to provide that answer, in seconds.

Figure 19: The serious game main menu (in Portuguese) – Imitation, Recognition, Storytelling and Options buttons respectively.

Figure 20: The serious game options menu (in Portuguese) - Status text box, volume slider, scoreboard button, Bluetooth connection button and Menu button respectively.

Visually, the serious game has a very simplistic and clean design, not only in the main menu, but also throughout the game itself, so the users' attention will not change its focus towards unnecessary features. Note that the chosen game language is Portuguese, due to the target group.

The avatars that where created specifically for this application are represented in figures 21 to 23. The six main avatars have very simplistic facial features, focusing on the emotion that they are meant to portray. This was achieved through trial and error and the finished versions were validated and utilized during the test phase of the project (detailed information about the validation process is present in chapter 4).

The creation of these avatars was possible thanks to a website called Piratetar (https://piratetar.framiq.com/). This tool allows the user to modularly pick between a large set of options (such as eye styles, mouth styles, eyebrow styles and so on), which facilitates de fine tuning of facial expressions.

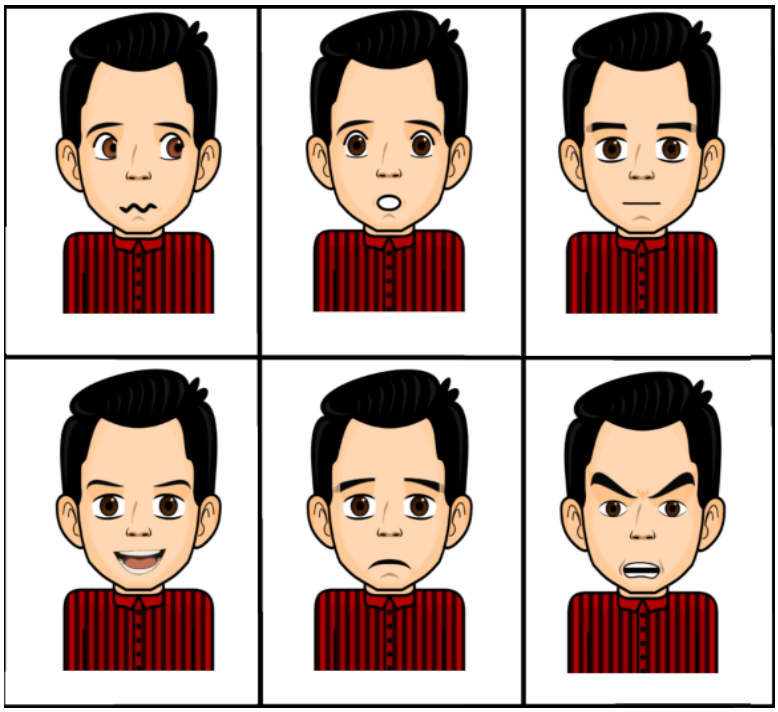

Figure 21: Avatars created to represent specific facial expressions – from left to right, first row: fear, surprise, neutral; second row: happiness, sadness, anger.

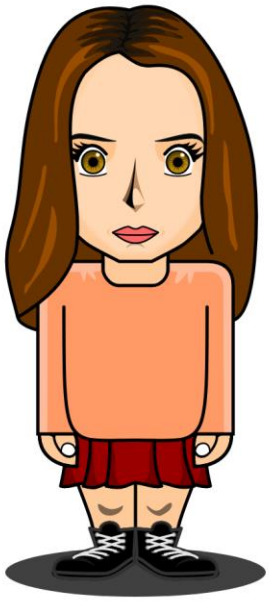

Figure 22: Female avatar that is present in some sections of the game

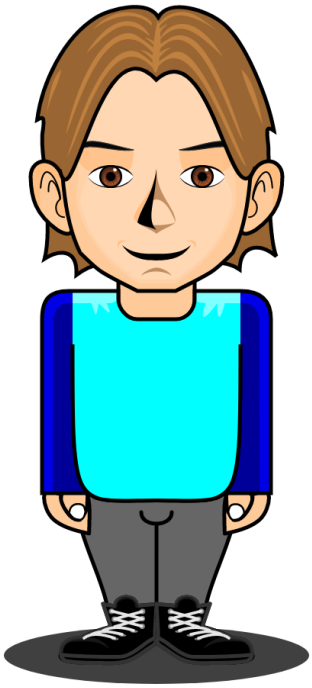

Figure 23: Male avatar that is present in some scenarios of the storytelling activity

3.6 Experimental set-up and test methodology

A meeting took place in the school, previously to the beginning of the tests, where the team gathered with the professionals that work daily with the children with ASD (teachers and therapists). During that time, the application was explained, as well as our goals and how the tests would happen. The final agreement was that after receiving the consent forms filled by the children's parents, the usability test with typically developing children and the tests with children with ASD during four sessions could start. Each child performed the test individually, assisted by a teacher/therapist when required, and accompanied by at least one member of the project's team. The sessions with children with ASD were also video recorded, which allowed a better analysis of the results.

These sessions took place in a separate room, where the child that was playing the game was isolated from distractions from other children or school personnel (Figure 24). The space designated for this purpose only had a table, chairs (usually two or three, varying when the user was accompanied by a professional), the application and the camera equipment necessary to make the recordings.

Each session had the duration of 15 to 45 minutes, depending on the child that was using the application at that time and the number of game activities that child performed.

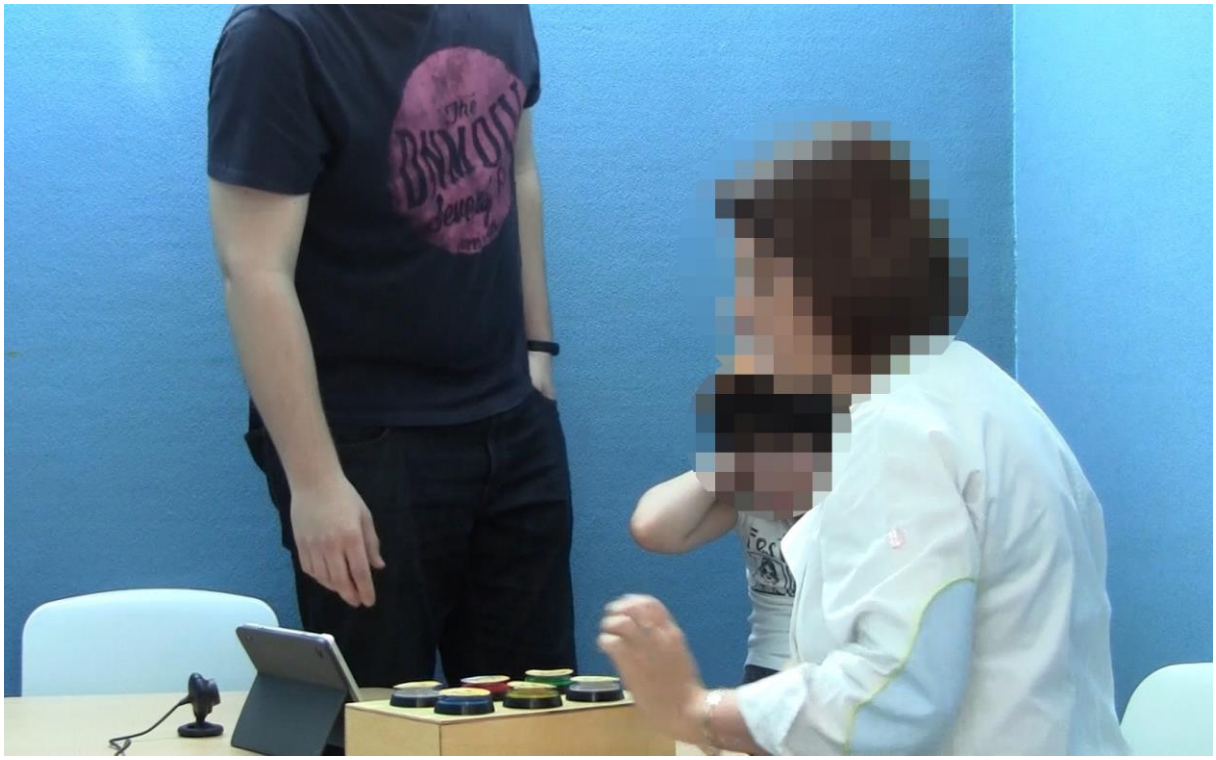

Figure 24: The beginning of one of the sessions

Resuming, the application makes uses of the concepts of both serious games and playware objects to achieve the goal of promoting emotional skills in children with ASD. To accomplish this, three game activities were implemented in the serious game and a playware object was developed. For the task of representing the different facial expressions, avatars were created and incorporated in the different game modes and emojis were utilized for the playware object.

The system works as intended and performed several tests. The different tests and the data gathered from them are detailed in the following chapter.

4. RESULTS

Several tests were performed in the elementary school with typically developing children and children with ASD and a questionnaire was created and filled by several people. This questionnaire had the purpose of validating the avatars created to portray the different facial expressions and was the first step in the chain of tests. Typically developing children were then asked to play the recognition activity, which had the intention of assessing the application's usability. Lastly, the game (with all three game modes) was tested with its target group, i.e., children with ASD.

