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AUGMENTED REALITY GAME THERAPY FOR CHILDREN WITH AUTISM SPECTRUM DISORDER

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Abstract- This paper presents progress on treating children with Autism Spectrum Disorder (ASD) using Augmented Reality based games. The aim of these games is to enhance social interaction and hand-eye coordination in children with ASD thus easing them into becoming more comfortable around unfamiliar people. Colour detection and tracking and motion tracking concepts in augmented reality have been used to develop games for young children with ASD. The idea is that these games will encourage concentration and imagination from children through repetitive movement and visual feedback.

Index terms: Augmented Reality (AR), colour tracking, motion tracking, Autism Spectrum Disorder (ASD), autism

I. INTRODUCTION

a. Autism Spectrum Disorder

Autism Spectrum Disorder (ASD) is a lifelong disability that can be identified early in children affecting their development capabilities especially in regards to communication and interacting with others [1]. America's Autism Society has estimated that the cost for caring for an autistic child their whole life ranges between $3.5 million to $5 million [1]. There are three main types of ASD, Autistic Disorder, Asperger's Disorder and Atypical Autism. Asperger's Disorder and Atypical Autism are milder forms of Autistic Disorder and produce similar features in people affected [2].

Autistic Disorder often classified as childhood autism, impairs social, communication and imagination abilities. The disability has been known to cause language problems such as delayed responses or very little to no speech, perseveration and echolalia. Infants begin to favour being in solitude and are more comfortable doing repetitive activities or tasks [3]. Autistic people often require on-going care and support throughout their lives and thus can harm their possible success in the workplace.

Autism is associated with the word 'spectrum' as spectrum indicates that ASD varies between those affected because of the range in severity of the disorder. Asperger's disorder and pervasive developmental disorder are defined under the umbrella of autism or ASD [4]. According to Autism Spectrum Australia [4], there are three main basic areas affected in a person with autism. These include, inability to communicate, impairment in social interaction and restricted and repetitive interests, activities and behaviours.

Depending on the severity of the disorder an autistic person may be delayed in language development, starting and keeping conversations alive. Communication impairments can also include repetitive use of phrases referenced from media and limited imagination [4].

Social interaction is a common difficulty with most autistic people. They may face frustration, anxiety and hardship when it comes to making and sustaining friendships. Their understanding of gestures and facial expressions tend to be limited thus causing struggle with social and emotional responsiveness. Autistic people may have issues with caring to share interests and emotions with others as a part of their behaviour [4].

A different angle of research taken into Autism Spectrum Disorders has indicated that children are not exempted from motor delays in simple tasks such as, sitting, reaching and walking. Motor skills are highly important for effective communication and social interaction thus causing it to perhaps be one of the main factors behind autistic children finding it difficult to conform to the norm of social interactions in today's society [5]. A study was conducted by Cheryl Glazebrook et al [6] on the sort of motor delays evident in ASD. Individuals were required to perform hand and eye movements simultaneously and then separately. They were then asked to display their level of coordination by landing on a predetermined target without any help from visual feedback. Through this study, it was deduced that children and young adults with ASD found it difficult to perform advanced or complex motor tasks. There was a higher variance between eye-hand coordination as the ocular system (inside the pupil in an eye) and manual systems did not efficiently work together to achieve complex movements. It was also hypothesised that children, adolescents and young adults with ASD preferred visual feedback to allow for correction in their movements and successfully land on a pre-determined target [6].

b. Treating Autism Spectrum Disorder

The key to treating children with an Autism Spectrum Disorder is working with them and not against their interests and abilities [3]. McGee, Feldman & Morrier [7] carried out a study on 64 preschool children where half diagnosed with autism were placed in a small, regular classroom setting for three days. The study showed results where autistic students did engage in activities however did not spend a lot of time in close proximity to their classmates, were less vocal and focussed and were more engaged in atypical behaviour. These behaviours can affect children with ASD's opportunities for potential development of social skills [7].

c. Advances in ASD Treatment Technology

Current research in therapeutic technology for autism is aimed toward improving maintaining eye contact, determining facial expressions and other behaviours that impact social interactivity. Today technology can be a safe and motivating way of engaging autistic children in social interaction activities. The Economic and Social Research Council (ESRC) and the Engineering and Physical Science Research Council (EPSRC) in the UK developed a joint research project called ECHOES, a Technology Enhanced Learning (TEL) programme. The aim of this research project was to help teachers, parents, practitioners and researchers to understand the unique strengths and weaknesses in their children. The project was brought into the classrooms of students with autism which allowed children to play with virtual and interactive characters through interacting with echoes on a large multi-touch screen. The screen allows children to handle objects, explore the virtual environment and interact with Andy, the semi-autonomous agent. Andy facilitates engaging activities with children acting as their social partner through the program. Teachers have reported on the success of the program and how it has improved communication and social skills in their students [8].

