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Augmented Reality-based Graphics Application to Assist Children with Autism Spectrum Disorder

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A Mixed Reality System to Promote Emotion Self-Regulation and Improve Emotional Intelligence of Children with Autism

Abstract

Emotional skills are essential to a child's developmental growth. A child facing challenges in emotional development may potentially face problems in social situations also. Social-emotional skills include the child's ability to recognize their feelings, others' feelings and maintain effective relationships. Evidence shows that children with autism have trouble recognizing social cues, emotions, and facial expressions. In this study we have developed a game that combines elements of observational learning (attention, retention, reproduction, and motivation) and augmented reality to assist children with autism in recognizing emotions in social situations. The prototype involves four day-to-day challenges the fictional 3D character faces-like overcoming fears, using manners, playing with others, and sharing. The framework facilitates the child to solve each problem and move on to the next scene. Augmented reality allows prominent features to be highlighted to enhance the attention and motivation of the child. Being able to explore and interact are critical factors in the learning process. The design of the augmented and mixed reality environments in this study has been done to facilitate a simple learning experience.

Keywords

Augmented Reality, Autism, Emotion, Self-Regulation, Children, Technology.

1. Introduction

Autism spectrum disorders (ASD) are characterized by impairments in verbal and nonverbal communication. Social-emotional reciprocity is one of the core deficits as people with autism face severe problems in developing, maintaining, and understanding relationships with others (American Psychiatric Association, 2013). Emotions play a fundamental role in a child's overall growth and development as it helps establish interpersonal connection early in life (Rump, 2009). According to Papoutsi et al. (2018), people with autistic spectrum disorder have difficulties understanding, expressing, understanding others' emotions, and showing signs of empathy. Research shows that parents with children on the autism spectrum require instructional, experiential, and informational support starting when their children are diagnosed to manage uncertainties, make sense of autism, and reflect on their care practices (Doğa, 2020). Over a decade's research has shown that computer-assisted technology can be used as an educational and therapeutic tool in this population (Ploog, 2012). The design of the augmented and mixed reality environments in this study has been done to facilitate a simple learning experience. Another critical aspect that is closely interrelated to design is 'cueing'. The role and importance of visual, auditory, and tactile cueing in designing augmented environments has been highlighted by many notable works (Angelopoulos, 2018; Janssen, Steveninck, Salim, Bloem, Heida, & Wezel, 2020; Miller, Cooper, & Szoboszlay, 2019; Pangilinan, Lukas, & Mohan, 2019). Visual, auditory, and tactile cues need to be given meticulous consideration in the design process since simultaneous presentation of so much information to the participant all at once without careful consideration can in-fact increase the cognitive overload and can adversely affect the learning process (Oskarsson, Eriksson, Lif, Lindahl, & Hedström, 2008).

We would like to briefly explain the rationale for choosing Augmented and Mixed Reality (AR/MR) for this study. Interactive worlds can be visualized through a wide range of modalities such as desktop VR, CAVE (Computer Assisted Virtual Environments), HMD (Head Mounted Displays, and augmented VR, mixed VR, etc (Chandramouli, Takahashi, & Bertoline, 2014). Each of the aforementioned modalities have advantages and disadvantages. For instance, the high fidelity and immersion offered by the CAVEs comes at a cost of large spaces and cumbersome installation procedures. Furthermore, CAVEs also require significant costs associated with installation, operation and maintenance. On the other hand, dVR (desktop Virtual Reality) systems offer good functionalities for online dissemination and dynamic interaction (real-time). However, the level of immersion and navigation offered by such systems is not comparable to that of the other modes (Chandramouli & Heffron, 2014).

In this study, AR/MR were selected mainly in consideration of the following factors

- Ease of accessibility
- Ease of dissemination to the target audience
- UI/HCI features available through the selected mode