In the following sub-sections are presented the results gathered from the different phases of testing and validation, starting with the questionnaire, followed by the usability tests with typically developing children and closing with the activities performed by children with ASD.

4.1 Questionnaire

After creating the different avatars representing each of the six facial expressions there was a need to validate the suitability and relevance of those images before implementing them in the application. For this purpose, an online questionnaire (which is available in the appendixes section) was developed and presented to different groups of teenagers and professionals with experience in aiding students with ASD, with ages ranging between 17 and 58 years old. The volunteers were asked to answer 6 pairs of questions (previously validated by an specialist in the field of ASD), each pair being composed by a question where they had to label the emotion the displayed avatar was portraying, followed by a secondary question where they were asked to specify how well that emotion was being represented by the avatar, in a scale of 1 to 5 (with 1 being the worst, 3 being neutral and 5 being the best answer).

In total, the form had 114 submissions, 71 being from female individuals and 44 from males, with an mean age of 27.2 years. After analyzing all the entries, each image had an accuracy of over 90% regarding the emotion that it was trying to portrait (Figure 25). These numbers correspond to fear – 94.7%, surprise – 93%, neutral – 95.6%, happiness – 99.1%, sadness – 98.2% and anger – 99.1%.

Regarding the answers for the secondary question (specify how well that emotion was being represented by the avatar), the average values in the scale of 1 to 5 previously mentioned were: fear – 3.9, surprise – 4.3, neutral – 4.2, happiness – 4.7, sadness – 4.5 and anger – 4.9.

With these results, the avatars were deemed validated and integrated in the serious game, without suffering any more changes.

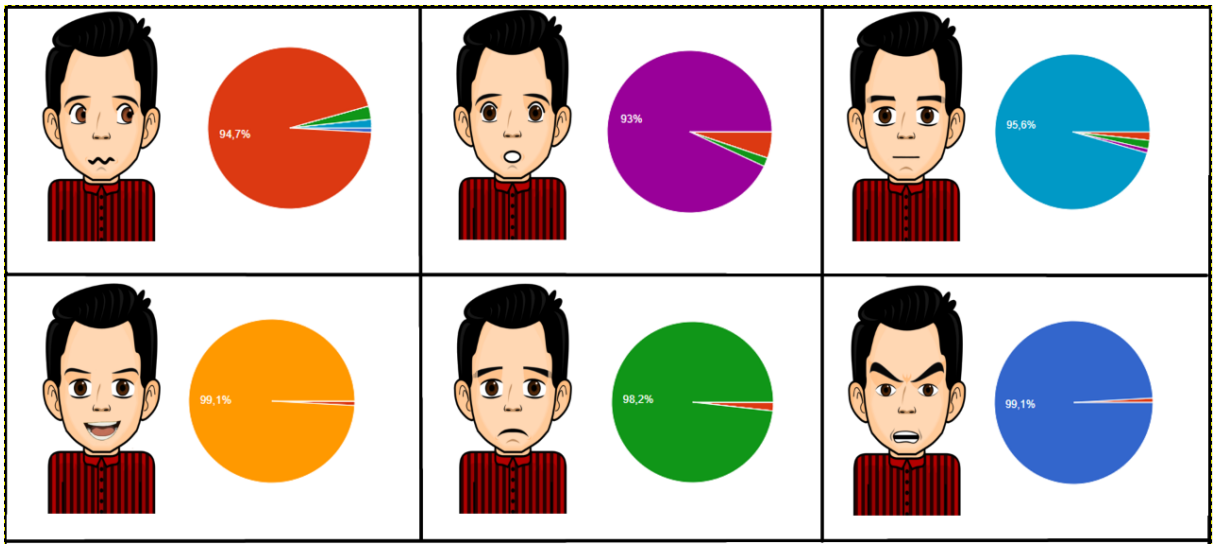

Figure 25: Data gathered from the answers to the questionnaire. Note that the colours represent the following facial expressions: red – fear; purple – surprise; light blue – neutral; orange – happiness; green – sadness; dark blue – anger.

4.2 Results with Typically Developing Children

The next step was to test the recognition activity with typically developing children in order to validate the application's usability. The target group was constituted of six children of the elementary school (three males and three females), with ages of 6 to 7 years old, that performed the task individually, each not taking more than ten minutes. They were asked to look at the avatars that were presented and after stating what emotion it was representing they would choose the emoji they considered to more accurately represent it (recognition game mode). This process was repeated for each of the six avatars and their answers were registered. After analyzing the data gathered, the mean accuracy of their answers was 94.4%.

It is worth noting that these children showed no difficulty playing the game or interacting with the playware object and stated that it was enjoyable, and they would do it again.

4.3 Results with Children with ASD

The last round of tests was performed over the course of a maximum of four sessions with children with ASD (three males and three females) from the elementary school, with ages ranging between 6 to 10 years old (mean age 8 +- 1.7), where data was saved considering the time they took to answer and if that

answer was correct or not. They are part of a special unit in the elementary school to work with children with ASD and some of them (mostly the older ones) have been accompanied by professionals for some time.

For the purpose of anonymity, the children will be referred as subject 1 to 6 (or S1 to S6).

4.3.1 Subject 1

The teachers considered that the activities of recognizing and imitating facial expressions, would be easy for Subject 1, but on the other hand, the storytelling game would be challenging for her. This was essentially due to her age and having previously worked with facial expressions and emotions.

In fact, as it is visible in figures 26 to 28, the tasks of both the imitation game mode, as well as the recognition game mode were executed flawlessly, and it is possible to see a significant increase in the percentage of correct answers between both sessions for the storytelling game mode.

It is to note that subject 1 was highly participative and stated that she enjoyed these activities very much.