Socially Assistive Robotics (SAR) is a new field of robotics being explored to treat autism. SAR focuses on social interaction where robots are designed to enhance user engagement, emotional expressions and physical appearance for the child. SARs are developed to assist a child with social interaction through coaching and motivating changes in their behaviour [9]. These systems need to be able to adapt to the varying moods of children with ASD. Researchers are aiming to control drastic mood changes in children by exposing them to autonomous robots with consistent reactions. However, this is not entirely effective for long periods of time and there is a lot of room for improvement towards creating robots that can handle more dynamic, complex situation handling and unpredictable moments in an autistic child’s behaviour. Socially assistive robots can be designed to suit a child’s height and weight, can be silicone-based with highly expressive facial features or made up of simple features with basic expressiveness. These robots can also resemble animals or toy-like imaginative characters that are simple and easy to use [9]. The robots are often used as mediators between an adult and the child, working to create a comfortable environment for the child around other people rather than socially engaging with the child directly in a solo situation. The biggest challenge researchers face with socially assistive robots used in autism therapy sessions is creating non-threatening and simple robots for a child with ASD [9].

d. Augmented Reality

Virtual Reality (VR), creates a captivating synthetic environment for the user, simulated by a computer. Some VR applications include; haptic devices, joysticks and wrap-around displays. These VR applications can be extended to create applications that combine the environment from the real world with digital information, in short augmenting the perception of one's reality through alteration of the sensory-motor bond with essentially a virtual environment [10]. This concept is called Augmented Reality (AR).

Computer vision methods in augmented reality are mostly related to video tracking. Feature and edge detection and other image processing methods are used in tracking to interpret camera images. Computer vision distinguishes tracking techniques in two separate classes: feature and model-based tracking. Feature-based tracking is about uncovering the connection between features of 2D images with their 3D world frame coordinates [11]. Whereas model-based tracking methods are about putting features from the model of the tracked objects into use like CAD models that are based on distinguishable features [11].

Augmented Reality has the ability to grow and nurture imagination in a child where he or she may struggle with spontaneous pretend play. AR allows children to see a representation of imaginary content overlaid on the real world environment thus imagination and pretend play makes sense. Pretend Play, an AR system designed by Bai, Blackwell and Coulouris [12] from University of Cambridge, uses marker-based tracking and lets the player pretend that a simple block is a car which can be pushed over a bridge, a train pushed through a tunnel or an airplane that releases cotton balls acting as bombs that hit an animated target. The system received positive feedback in its early stages of release as it was tested out with two neurotypical children between the ages of 4-5 that showed potential for pretend play in a simple situational environment [12].

II. ASD AR-THERAPY GAMES

The core concept of designing games for children with ASD was to be used as motivation and coaching on being comfortable with social interaction. The games developed for ASD patients are based off online virtual autism games developed found on the website ‘Autism Games’. The Emotions game in particular was inspired by 'Ron Gets Dressed' on Swinburne University's site. Two games are being developing using augmented reality theories of colour detection and tracking and motion tracking. Both games have been designed to be played with repetitive movements and instructions hoping to instil basic knowledge on facial features and feelings in an easy to understand manner.

The games can be played using objects from the player’s surroundings, thus allowing a child with ASD to use familiar objects or toys they are more comfortable with holding.

a. Methodology

For the purpose of designing educational therapeutic and affordable games for children with Autism Spectrum Disorder, two augmented reality games are proposed in this paper. The aim of these games is to assist children with ASD with social interaction and communication skills. Both games are tackling the developing social skills in an atypical child. The games are:

1. Emotions Game
2. Happy Minion Game

To be successful, the games required a child-like design that would appeal children between the ages of 8 to 15. This meant the games needed to be designed with bright colours, sounds and known characters. To be able to create an attractive Graphical User Interface (GUI) and animated graphics as well as incorporate computer vision features into the games, Adobe Flash Professional CS6 was used. Adobe Flash Professional CS6 contains a broad range of multimedia development abilities. It allows development of web applications, games, movies and mobile phone applications. Adobe Flash Professional CS6 is also an Integrated Development Environment (IDE) for Actionscript 3.0.