Augmented Reality (AR) technology involves integrating virtual objects and other digital content, including images with physical or real-world content. AR technology functions in multifarious ways to integrate such virtual and real content by superimposing or overlaying them. Research evidence supports AR's potential applications in engaging children in learning, especially for children with disabilities (Chen et al.,2016; Escobedo et al., 2012; Dragomir et al., 2018). Augmented Reality can be used to engage children with autism spectrum disorder as it offers a fun and safe environment for children to learn, play, and grow. In the last couple of years, many researchers have developed various mobile applications to support the needs of children with autism ranging from recognizing, detection and analyzing emotion and social development. An AR learning system to train adolescents with ASD in recognizing various social signals is offered by **"ARSFM"**. Twenty stories were developed to assess the perception of their self-facial emotions and the intentions of others. The effectiveness of the ARSFM system was assessed using a multiple baseline design across three subjects. The research concludes that through repeated ARSFM training, adolescents with ASD can more accurately recognize and appropriately respond to emotional facial expressions in everyday social situations. Augmented reality shows a positive result in adolescents' emotional expression and social skills with ASD (Chen, 2015). **"StoryFaces"** designed a composition and storytelling tool to enable children to explore the role of emotional expressions. The tool allowed children to construct and manipulate stories using their facial expressions. Their results showed that a digital authoring environment could allow young children to collaborate, play, and reflect on their pretend emotions (Kimiko, 2012). **"Tobias in the Zoo"** offers a severe GameBook to assist children with ASD in recognizing and acquire emotions. The tools are designed to increase the attention, motivation, and competence of children with ASD (Brandão, 2015). **"MOSOCO"** offers an AR mobile assistive application that supports the social compass curriculum to help children with autism practice social skills in real-time situations. The Social Compass curriculum is a behavioral and educational curriculum that includes 26 lessons divided into four modules: Nonverbal Communication, Emotion, "We" skills, and Social Problem Solving (Escobedo,2012). The system was deployed in a public-school setting where results showed positive ease of use and students practicing social skills. Research also concluded that smartphones motivated children with autism toward social interactions without the additional prompting of teachers. However, the effectiveness of the system outside the classroom is yet to be studied. This paper explains the design and implementation of a prototype framework to assist children with autism spectrum disorder (ASD) to recognize and acquire emotional skills. This application is intended to aid parents in facilitating better emotional understanding and regulation for their children.

2. Background

2.1. Technology Used

Recent Augmented Reality technology for autistic children is aimed at facial and emotion recognition, visual support, training, and pretend play (Brandão, 2015; Chen, 2015; Chen, 2016). Children with autism have shown positive attitudes towards technology as it can be used to accommodate the child's needs (Brandão, 2015). To train participants for optimal performance and response in such situations requires careful design and cueing. In their work on augmented reality (AR), Pangilinan, Lukas, & Mohan (2019) point out the critical importance of design by stating unequivocally that “designing is for senses and not devices". As explained in the earlier section, the selection of AR/MR for this study was done with this focus on the anticipated learning outcomes by targeting the sensory stimuli. The advantages of technology on children with autism are that it can support their preference for routine and receptive behaviors and offers focused learning in a predictable environment (Brandão,2015). Research shows that digital devices like smartphones and tablets are increasingly being used as self-guided learning by children. Kimiko (2012) argued that children's genuine interest in pretend play and emotional expression could motivate self-guided play and learning with digital tools. Papoutsi & Drigas (2018) stated that most autistic pupils tend to have more visual capabilities, and mobile technology is attractive. However, this framework will carefully take into account visual stress and overloading. Autistic children enjoy technologies like smartphones and tablets for their simplicity and engaging environments (Papoutsi, 2018). We provide a visually engaging framework to encourage autistic children to interact with the structured environment.

2.2. Emotional Development

Emotional development involves handling and regulating emotions as well as understanding the emotions of other people (Albrecht, 2017). Research shows that the lack of emotional regulation and recognition in childhood can lead to aggressive behavior and adversely impact a child’s social development (Albrecht, 2017). Albrecht (2017) states that a child's environment can have a negative or positive effect on a child's emotional and social development. Some factors that contribute to a hostile environment are violence and parental low-income. The environment fundamentally plays a factor in how a child develops and processes relevant emotions (Albrecht, 2017). Children start understanding emotions as early as five months. At the age of 2, children start to recognize and decode raw emotions and emotional states (Albrecht, 2017). Eirini et al. (2013) states that recognizing emotions from facial expressions is improved gradually with age, and a right accuracy level seems to be acquired by ten years of age. The full proficiency level is reached only after puberty (Eirini, 2012). Abirached (2012) conducted a study where parents of autistic children were interviewed based on their child's needs. The following are the three critical difficulties reported by parents in teaching emotions to their children: 1) Recognition of basic emotions, 2) Recognition of more complex emotions, and 3) Understanding the reason behind emotional responses.