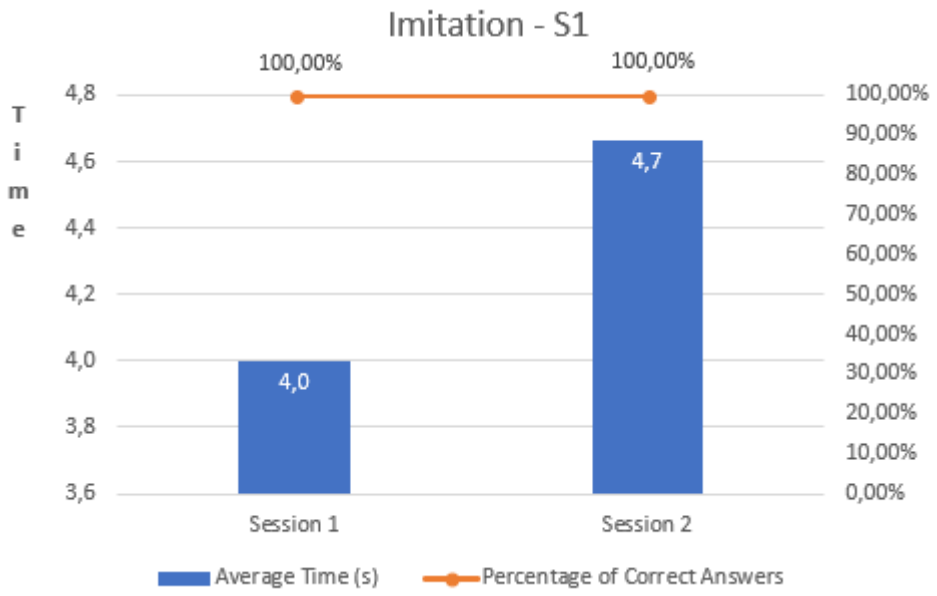

Figure 26: Results for the imitation game activity from S1

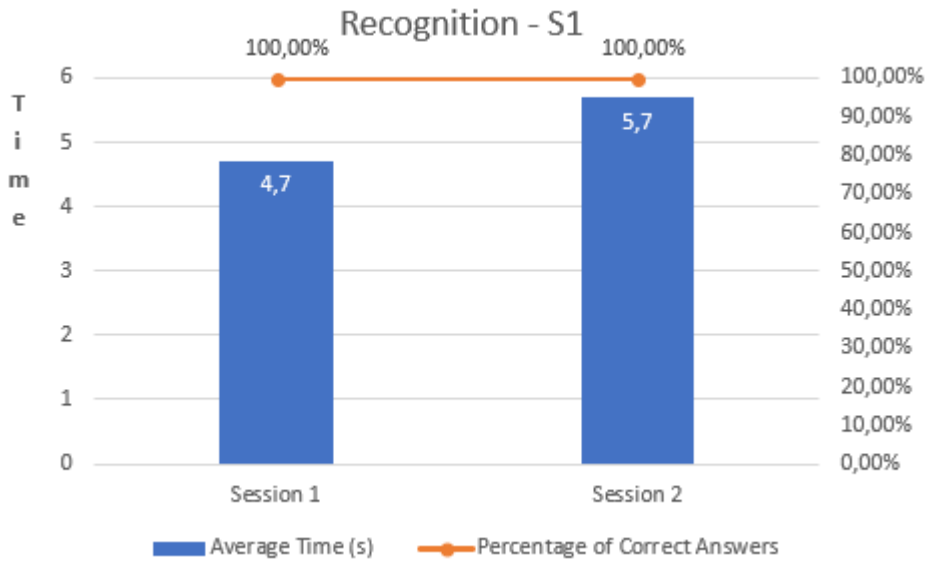

Figure 27: Results for the recognition game activity from S1

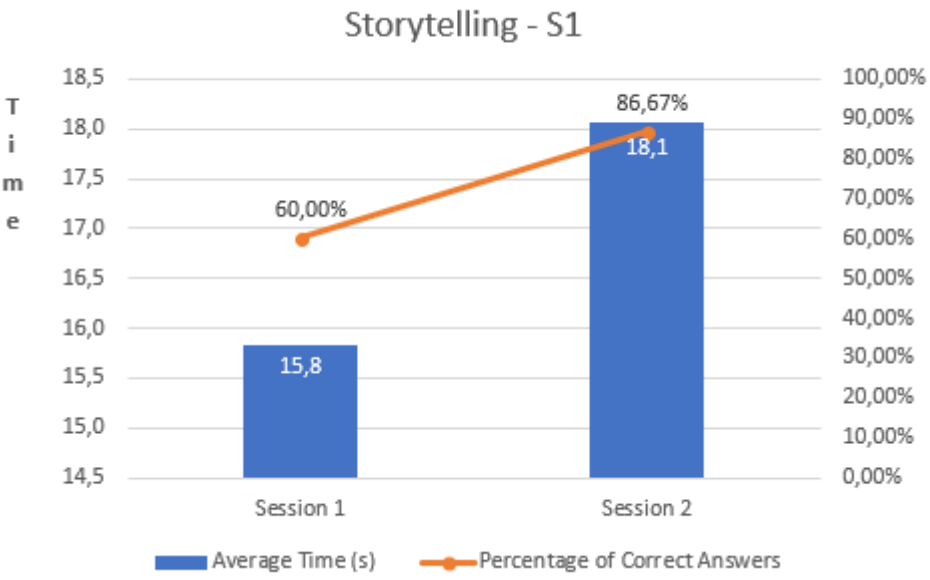

Figure 28: Results for the storytelling activity from S1

4.3.2 Subject 2

Subject 2 demonstrated a good understanding of the game and it is clearly visible the improvement in both time and percentage of correct answers for the recognition activity (Figure 30).

The imitation game mode was slightly more difficult, but S2 was able to identify emotions and replicate them, for the most part (Figure 29).

The storytelling activity was by far the hardest (Figure 31), which was expected. It should also be mentioned that even though the number of correct answers for this game mode improved in the second

session, the therapist needed to be more interventive, which did not happen for the two other game modes, in any of the sessions.

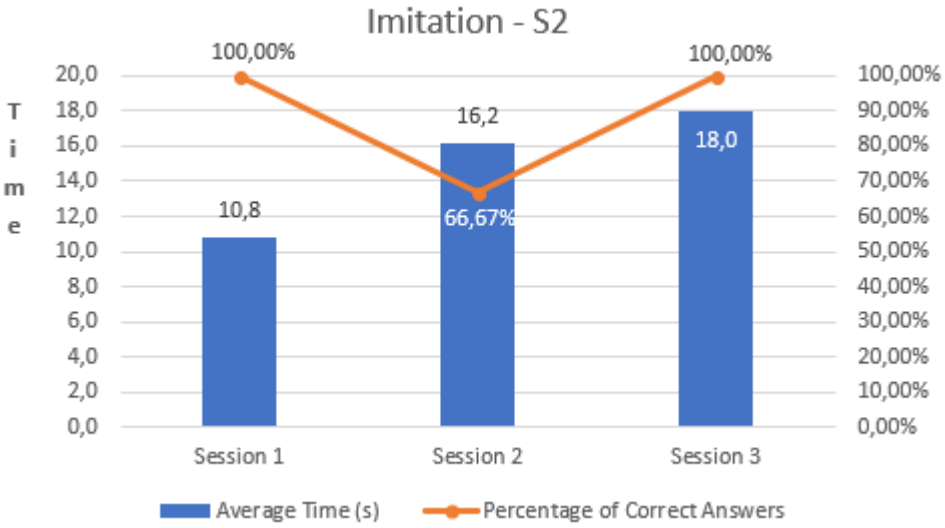

Figure 29: Results for the imitation game activity from S2

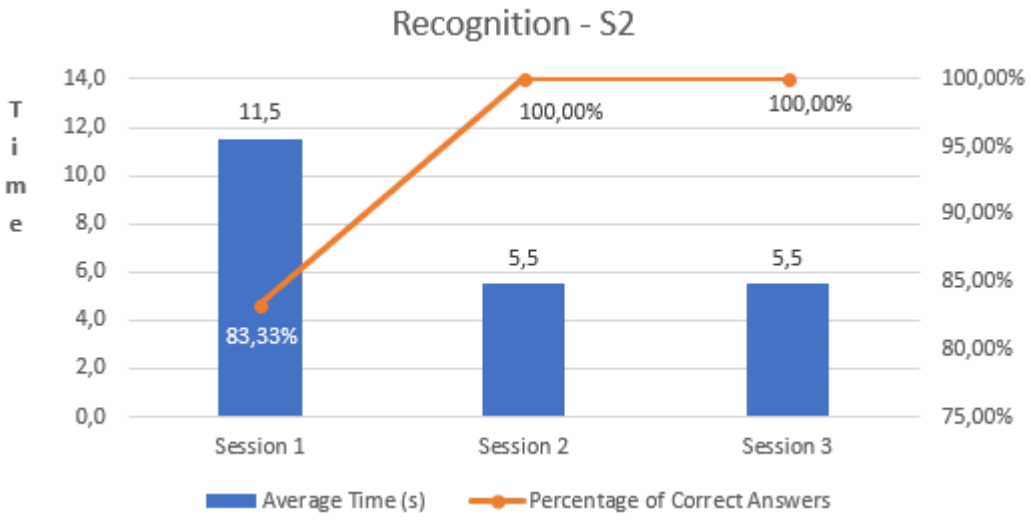

Figure 30: Results for the recognition game activity from S2

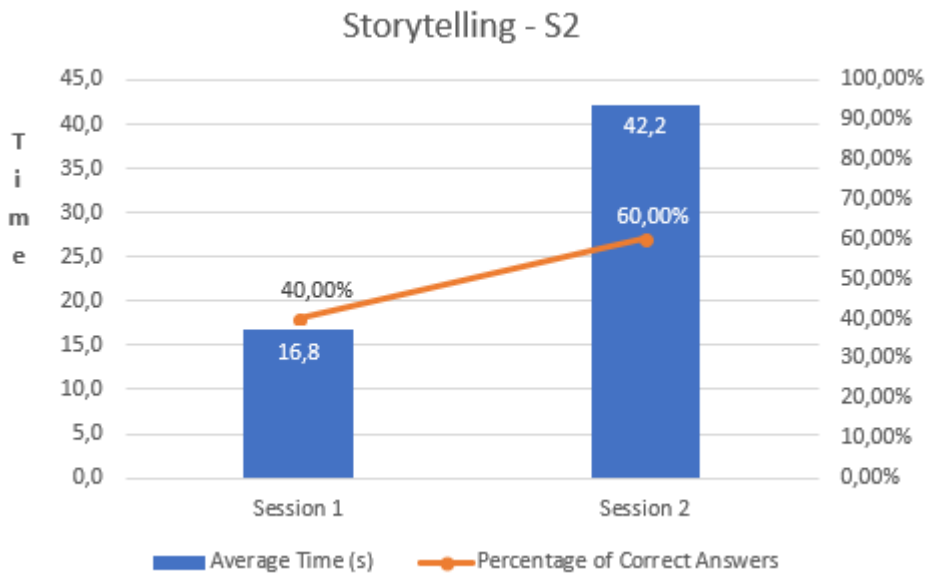

Figure 31: Results for the storytelling game activity from S2

4.3.3 Subject 3

This child had already studied emotions before and was very participative, which contributed to the good performance demonstrated and visible in figures 32 to 34. The main issue was the "fear" of giving wrong answers, something that was more present in the last sessions and even led him to quit the activity. Improvements are very visible, especially in the first two game modes.

The storytelling activity is a particular case, because the data gathered from session 1 is only regarding seven answers. Subject 3 quit the activity at that point and only completed all the fifteen stories on the second session.