The object-oriented (OO) programming language Actionscript 3.0 was used to develop both games. Actionscript 3.0 is also an Adobe Systems product which is quite similar to the OO programming languages, Java and C#. As it is an object-oriented language, the code is readable, more modular and scalable. The language comes with a wide range of Application Programming Interfaces (APIs).

The Happy Minion Game which uses motion tracking, was developed using the GreenSock Tweening Platform. This library contains a number of tweening classes that enable Flash to automatically create frames in between two key frames thus the developer is able to move an object from point A to point B over a given period of time [14].

In order to capture real time video feed in the games, a web camera was used. An in-built laptop web camera was used in this project however; an external web camera connected to a computer may also be used. The video feed was used to establish the augmented reality feature in both games by overlaying virtual objects in the real world captured through the camera. The live video feed aims to also act as immediate feedback on the reaction of the child playing it and whether there is improvement or not.

Finally, both games can be played with any objects in the player’s surroundings. The aim of this project is to make them cost effective for those families already paying for expensive therapy sessions or simply cannot afford clinical sessions. Also children with ASD may not find it comfortable being told to use a foreign object to play the games. This allows the child to choose and control the games with the most comfortable object around them. The constraint with using any object has to be small enough to fit in the game window; this can explain to the child. For the purpose of this paper, a standard blue pen lid was used to control the Emotions Game and any object the size of a human hand and it is similar for the Happy Minion Game. However, the Happy Minion Game can be controlled without an inanimate object and through the player’s hand themselves.

The flexibility of essentially game controllers means that there’s minimal fuss for children that may not like change or using foreign devices. The sole focus of the games is to improve their ability to identify and understand human emotions as well as improve their hand-eye coordination. Children with ASD struggle with pretend play skills and often prefer playing with common objects such as rocks, ballpoint pens and sticks [20]. The fact these games allow them to play in solitude creates comfort [20] and hopefully full concentration on developing their ability to recognise emotional features on a face or common situational based reactions.

Both games have been designed keeping in mind the environment a child with ASD is most comfortable in. The purpose is to develop social interaction and hand-eye coordination through simple instructions and concentration. The idea is not to create confusing games that may detract the player away from their true intention.

b. Emotions Game

The game so far, is a simple game that allows a child to drag and drop features onto a blank face to create a facial expression. The facial expressions are created depending on the situation presented in the instructions of the game. For example, the child is told that the character or owner of the blank face is happy today because it's a sunny day and then prompts the child to create a happy face. This design allows a child with ASD to recognise the cause for happiness and what it looks like on a human face following simple instructions.

The game can be played on any laptop with either an external web camera or an inbuilt camera. The player is presented with a blank face on the left hand side of the screen and individual facial features on the right. These virtual objects are overlayed on a live video feed where the player can see themselves in the background. The instructions at the top left hand corner of the screen prompt the user to create a happy, sad or angry face by dragging and dropping face features such as a smiling mouth, eyes and nose.

The player clicks on a self-chosen marker from their surroundings. The game detects the colour of the object and registers it as a tracker. Using the tracker, the player will be able to pick up an individual face feature, for example, eyes and drag it onto the face where they think the appropriate position for a pair of eyes is. A child is able to explore their imagination and methods of pretend play through this game [12]. The game also acts as feedback to their guardian on the level of understanding the child may have on facial expressions and emotions hence demonstrates if there is any need for improvement in their social interaction development.

The figures below display the emotion game screen where the user can see him/herself interacting with the objects. They also illustrate a red box around the colour tracker displaying that a colour has been detected and will be tracked and also the player can drag objects onto the face. It provides the player with option to mirror the face in the background, once completed.