a. Emotional-Self-Regulation

Self-regulation refers to the cognitive and behavioral processes through which individuals monitor and manage states of emotions, thoughts, and behaviors that promote positive adjustment and adaptation, reflected in positive social situations (Dijkhuis, 2017). Children as young as the age of 1 were reported to have difficulties in self-regulation (Dijkhuis, 2017). Emotional processing and regulation are essential to self-regulation. For instance, when a child gets frustrated in the process of goal achievement, it is important to learn to identify and manage that emotion in a positive manner. Autistic children have significantly higher levels of emotion dysregulation compared to their peers (Talia, 2020). Burton et al. (2020). conducted a study that found insufficient levels of self-reported emotion regulation were associated with decreased social skills and increased mental health difficulties, as rated by both parents and teachers in a sample of children with ASD aged 7 to 13 years. Emotional regulation is very similar as it can also be described as modifying a person's emotional state that promotes adaptive or goal-oriented behavior (Dijkhuis, 2017). People with ASD are at high risk of reduced emotion awareness, such as lacking the ability to identify, experience, verbally describe, and reflect their own emotions (Dijkhuis, 2017).

3. Methodology

Given the benefits of AR, the proposed framework will be designed to engage children with ASD with critical features to be highlighted, giving increased attention to features. Unity© is the software chosen for developing the augmented reality framework. An AR training application can also aid in the transition from guided training to actual application with the desired learning outcomes. The framework aims to teach children with ASD the six raw emotions: happiness, sadness, madness, fear, disgust, and surprise. There will be three scenarios in which the child interacts. Each scenario will pose a problem for the main character in which the child has to determine its emotional state. Figure 1 shows the workflow in creating the application.

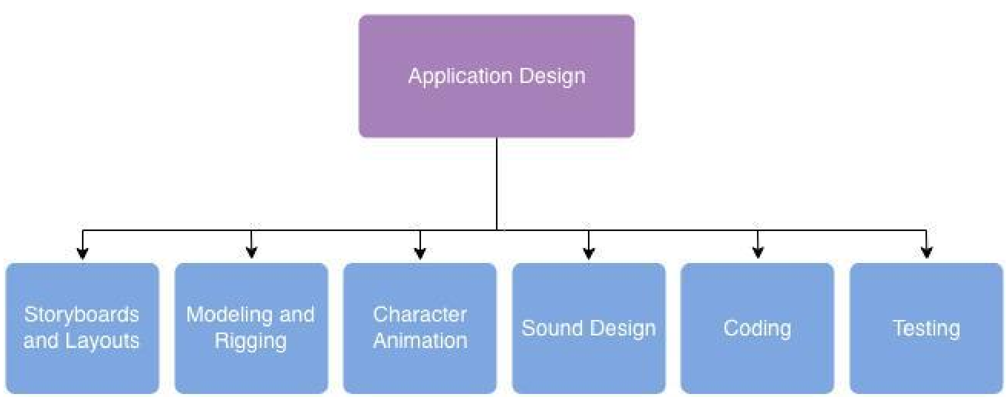


Figure 1: Workflow of the proposed application

A. Scenarios

These scenarios are part of the carefully organized AR training constructs to employ optimal features within the simulated environments, augmented overlay content, and assets in order to maximize learning outcomes.

(1) The narrator introduces the character's problem and its related visual support.
(2) The narrator highlights critical features in the framework that supports how the child can solve the character's main problem, but before the child can determine this.
(3) The child must identify the emotional state of the main character through the visual support of three options.
(4) The narrator focuses the child's attention through positive reinforcements of music, sounds, and animation with which they can interact.
(5) Based on the response, the level will be completed, and the child will be rewarded. If the child picks the wrong emotional response, the previous question will be repeated until the correct response is chosen.
(6) The child is encouraged to move to the next scenario or play in the current one.

The character will cycle through all six basic emotions in social situations using the same scenario pattern. An example of the emotional states of the scene scenarios can be displayed in figure 2. Future work will showcase all 6. By the end of each scenario, the child will be able to understand and recognize emotions. In skill development scenarios, AR may serve as an efficient technique for the acquisition and retention to actual real-life performance.

Figure 2: Four Emotional States: top-left(neutral), top-right(happy), bottom-left(sad), bottom-right(angry)

B. 3D Models

Evidence shows that children with autism showed increased interest in cartoon faces relative to real-life faces (Rosset, 2008). In designing the main character, a 3D style design was carefully chosen to offer an appealing and realistic experience. Autodesk Maya was chosen as the leading software in creating most game elements. Autodesk Maya© is a 3D computer animation, modeling, simulation, and rendering software. It offers the ability to create visually stunning environments. The main character (MC) was created in Maya, where each moving part of the body had to be rigged and animated. Advanced animation of the specific features such as mouth, tail, head, and legs were performed using controllers. Figure 3 shows the rigged joints as well as the mesh and controllers.

