Autism Serious Game Framework (ASGF) for Developing Games for Children with Autism

by

Geoffrey Thomas Gaudi

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Examining Committee:

Chair of Examining Committee	
Research Supervisor	Dr. Bill Kapralos
Research Co-supervisor	Dr. Alvaro Uribe-Quevedo
Examining Committee Member	Dr. Patrick Hung
Thesis Examiner	Dr. Diana Petrarca

The above committee determined that the thesis is acceptable in form and content and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate during an oral examination. A signed copy of the Certificate of Approval is available from the School of Graduate and Postdoctoral Studies.

ABSTRACT

Autism spectrum disorder (ASD) is characterized by impaired social communication and interaction, and by restricted, repetitive interests and behaviours. The mean clinical age of diagnosis is still four to five years, despite advances in knowledge about early signs of the disorder and is associated with substantial disability throughout the affected individual's lifespan. There is currently no one standard treatment for ASD given that its symptoms vary across individuals although research indicates that interactive media including virtual worlds and serious games (that is, games whose primary purpose is education and training), can be effective. However, designing such virtual worlds and serious games is not a trivial task, and is time-consuming requiring expertise in game development/computer science, education, and knowledge in ASD. As a result, serious games are often designed and developed to address one specific problem/scenario that cannot be easily modified. Changes to scenarios require the serious game's source code to be modified, which is a difficult and time-consuming process. To overcome some of the limitations currently associated with serious gaming, working with ASD content experts, I have developed the Autism Serious Game Framework (ASGF) to allow therapists who may have a limited (or lack any) technical/programming background and experience, to create serious games (or modify existing ones), specifically for children with autism. Preliminary testing with childhood autism experts indicates that ASGF will allow for the simple development of autism-based serious games, and will assist and help children with autism to develop skills and obtain functional gains, such as recognizing faces.

Keywords: Serious Games; Framework; Autism; ASD; Neuroplasticity

AUTHOR’S DECLARATION

I hereby declare that this thesis consists of original work of which I have authored. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Geoffrey Thomas Gaudi

STATEMENT OF CONTRIBUTIONS

The Autism Serious Game Framework (ASGF) was built at the request of the McMaster University (Hamilton, Canada) research team, which included Dr. Diana Parvinchi and Dr. Geoffrey Hall. They worked in liaison with Dr. Bill Kapralos, Dr. Alvaro Uribe-Quevedo and myself, Geoffrey Thomas Gaudi, to determine the best direction for the underlying purpose of the framework. The paper, *A Framework for Developing a Set of Games for Children Diagnosed with Autism*, which I co-authored with Dr. Bill Kapralos and Dr. Alvaro Uribe-Quevedo was presented at the *International Conference on Interactive Mobile Communication, Technologies and Learning* (IMCL) in Thessaloniki, Greece (Oct. 31 – Nov. 1, 2019) and appears in the IMCL 2019 conference proceedings. The research and iterative process of actually developing the ASGF was my responsibility. I also took a leading role in preparing the IMCL 2019 publication.

DEDICATION

I would like to dedicate this thesis to autism research and to all those whose lives are affected by ASD.

ACKNOWLEDGEMENTS

I would like to thank my supervisors, Dr. Bill Kapralos and Dr. Alvaro Uribe-Quevedo for their enduring and unfailing support and guidance throughout my research. Additionally, I would like to thank Dr. Diana Parvinchi and Dr. Geoffrey Hall for being supportive of me throughout this process, and involving me in such an important part of autism research. Finally, I would like thank my parents for supporting me through my life's journey.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABA	Applied Behavioural Analysis
ASD	Autism Spectrum Disorder
ASGF	Autism Serious Game Framework
DIR	Developmental, Individual Difference, Relationship-Based
VR	Virtual Reality
AG	Augmented Reality
SUS	System Usability Scale
QUIS	Questionnaire for User Interaction Satisfaction
SG	Serious Games
PRT	Pivotal Response Treatment
TEACCH	Treatment and Education of Autistic and Communication Related Handicapped Children
DSL	Domain-Specific Language
GUI	Graphical User Interface

Chapter 1. Introduction

As part of my thesis requirements, I designed the autism serious game framework (ASGF) to allow therapists who have limited or no programming experience to modify a set of games developed for specific interventions in autism therapy. The games that will be developed using the ASGF have an end in mind "– each one targets a specific ability that is known to be affected in autism, such as the ability to shift attention, given an aspect in a task or the ability to read emotion from the face" (Targeted Cognitive Training: Assessment and Plasticity in ASD | Diana Parvinchi - YouTube, 2017). The development of ASGF was iterative and I collaborated with the two content experts throughout the development process. My ASGF system is built to adapt to the autistic child's needs. Current games are static (i.e., cannot be easily modified) but in my system the therapist can modify the parameters to create a targeted intervention.