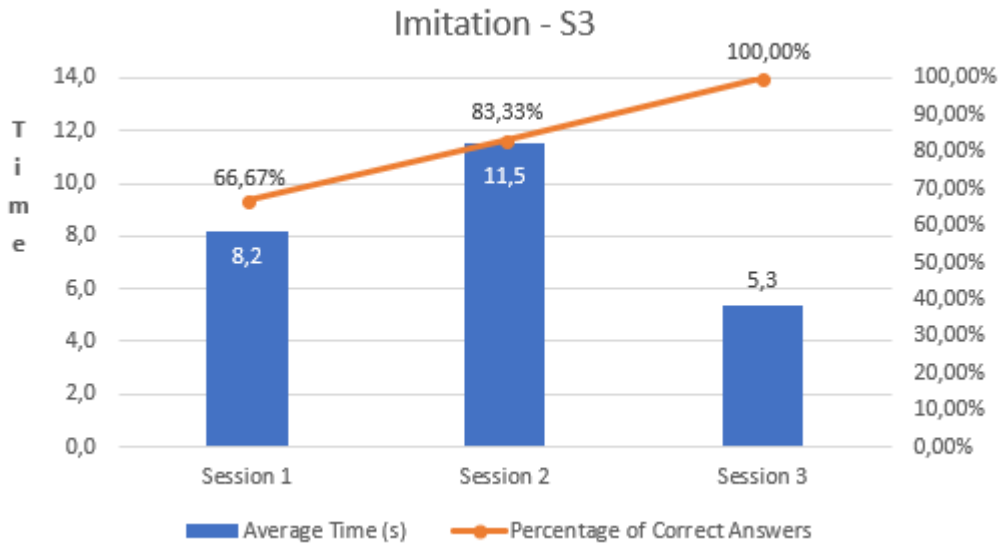

Figure 32: Results for the imitation game activity from S3

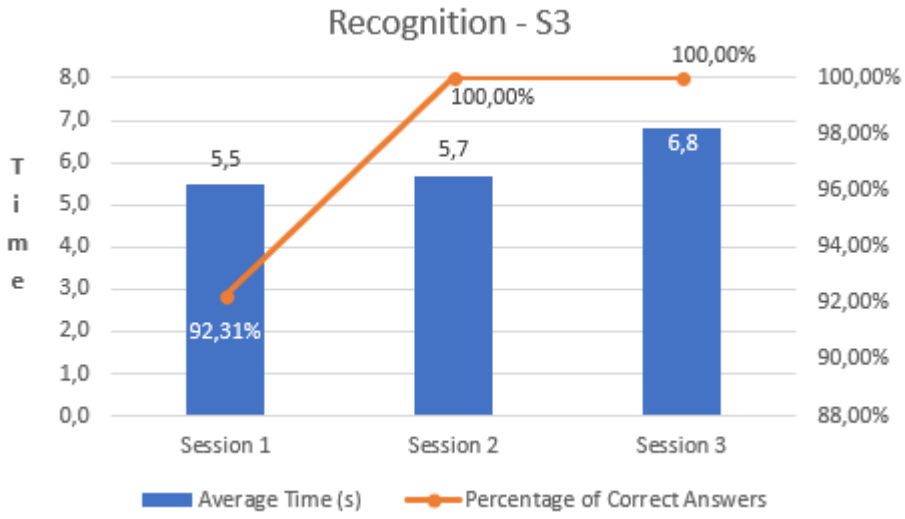

Figure 33: Results for the recognition game activity from S3

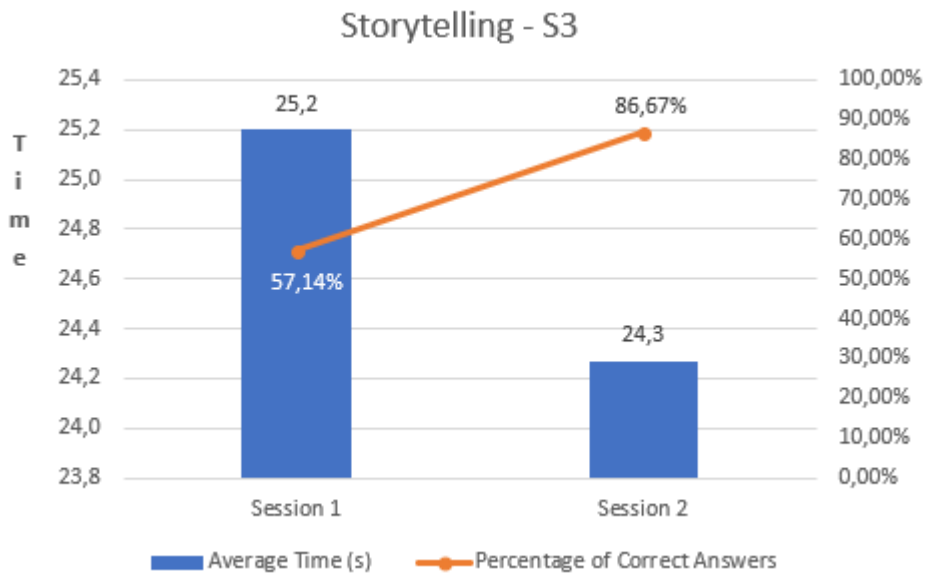

Figure 34: Results for the storytelling game activity from S3

4.3.4 Subject 4

Subject 4 was very young (6 years old) and had a lot of difficulties playing the game in a correct manner. Most of the time he was distracted, focusing on the screen of the Android device and trying to touch the avatar's face. He could not replicate emotions and did not show any interest in doing so, which led the activity to fail completely.

The recognition game mode followed similar steps. The therapist had to intervene in the session trying to obtain an answer from the child, which was almost always the wrong one.

Since both the imitation and the recognition activities were unsuccessful, the conclusion was that there was no point in keep trying during further sessions, because he would not engage in the activity, due to the lack of attention demonstrated.

4.3.5 Subject 5

This child was very participative and autonomous, stating more than once that the game was interesting and funny to play.

Her main difficulty was interpreting emotions, especially when those emotions were shown by the emojis. In the imitation game mode, she had an easier time replicating the facial expressions than identifying emotions (Figure 35).

Similarly to the imitation activity, the recognition game was played during all four sessions. The results are visible in figure 36 and show an improvement in the number of correct answers, even though interlinked with an increase in response time.

The storytelling activity was the one where she showed more difficulties (Figure 37), what was expected since she would have to interpret specific situations and have a deeper knowledge regarding emotions.