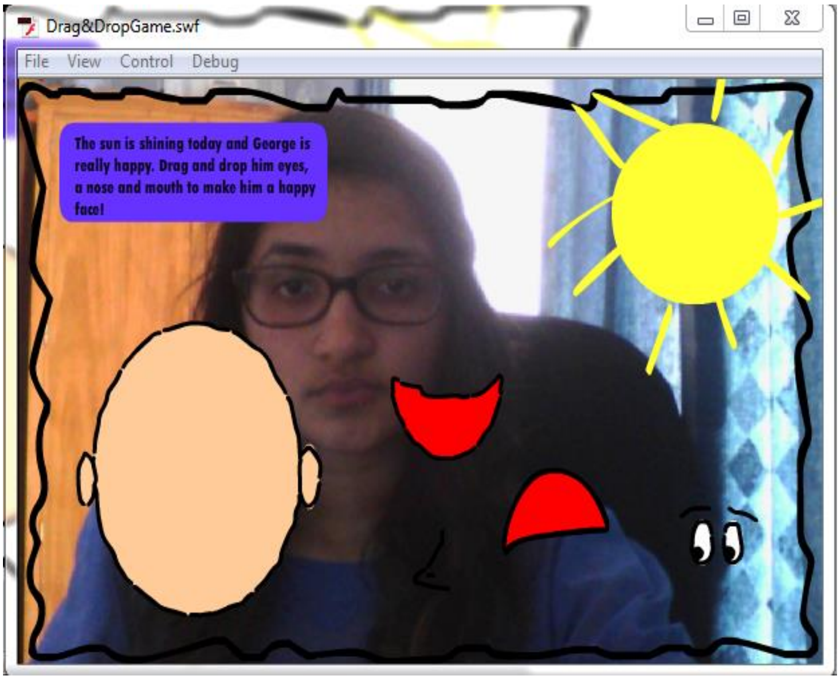

Figure 1. Emotion Game Opening Screen

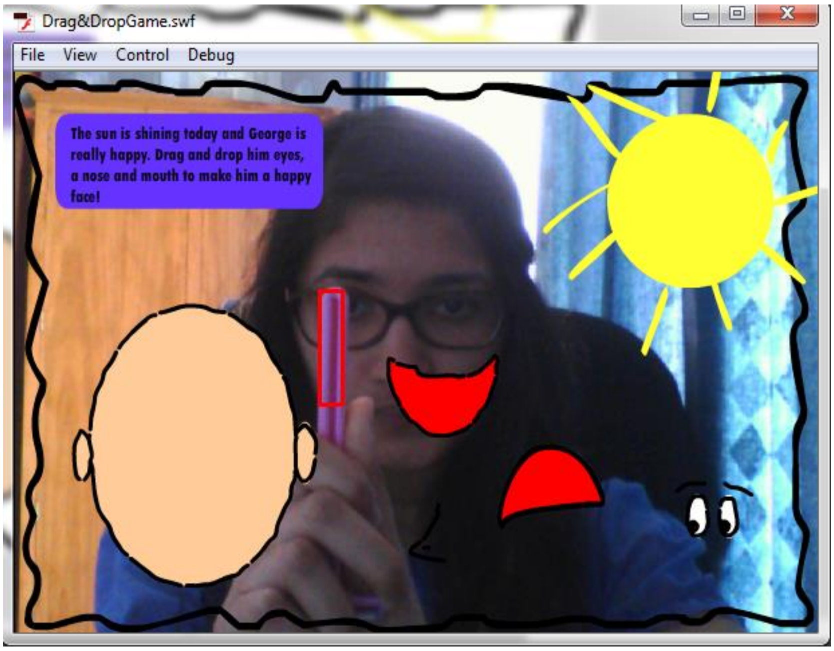

Figure 2. A red box around the colour tracker displays that a colour has been detected and will be tracked