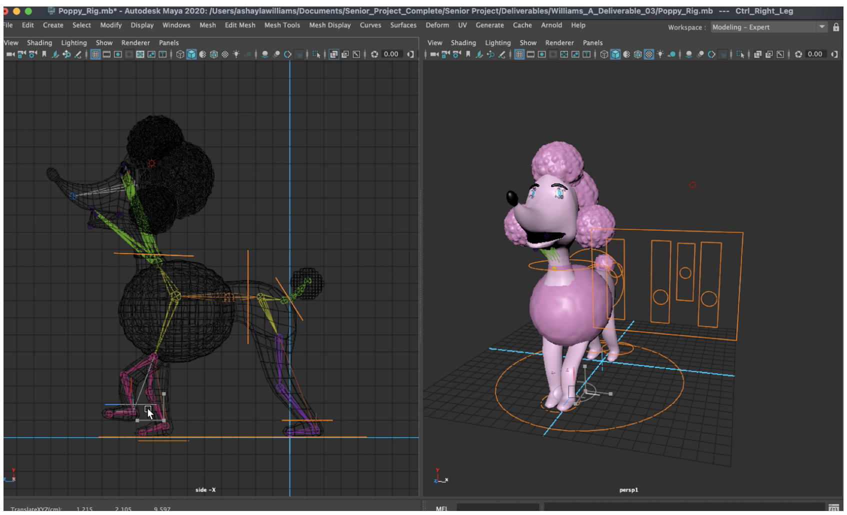


Figure 3. Rigging of 3D character inside Autodesk Maya

All other game objects were modeled in Autodesk Maya, such as the flowers, clouds, and the sun. Some issues experienced during the creation of the 3D character are explained here. In 3D modeling baking is the process of flattening an animation onto skeleton joints and blendshapes. It is most useful when dealing with complex animations. When baking the MC, sometimes the mesh would distort around areas of the mouth. Problems also occurred with broken joints such as movement in the tail. As this is a prototype, these issues were simplified to test the usability of the framework still. Each game element with animations had to be baked and exported as a .fbx files, where it was then to be imported inside Unity.

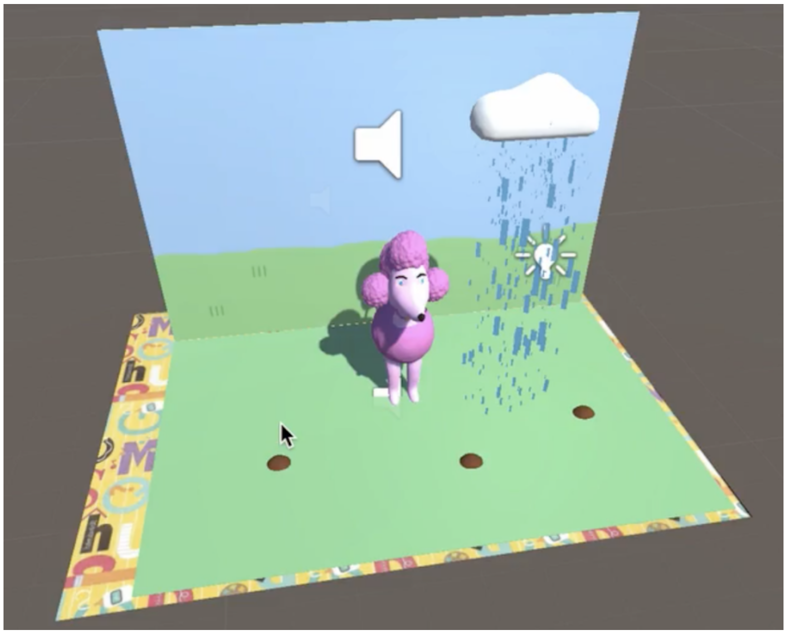
C. Implementation of the framework

Two applications were used to create the game: Unity© and Vuforia Engine©. Unity is used to develop interactive three-dimensional animations, architectural elements, real-time animations, and video game content (Nubia, 2015). Unity is available on OS X and Windows operations systems. An advantage of using Unity in developing this framework was that it offered cross-platform compatibility for android, iOS, and game systems (WII, PlayStation, Xbox)(Nubia, 2015). Assets created outside of Unity were imported, but the system's main functionality was AR Image Tracking. Vuforia is a software development kit developed by Qualcomm Technologies that allows the creation of augmented reality applications. Vuforia© was integrated inside Unity along with the created database used for image tracking. Vuforia works in that it detects through the camera device and tracks the points of the image target. The image target is created and imported to the vuforia database. It is referenced inside the Unity engine, resulting in a 3D object being superimposed. The superimposed 3D object can only be seen through the tablet or device. This facilitates tracking functionality within the platform and its behavior can be programming through coding. Figure 4 shows the image target used as a physical platform created with foam for the child to use and interact with.