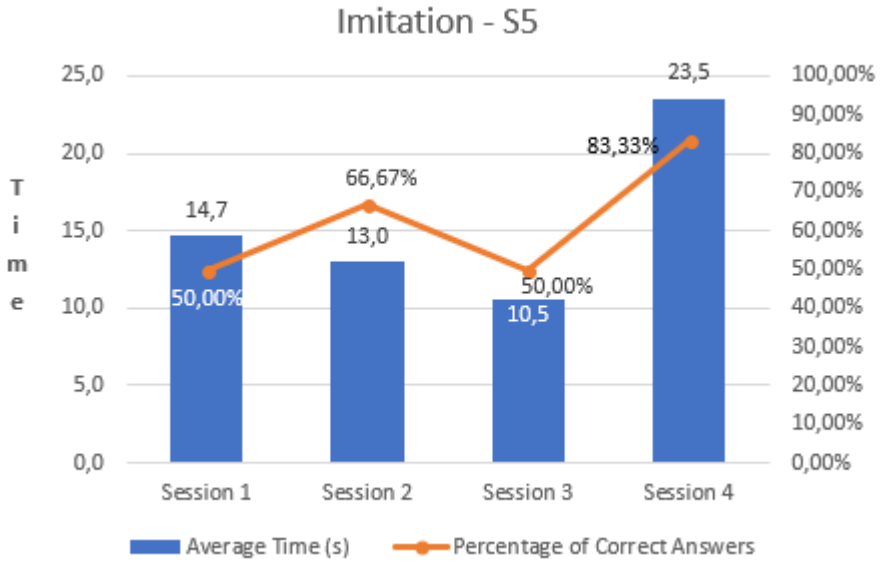

Figure 35: Results for the imitation game activity from S5

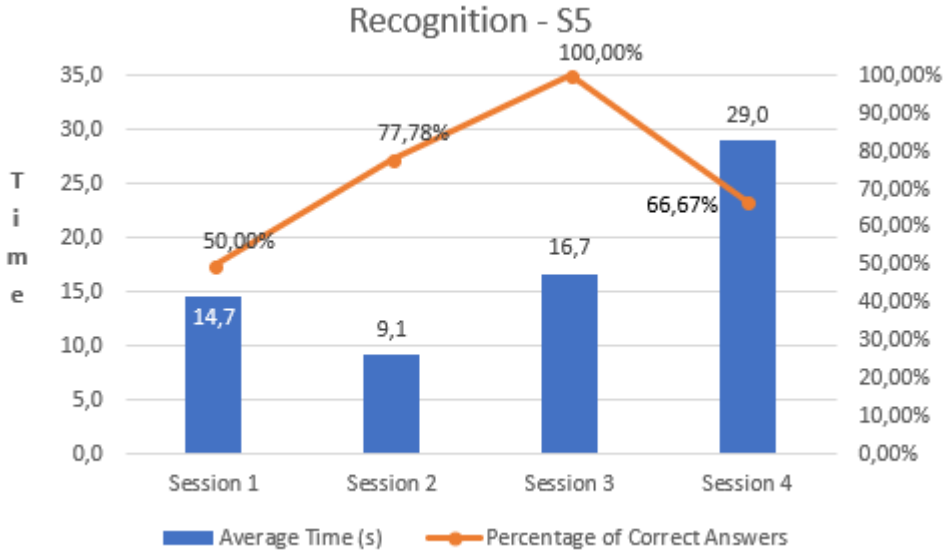

Figure 36: Results for the recognition game activity from S5

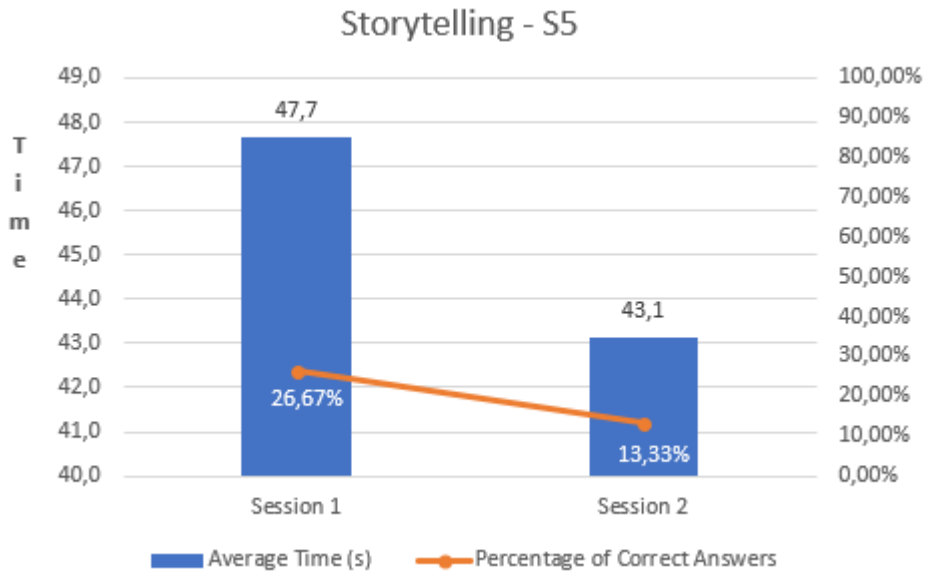

Figure 37: Results for the storytelling game activity from S5

4.3.6 Subject 6

No data was gathered regarding subject 6 because he did not engage in the activity at all.

The lack of attention was the main issue. This child went into the room and shifted his focus between everyone and everything around him. Furthermore, he could not understand the game or even pay attention to the application long enough to start playing.

4.4 Discussion

Each test phase was successful, with the results falling in line with what was expected.

The online questionnaire counted with the participation of a very positive number of people (114) and the outcome was excellent, which validated the avatars.

The usability test, even though it was only performed by six children, also demonstrated the easiness to play the game and the attractiveness of the application.

The tests performed with children with ASD, despite the small sample size and the small number of sessions, had as the main objective to assess if this application could be a tool to complement and improve the more regular interventions during these children's learning process. All the feedback from the tests point in that direction, since the application was considered engaging and interesting to work

with. The professionals that accompany the children with ASD also showed their interest and provided their approval regarding the methodology and the application itself.

5. Conclusions and Future Work

This dissertation presents the work developed using a serious game and a playware object, aimed at improving the socio-emotional skills of children with ASD.

Serious games are an excellent tool to help the user to understand specific concepts without the act of learning becoming "boring" or tiresome, essentially because information is being assimilated while doing an activity that is enjoyable.

Playware follows identical lines, where the user is engaging with a physical object that is not static, meaning that it will react differently depending on the input provided. This type of interactive tool is very attractive from a user point of view and its inclusion will make some activities more interesting, increasing play time.

The main goal of this study was to develop and validate an application intended to contribute to the development of pedagogical resources to be used by professionals and families in the support of children with ASD, and its impact validated in future work.

The application approaches six basic facial expressions (happiness, anger, surprise, sadness, fear and neutral/normal) and follows the work done by Sandra Costa (Costa et al., 2014).

A serious game and a playware object were created and tuned to work with each other, the later acting as a controller for the game, allowing the user to physically interact with the virtual world.

A set of avatars was also developed to incorporate in the serious game. These portray the previously mentioned emotional states and were validated through an online questionnaire with excellent results (all over 93%).

The system was first tested with six typically developing children to evaluate the application constraints, which proved to be successful and engaging. Similar to the results obtained with the questionnaire for the avatars, the children that performed this usability test also had a very high success rate (mean accuracy of 94.4%).

Finally, four sessions were followed with six children with ASD. The purpose of the game and the instructions on how to play it were very well assimilated and the playware object alongside the serious game revealed itself to be a very attractive and intuitive tool to interact with.

The tests with children with ASD allowed to infer that using serious games with playware object as intermediate in the interaction may be an adequate tool. In fact, children reacted positively, giving the answers by pressing the buttons.

Even though the sample size was too small, improvements were visible, indicating that this type of tool could act as a mediator in the learning of emotional skills.

Future work with the application will be based on more testing, with a larger group and over a larger period. This type of testing allows for a better support and provides more reliability to the results and respective conclusions, consequently determining if this type of tool really acts as a facilitator in the learning of social skills. There is also a high possibility of integrating this application with other works developed by the group Robótica-Autismo (http://robotica-autismo.dei.uminho.pt/) which would involve humanoid robots like ZECA (Costa et al., 2014).

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APPENDIXES

A. Consent form delivered to the parents of typically developing children (in Portuguese)

Exmo.(a). Senhor(a) Encarregado(a) de Educação/Tutor(a),

O **projeto Robótica-Autismo** (http://roboticaautismo.com) visa a aplicação de ferramentas robóticas como forma de melhorar as habilidades de interação e comunicação das crianças com Perturbações do Espectro do Autismo (PEA). No âmbito de teses de Mestrado e de Doutoramento em Engenharia Eletrónica Industrial e Computadores da Universidade do Minho estamos a desenvolver um sistema de imitação e reconhecimento de emoções em que um jogo de computador e o robô Zeca são os mediadores da interação. Numa primeira fase gostar´amos de trabalhar com crianças do 1º ciclo sem PEA de forma a validar o sistema. Assim, gostar´amos de convidar o seu educando a participar nas sessões de teste: a criança deve exprimir ou adivinhar uma emoção (contente, triste, medo, zangado, assustado ou neutro). Estas sessões têm uma duração de cerca de 10 minutos, são realizadas durante o tempo letivo, mas sem preju´zo do normal funcionamento das aulas, NÃO são gravadas e as respostas são anónimas. Solicitamos, assim, a sua colaboração dando o seu consentimento através da devolução do anexo devidamente preenchido e assinado.

7 de Maio de 2018

Filomena Oliveira Soares
Coordenadora Científica do Projeto Robótica-Autismo
Professora Associada do Departamento de Electrónica Industrial da Universidade do Minho

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Eu_____encarregado(a) de Educação do(a)/tutor(a) do(a) _____ declaro ter compreendido os objetivos do estudo, ter-me sido dada a oportunidade de fazer todas as perguntas sobre o assunto e para todas elas ter obtido resposta esclarecedora, ter-me sido garantido que não haverá preju´zo para os direitos assistenciais se eu recusar esta solicitação, e ter-me sido dado tempo suficiente para refletir sobre esta proposta. Declaro também que autorizo o meu (a minha) educando(a) a participar no Projeto de Investigação Robótica-Autismo, em particular na interação com o robô Zeca.

Fui informado(a) que:

- Os resultados decorrentes desta investigação serão utilizados única e exclusivamente na divulgação cient´fica do projeto.
- Os dados pessoais e os dados obtidos na investigação não serão divulgados e serão mantidos por um período de dez anos, ao fim do qual serão destruídos.
- Todas as informações de caráter pessoal recolhidas no decurso da investigação serão consideradas confidenciais e tratadas de acordo com as regras relativas à proteção de dados e da vida privada.
- Se o encarregado(a) de educação/tutor(a) o entender, o aluno (a aluna) pode abandonar o projeto em qualquer altura.
- A participação, a recusa na participação ou o posterior abandono do(a) encarregado(a) de educação/tutor(a), e/ou a do seu (da sua) dependente não prejudicarão a relação com a equipa de investigadores.
- Não se preveem quaisquer riscos para os participantes durante as sessões. Caso a criança demonstre desconforto, a sessão será terminada.