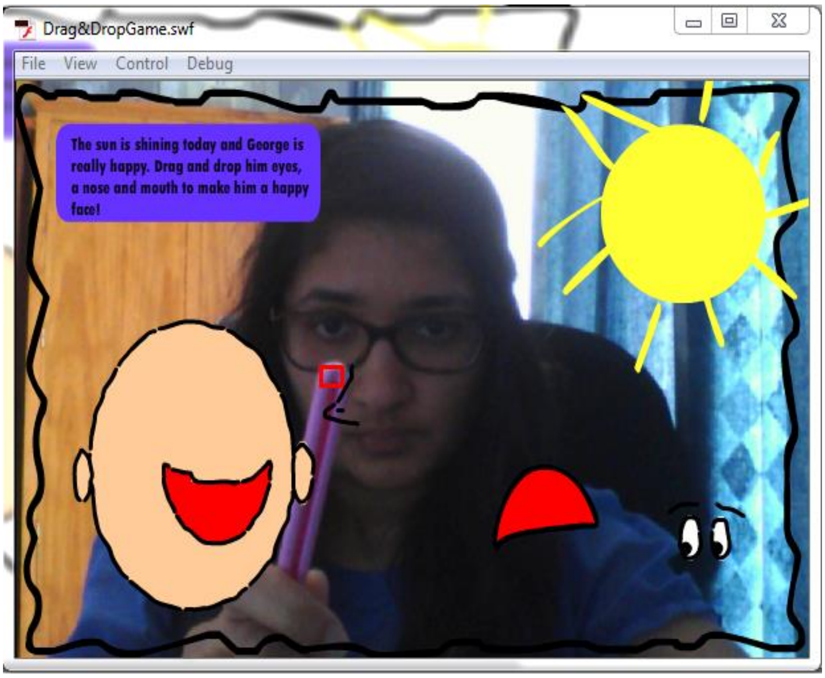

Figure 3. Using the tracker, the player can drag objects onto the face

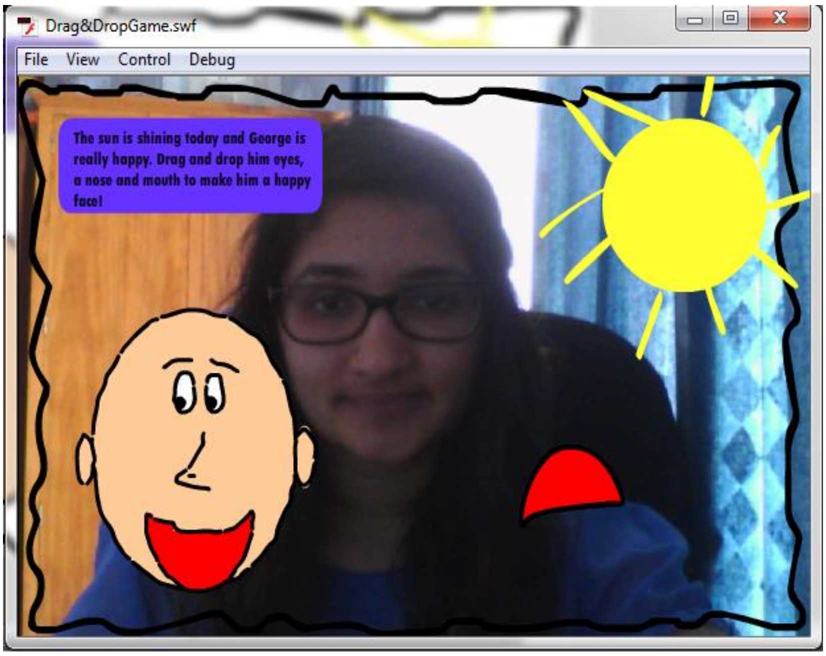

Figure 4. The player has the option to mirror the face in the background once completed

c. Happy Minion Game

To tackle hand-eye coordination and movement delay in children with ASD, this game promotes repetitive movements with cause and effect results [13]. The game trains hand-eye movement to work simultaneously with an appropriate speed.

The game was developed using libraries from GreenSock Animation Platform [14].

Just like the Emotions game, this game allows a child to recognise an imaginary cartoon's happy and sad face depending on the situation, for example when Mr Minion is able to hit the banana, he is happy but when he misses it, a pop up with his sad face is displayed stating that he is sad now as he missed the banana.

The game starts with some instructions for the player to follow and once the 'START' link is clicked, the player is required to move their hand from left to right in the screen in a waving motion. This motion controls the Mr Minion character and allows the player to hit the banana and keep it up. A score is kept at the bottom of the screen, providing the player with feedback on their progress.

If the banana is dropped, a popup is displayed stating that Mr Minion is now sad as the player has dropped the banana and to 'Try Again'. An image of a sad Mr Minion is also displayed in the popup.

Once the player clicks on the link to 'Try Again' the game resets the score to 0 and starts again. Once again this game can also be played on a desktop or laptop with an external web camera attached or an in-built camera. Also, a live video feed of the player in the background allows the player to monitor their hand movements while playing the game. Currently the live video feed produces a blurry image of the player and cannot be clearly captured as in figure 8, which we are working to improve.