Figure 4: Image Target- handmade playmat created using foam

D. Assets and Code

The framework uses image tracking along with multitouch. To perform this action, the free unity asset LeanTouch was integrated with the framework. Lean Touch adds touch controls by picking a component and customizing the settings. It is widely available to developers requiring no code, making it easily accessible to people with no prior coding experience. Lean Touch was used to move the clouds over the MC to demonstrate sadness in the sad scenario. Lean Touch was also used to demonstrate happiness in the happy scenario, such as tapping the flowers to trigger the



dance animation. The programming language used was C#. Coding controlled the rules of the game. For example, In order for the flowers to dance, the state had first to be identified. Multiple scripts were used to control the rules for the MC, and game elements. The narrator was created using a custom audio file, where it was implemented inside unity. A script was created specifically for the narrator to follow along with the gameplay. The animation was carried out within Unity. Animation controllers and trigger events were used to animate the game assets. Game objects were controlled by commands such as tapping and dragging. The framework employed different sounds such as sparkles, bubbles, and rain. Appropriate sound files were employed to simulate situational music to reflect the emotional state. The sounds also had conditions created within the scripting.

Figure 5: Inside Unity: Sad Scene

One necessary condition was when the image target was detected, the game was then initiated. If the image target was lost, the user had to start over. The image target is essential to running the framework. Without this unique image target the framework will not run. The purpose of using the handmade image target in oppose to a planar surface was to make the game feel safe for the child using it. Essentially the image target will serve as a playable platform that will replicate the current framework in the future. When the framework is initiated an event will trigger the appropriate sounds. The scripting essentially controls the interaction between the game and the child. Animations are controlled by commands such as tapping, dragging, and moving. Figure 5 shows an example of the sad scene inside Unity. There are rain particles on the cloud. The rain only appears if the cloud has been tapped and held. Once the rain hits the MC, an animation will trigger an event.

D. Emotion Recognition

The main character demonstrates two primary states: happiness and sadness. In the happy scene, the narrator states the main character's situation in which the user must identify. The elements of the happy scene will relate to the main character's situation. The UI will then prompt three emotions for the user to choose. The user will drag and drop one of the three UI stickers onto the 3D character. If the sticker matches the main character's current state, the user will then receive an incentive. The incentive will correlate to the happy scene, such as bubbles, joyful music, and encouraging narration. The sad scene works in the same manner. The main character will be faced with a problem, and it is up to the user to identify the character's emotional state. The sad scene will consist of elements related to the main character's situation. The narrator is the key to the game as it controls the interaction and storytelling of each situation. However, the framework will encourage parents to accompany their child further to strengthen the emotional connection.

4. Discussion

This framework's design and development invite children to learn and identify emotions they may have difficulty expressing or understanding. This framework aimed to provide an easily accessible, cost-efficient, and family-friendly tool for children with autism. AR technology is introduced to offer a fresh way of learning emotions to children with autism. Children will learn emotional intelligence skills such as self-awareness and self-regulation. As a result, they will be able to maintain healthy social relationships. We will test the framework on ASD children ages 3-8 in the future. The system will collect data in which will be analyzed to test its effectiveness. The prototype will later be used as a physical playing mat to replicate the game behavior used in this paper.

5. Conclusion and Future Work

Emotional skills are essential to children's overall growth and development. Challenges in emotional development faced by a child may lead to the child facing problems in social situations. Emotional skills include the child's ability to recognize their feelings, others' feelings and maintain effective relationships. The framework facilitates the child to solve each problem and move on to the next scene. Augmented reality allows prominent features to be highlighted to enhance the attention and motivation of the child. This framework aims to enhance the emotional intelligence of children with autism. By the end of these lessons, children would be able to identify, understand, and recognize their own emotions and others' emotions.

As this is a prototype, there are limitations to the functionalities accomplished in this project. Future work will focus on implementing all six basic emotions: happy, sad, mad, fear, surprise, disgust in social situations. Future work will also focus on measuring results on rather children showed positive or negative results in understanding the learned skill. The goal after using this application is that children with autism will be able to self-regulate their emotions so that they will thrive in social situations. Future work will also explore that parents at home with or without assistance could utilize this tool.

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Magesh Chandramouli

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