_____

Assinatura Completa do(a) Encarregado(a) de Educação e/ou tutor(a)

Figure 38: Consent form delivered to the TDC's parents (in Portuguese)

B. Consent form delivered to the parents of children with ASD (in Portuguese)

Exmo.(a). Senhor(a) Encarregado(a) de Educação/Tutor(a),

O **projeto Robótica-Autismo** (http://roboticaautismo.com) visa a aplicação de ferramentas robóticas como forma de melhorar as habilidades de interação e comunicação das crianças com Perturbações do Espectro do Autismo (PEA). No âmbito de teses de Mestrado e de Doutoramento em Engenharia Eletrónica Industrial e Computadores da Universidade do Minho estamos a desenvolver um sistema de imitação e reconhecimento de emoções em que um jogo de computador e o robô Zeca são os mediadores da interação. Assim, gostaríamos de convidar o seu educando a participar nas sessões de teste: a criança deve exprimir ou adivinhar uma emoção (contente, triste, medo, zangado, assustado ou neutro). Estas sessões têm uma duração de cerca de 10 minutos, são realizadas durante o tempo letivo, mas sem prejuízo do normal funcionamento das aulas. As sessões serão gravadas em vídeo e as respostas são anónimas. Em caso de divulgação científica dos vídeos, a cara da criança será desfocada. Solicitamos, assim, a sua colaboração dando o seu consentimento através da devolução do anexo devidamente preenchido e assinado.

7 de Maio de 2018

Filomena Oliveira Soares
Coordenadora Científica do Projeto Robótica-Autismo
Professora Associada do Departamento de Electrónica Industrial da Universidade do Minho

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Eu _____ encarregado(a) de Educação do(a)/tutor(a) do(a) _____ declaro ter compreendido os objetivos do estudo, ter-me sido dada a oportunidade de fazer todas as perguntas sobre o assunto e para todas elas ter obtido resposta esclarecedora, ter-me sido garantido que não haverá prejuízo para os direitos assistenciais se eu recusar esta solicitação, e ter-me sido dado tempo suficiente para refletir sobre esta proposta. Declaro também que autorizo o meu (a minha) educando(a) a participar no Projeto de Investigação Robótica-Autismo, em particular na interação com o robô Zeca.

Fui informado(a) que:

- Os resultados decorrentes desta investigação serão utilizados única e exclusivamente na divulgação científica do projeto.
- Os dados pessoais e os dados obtidos na investigação não serão divulgados e serão mantidos por um período de dez anos, ao fim do qual serão destruídos. Em caso de divulgação científica dos vídeos, a cara da criança será desfocada.
- Todas as informações de caráter pessoal recolhidas no decurso da investigação serão consideradas confidenciais e tratadas de acordo com as regras relativas à proteção de dados e da vida privada.
- Se o encarregado(a) de educação/tutor(a) o entender, o aluno (a aluna) pode abandonar o projeto em qualquer altura.
- A participação, a recusa na participação ou o posterior abandono do(a) encarregado(a) de educação/tutor(a), e/ou a do seu (da sua) dependente não prejudicarão a relação com a equipa de investigadores.
- Não se preveem quaisquer riscos para os participantes durante as sessões. Caso a criança demonstre desconforto, a sessão será terminada.

_____

Assinatura Completa do(a) Encarregado(a) de Educação e/ou tutor(a)

Figure 39: Consent form delivered to the parents of children with ASD (in Portuguese)

C. Article submitted for the conference "Joint Conference on Serious Games 2018"

An Application to Promote Emotional Skills in Children with Autism Spectrum Disorders

Abstract. This paper presents an approach regarding the use of a serious game with a playware object to improve the development of emotional skills in children with Autism Spectrum Disorder (ASD). The playware object is an interactive way for the user to play the game. It acts as the game controller, has six buttons, each displaying an emoji with a different facial expression, and communicates wirelessly with the android device through Bluetooth. For this purpose, the six facial expressions tested are happiness, sadness, fear, anger, surprise and a neutral/normal, which were implemented in three different game activities: imitation, recognition, and storytelling. The avatars used in the game to represent these facial expressions were first validated through an on-line questionnaire (with 114 answers) with a mean success rate of 96.2%. In order to assess the usability of the game and the playware object, a test was performed with six typically developing children, with 94.4% answer accuracy. At last, the recognition activity was tested with six children with ASD during three/four sessions. Due to the small group test and the short number of sessions, the goal was to test the acceptance of the game rather than the users´ improvement in the activity. It is worth referring that both the serious game and the playware object had a high level of approval from the children and they expressed their interest during the activities. With this preliminary study its intended to contribute to the development of pedagogical resources to be used by professionals and families in the support of children with ASD.

Keywords: Serious Games, Playware, Autism Spectrum Disorder, Emotions.

D. Article submitted for the conference “SENSORDEVICES 2018”

Serious Games Assisted By Playware As A Way To Improve Socio-Emotional Skills In Children With Autism Spectrum Disorder

***Abstract*—**This paper presents a project developed with the aim of promoting emotional skills in children with Autism Spectrum Disorders (ASD). The project involves a serious game and a playware object, which is a physical component that allows the user to interactively play the serious game. The playware object has six buttons, each one showing an emoji with a specific facial expression and communicates via Bluetooth with the serious game app installed in an Android device. The facial expressions used are: happiness, sadness, fear, anger, surprise and neutral/normal. They were applied to the three game activities (imitation, recognition and storytelling). The chain of tests started with an online questionnaire to validate the avatars created to represent the previously mentioned facial expressions in the game, which was followed by a usability test of the application (serious game and playware object) with six typically developing children. Finally, the three game activities were tested with six children with ASD in three/four sessions. Due to the small test group and reduced number of sessions, the primary objective was to assess if the target group accepted the application. In fact, it had a high level of approval regarding both the serious game and the playware object.

Keywords - Serious Games; Playware; Autism Spectrum Disorder; Emotions.

E. Scenarios and narratives utilized for the storytelling game mode

Figure 40: Storytelling scenario 1

Narrative 1: “My sister’s name is Alice. Alice plays with me in the playground. Today, when we were playing, Alice took my ball. I hate when Alice does that. How did I feel?”

Figure 41: Storytelling scenario 2

Narrative 2: “In the classroom, I like to play with my blocks. My sister Alice sits next to me every day. Alice knocked down my blocks on purpose. How did I feel?”

Figure 42: Storytelling scenario 3

Narrative 3: “Every day I play games with my friend in the classroom. I really like to do puzzles, but when I lose a piece I can’t finish my puzzle. How do I feel when that happens?”

Figure 43: Storytelling scenario 4

Narrative 4: “After dinner I go to my room. When I’m laying in bed, ready to fall asleep, my mother turns of the light. Then, I see shadows on the wall and can’t sleep. How do I feel?”

Figure 44: Storytelling scenario 5

Narrative 5: “On Sunday I go for a walk with my parents. When its good weather, we go to the park and play a lot. One day, while I was playing soccer, I went far away and when I returned I couldn’t find my parents anymore. How did I feel?”

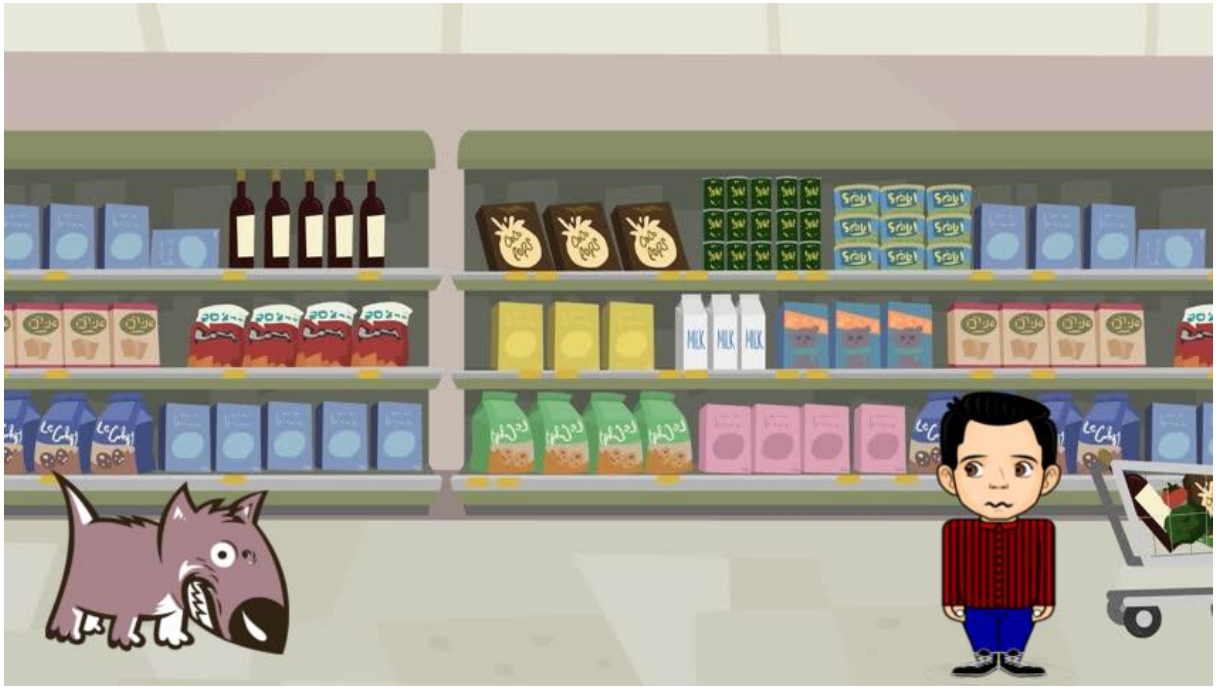


Figure 45: Storytelling scenario 6

Narrative 6: “I go shopping with my mother. I like to choose the yogurts that I’m going to eat. Today, by the exit of the supermarket, a very big dog started barking very loudly. How did I feel?”