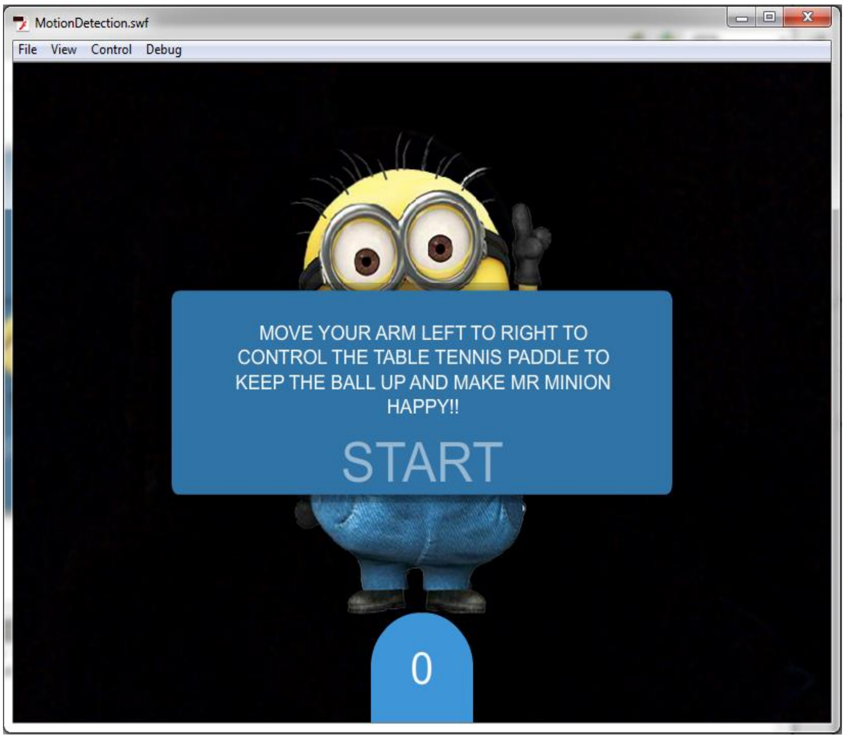

Figure 5. Happy Minion Game Opening Screen with instructions

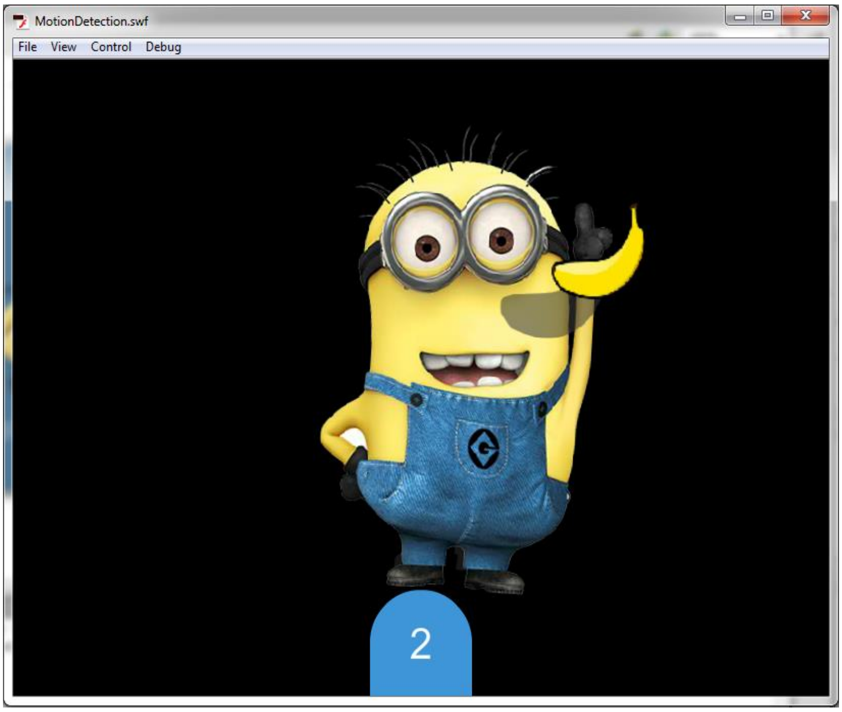

Figure 6. A score is kept at the bottom of the screen for every time a banana is hit