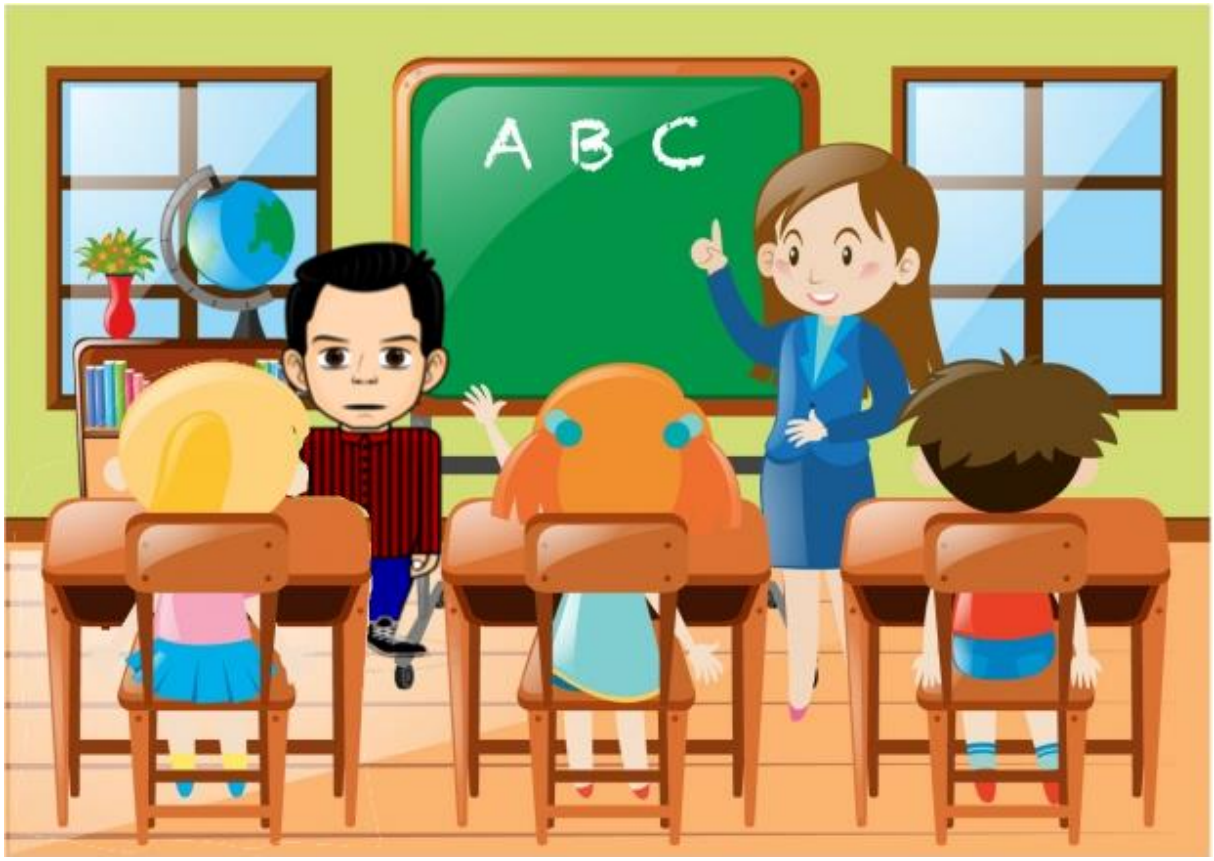


Figure 46: Storytelling scenario 7

Narrative 7: “Every day I go to school. I like to play with my friends. My teacher says that I did a good work. It is so good to be able to do what we like. How did I feel?”

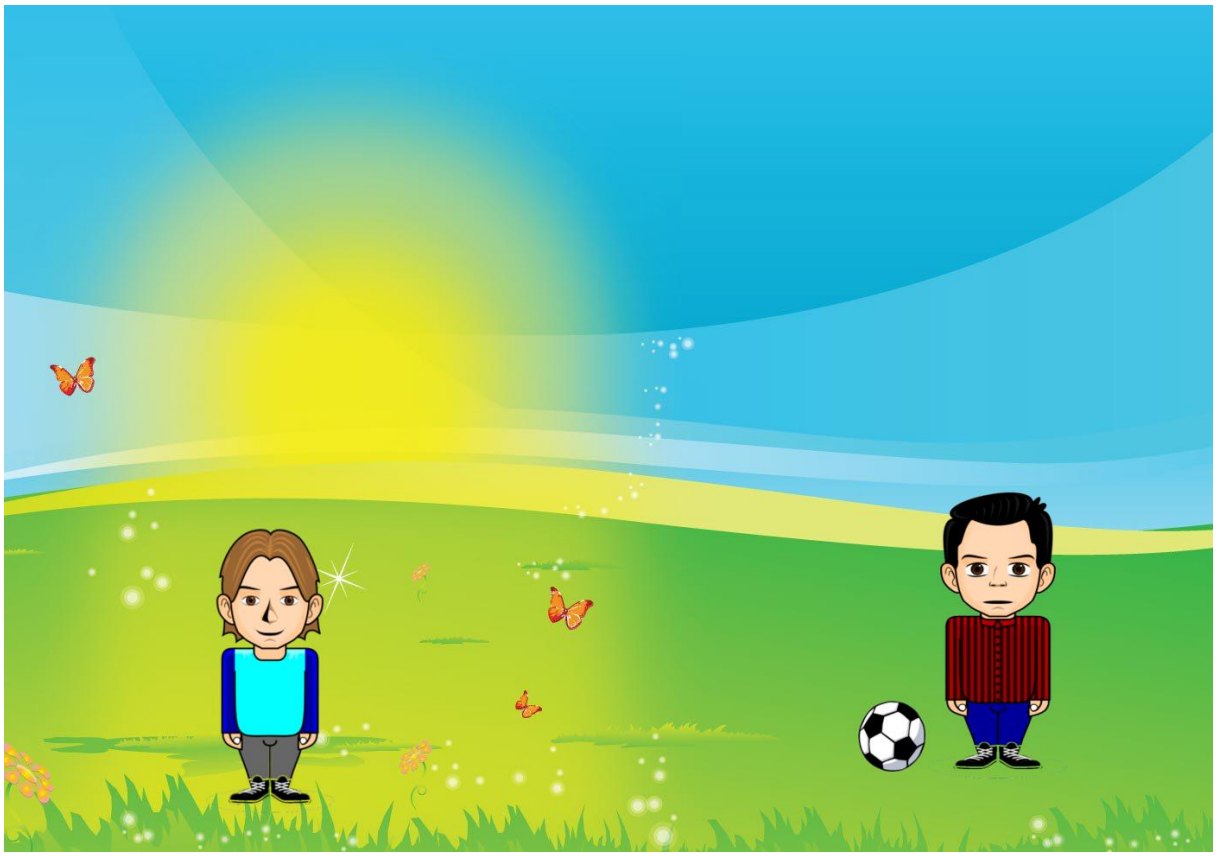


Figure 47: Storytelling scenario 8

Narrative 8: “Today I went for a walk and play soccer with my school friends. Playing soccer is a lot of fun and makes me smile. I smile when I do activities that I like. How does that make me feel?”

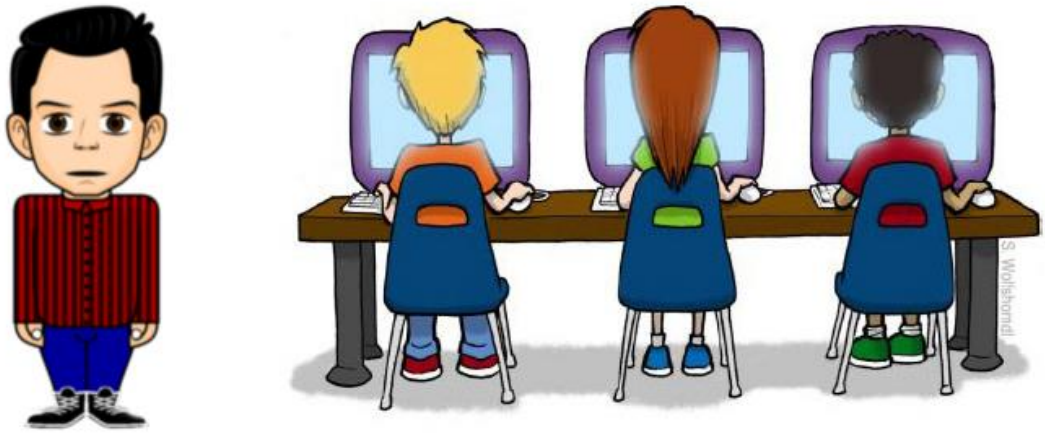


Figure 48: Storytelling scenario 9

Narrative 9: “In my school there are many computers. Sometimes, when another child is using the computer I have to wait. It is so good when its my time to use the computer. How did I feel?”

Figure 49: Storytelling scenario 10

Narrative 10: “When I was playing during playtime, while I was running, I fell. My arm and my leg were hurting a lot. I had a big scratch and I couldn’t stop crying. How did I feel?”

Figure 50: Storytelling scenario 11

Narrative 11: “I like to play when I’m at home. Today I took my ball and played with it in the living room. I gave it a strong kick and broke a window. My mother grounded me and I cried. How did I feel?”

Figure 51: Storytelling scenario 12

Narrative 12: "My friend's name is João. Today, João didn't come to the school. I asked the teacher about João and she said that he was sick. That day I had to play alone. How did I feel?"

Figure 52: Storytelling scenario 13

Narrative 13: “Every day I go to school. One day, when I got in the classroom, everyone screamed “Happy Birthday ZECA!”, because it was my birthday. I was so surprised. How did I feel?”

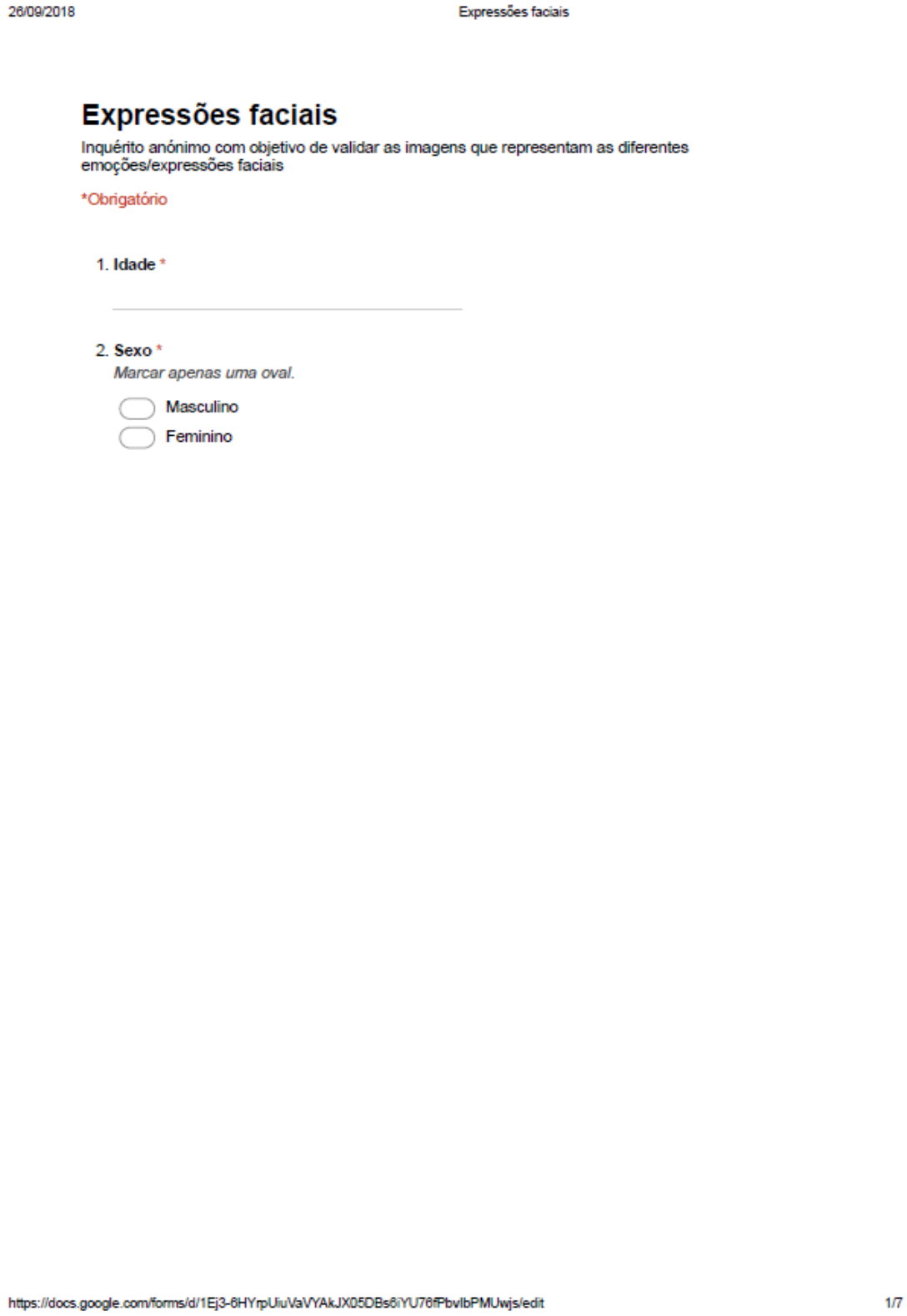
Figure 53: Storytelling scenario 14

Narrative 14: “One day, we played an interesting game in the classroom. During the game, my sister Alice hit me in the arm. But right afterwards, Alice apologized. How did I feel?”

Figure 54: Storytelling scenario 15

Narrative 15: “I love Christmas. And I like it when me and my sister Alice open our Christmas presents. When I opened the big present, I saw that I got the toy that I wanted. How did I feel?”

F. Online questionnaire for avatar validation



26/09/2018 Expressões faciais

Expressões faciais

Inquérito anónimo com objetivo de validar as imagens que representam as diferentes emoções/expressões faciais

*Obrigatório

1. **Idade** *

2. **Sexo** *
Marcar apenas uma oval.
- Masculino
- Feminino

https://docs.google.com/forms/d/1Ej3-6HYrpUiuVaVYAkJX05DBs6iYU76fPbvIbPMUwjs/edit 1/7

Figure 55: Online Questionnaire – Qualitative Questions

3. Que emoção está representada na figura? *

Marcar apenas uma oval.

- ◯ Raiva/Zangado
- ◯ Medo
- ◯ Felicidade
- ◯ Tristeza
- ◯ Surpresa
- ◯ Nenhuma - expressão facial neutra

4. Foi fácil identificar a emoção? *

Marcar apenas uma oval.

	1	2	3	4	5	
Não! A expressão facial precisa de ser melhorada.	◯	◯	◯	◯	◯	Sim! Foi imediato e intuitivo.

Figure 56: Online Questionnaire - Fear

5. **Que emoção está representada na figura?** *

Marcar apenas uma oval.

- ◯ Raiva/Zangado
- ◯ Medo
- ◯ Felicidade
- ◯ Tristeza
- ◯ Surpresa
- ◯ Nenhuma - expressão facial neutra

6. **Foi fácil identificar a emoção?** *

Marcar apenas uma oval.

	1	2	3	4	5	
Não! A expressão facial precisa de ser melhorada.	◯	◯	◯	◯	◯	Sim! Foi imediato e intuitivo.

Figure 57: Online Questionnaire - Surprise

7. **Que emoção está representada na figura?** *

Marcar apenas uma oval.

- ◯ Raiva/Zangado
- ◯ Medo
- ◯ Felicidade
- ◯ Tristeza
- ◯ Surpresa
- ◯ Nenhuma - expressão facial neutra

8. **Foi fácil identificar a emoção?** *

Marcar apenas uma oval.

	1	2	3	4	5	
Não! A expressão facial precisa de ser melhorada.	◯	◯	◯	◯	◯	Sim! Foi imediato e intuitivo.

Figure 58: Online Questionnaire - Anger

9. Que emoção está representada na figura? *

Marcar apenas uma oval.

- ◯ Raiva/Zangado
- ◯ Medo
- ◯ Felicidade
- ◯ Tristeza
- ◯ Surpresa
- ◯ Nenhuma - expressão facial neutra

10. Foi fácil identificar a emoção? *

Marcar apenas uma oval.

	1	2	3	4	5	
Não! A expressão facial precisa de ser melhorada.	◯	◯	◯	◯	◯	Sim! Foi imediato e intuitivo.

Figure 59: Online Questionnaire - Sadness

11. Que emoção está representada na figura? *

Marcar apenas uma oval.

- ◯ Raiva/Zangado
- ◯ Medo
- ◯ Felicidade
- ◯ Tristeza
- ◯ Surpresa
- ◯ Nenhuma - expressão facial neutra

12. Foi fácil identificar a emoção? *

Marcar apenas uma oval.

	1	2	3	4	5	
Não! A expressão facial precisa de ser melhorada.	◯	◯	◯	◯	◯	Sim! Foi imediato e intuitivo.

Figure 60: Online Questionnaire - Happiness

13. Que emoção está representada na figura? *

Marcar apenas uma oval.

- ◯ Raiva/Zangado
- ◯ Medo
- ◯ Felicidade
- ◯ Tristeza
- ◯ Surpresa
- ◯ Nenhuma - expressão facial neutra

14. Foi fácil identificar a emoção? *

Marcar apenas uma oval.

	1	2	3	4	5	
Não! A expressão facial precisa de ser melhorada.	◯	◯	◯	◯	◯	Sim! Foi imediato e intuitivo.

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Figure 61: Online Questionnaire - Neutral