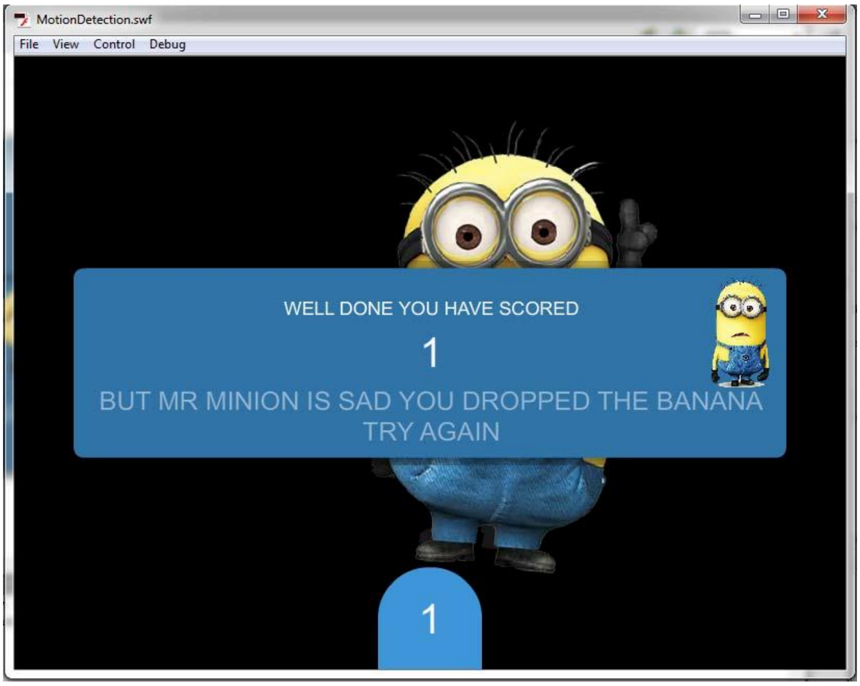

Figure 7. Instructions for when the banana is dropped

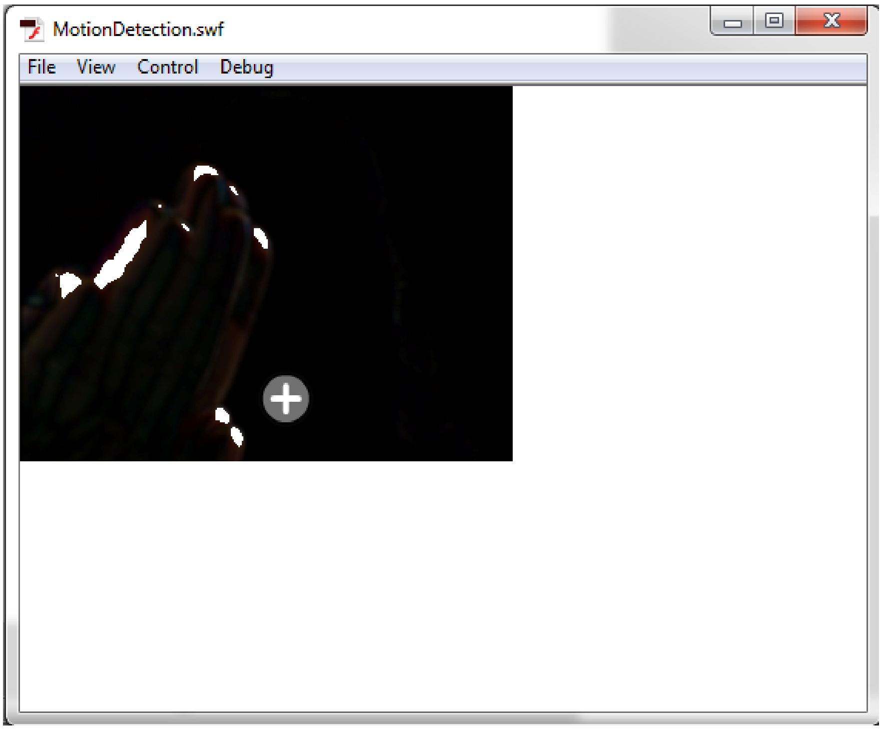

Figure 8. Example of the video in the background that can't be captured in a screenshot when the game is running

III. AR THERAPY USABILITY STUDY

We performed a usability study on our in-progress AR games for children with ASD with 4 typically developing children ranging from ages 10 to 15 and were right-handed. Each child was given 15 minutes of play time. Using a questionnaire that been developed as can be noticed in the appendix, the children provided us with feedback immediately after playing both the games. The questionnaire was influenced through other research papers and focused on gauging whether the games sparked interest from children between the ages of 10-15 and if there was scope for further development. No standard tools were referred to when designing the questionnaire.

The children were instructed on how the games are played and were allowed to play on their own with just our supervision. The children could see the relevant social interactivity benefits of the Emotions Game as they could mirror themselves immediately once they had completed the cartoon face and understood what a smiling, sad or angry face would typically look like. The Happy Minion game proved to be a little vague in terms of social interaction however, its focus is mainly on hand-eye coordination which is essential in developing confidence/self-esteem and vital behavioural factors such as maintaining eye contact when in a conversation with another person.

From the feedback that received, the children found the games easy to follow and understand as the instructions are in plain and simple English, perfect for the level of a 10 year old in primary school. The idea of tracking any objects in their surroundings to play the games was exciting for the older 2 out of the 4 children. They were able to appreciate the uniqueness of the games even though they had no understanding of the augmented reality concept.

The Happy Minion Game was found to be most fulfilling as the scoring system kept track of achievements and allowed for goal setting next time the game was refreshed. While the Emotions Game was more exciting and appealing to play with as they were able to see their own reflection in the background clearly and mirror the virtual face at the same time. The children found the live video amusing and enjoyable to play with.

Some negative feedback we received was that the games got repetitive and a little boring after some time. As we tested these games on typically developing children, this was to be expected. Also the Emotions Game is not fully completed thus it would lose its excitement once the first face is created.

VI. CONCLUSIONS AND FUTURE WORK

The paper presented two games that to be used in the Autism Spectrum Disorder therapy sessions specifically focussing on social interaction and hand-eye coordination. The games were developed using Actionscript 3.0 and Adobe Flash CS6. The Emotion Game has room for improvement in making it a more interactive game for a child with ASD. Some options include; to have a popup praising the child for their good work after all face features on the blank face have been placed correctly according to instructions. Also further research and work can be done to involve face recognition in the background which would give the player the chance to mirror the face they have created and confirm their ability to interpret and mirror human expressions.

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APPENDIX

Below is a list of questions we asked all the children that volunteered. The questions were answered by the child and their parents together. The questions were ranked on a scale of 1 (strongly agree) to 5 (strongly disagree) as well as were asked to provide any additional comments on each question if they wanted to.

1) I am familiar with AR technology and systems
2) I was able to play the game correctly
3) I felt comfortable playing the game using my own chosen tools and 'controllers'
4) I would play this game again
5) I felt the game was exciting and enjoyable
6) I felt plain/discomfort during the game
7) I can recognise the social interactivity application of the game

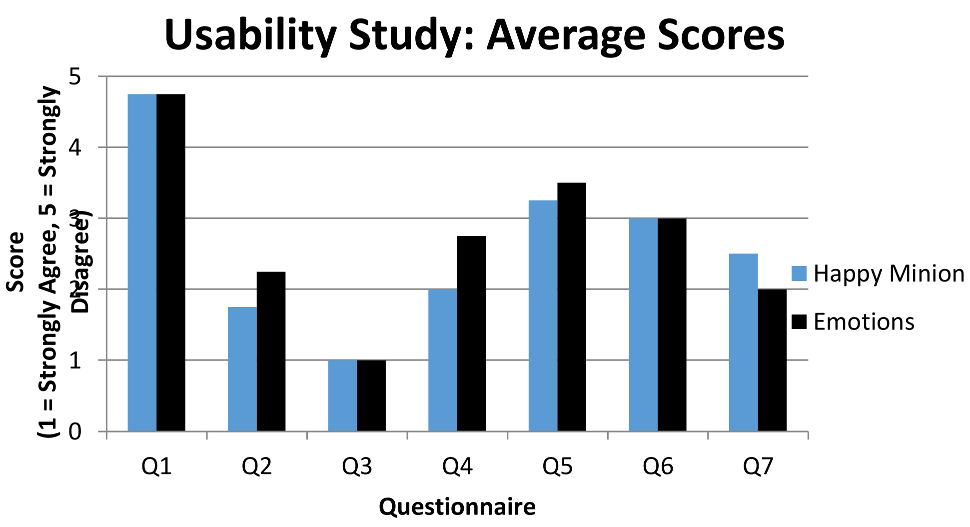

Figure 9. Usability Study Average Scores