Autism spectrum disorder (ASD) is a neurodevelopmental disorder that includes impairments in language, communication skills, and social interactions combined with restricted and repetitive behaviours, interests or activities (Baird & Norbury, 2016). According to the Diagnostic and Statistical Manual of Mental Disorders (DSM) 5 (Diagnostic Criteria – DSM-5 – Autism Canada, 2013), Children with ASD often have difficulty coping with change and display restricted or repetitive behaviours. They experience distress or difficulty coping with changing focus or action (Diagnostic Criteria – DSM-5 – Autism Canada, 2013). Many factors, including cognitive and language levels of the child, socioeconomic status, ethnicity, and waiting list times, can impact on diagnosis. The mean clinical age of diagnosis is still at four to five years, despite advances in knowledge about early signs of the disorder (Zwaigenbaum & Penner, 2018). Based on a Government of Canada publication, 2018, (Autism Spectrum Disorder among Children and Youth in Canada 2018 - Canada.ca, 2018) approximately 1 in 66 children and youth are diagnosed with ASD. Of those diagnosed by seventeen years of age, 56% had received their diagnosis by six years of age; almost three-quarters (i.e., 72%) had been diagnosed by eight years of age; and less than 10% were diagnosed after twelve years of age. In Canada, in 2015, eight-year-old males are diagnosed four point

one times more frequently than eight-year-old females (Autism Spectrum Disorder among Children and Youth in Canada 2018 - Canada.ca, 2018)
A recent Canadian public policy study estimated the lifetime cost of supporting an individual with autism spectrum disorder (ASD) at a range of between $1.2 million to $4.7 million based on level of symptom severity and disability (Dudley & Emery, 2014).

“Many families cut back on the therapies their children require – even though research shows that Applied Behaviour Analysis, the gold standard of autism therapy, and the more clinical Intensive Behavioural Intervention, are most effective before the age of 5” (Sharratt A., 2019, p. 1).

Lifelong support is needed for many living with ASD. “The shift to community care in the absence of appropriate community infrastructure has off-loaded much of the cost of care onto families, especially as individuals age into adulthood” (Dudley & Emery, 2014, p. 30). “Fragmented policy delivery, lack of lifespan programming, disorganized services, IQ-eligibility issues, challenges finding staff, lack of respite options, and quality-housing shortages are problems that add to the burden on families and individuals who need support (Dudley & Emery, 2014, p. 30).”

I have discussed many interventions in this paper, all of which have the goal of addressing the needs of autistic children. Some are designed to provide 1:1 brain-training support, and others build on existing successful models to expand the scope of treatment.

My ultimate goal is to make a practical tool that is simple and intuitive to use, freely available and thus augment the existing knowledge base and enhance research into autism. I anticipate that the games developed with the framework will allow the child to transfer their experience gained while playing and interacting with the games to the real world.

1.1 Motivation

A comprehensive study of Information Computer Technologies (ICTs) (Grossard et al., 2017) concludes that their use in autism therapies is promising because they offer new perspectives for treatment. They can be used in many different ways and settings, and are attractive to users. Using serious games for social skills training can facilitate interactions in diverse contexts and situations (Grossard et al., 2017). Under the umbrella of ICTs are the use and development of interventions using iPods and iPads Apps, which aim to facilitate a specific aspect in social life, and the use of robots for serious games for children with ASD (Grossard et al., 2017).

I have developed the Autism Serious Game Framework (ASGF) to address some of the challenges associated with Autism. I anticipate that the ASGF will provide a cost-effective way of offering game interventions to children, and will be flexible enough that other researchers can incorporate this framework to their own goals for autism. The customizable reporting metrics are built into the system, which provide feedback to the therapist so they can evaluate their clinical results after a play session.

Using the ASGF, I have developed two game interventions to meet the specific research goals of the content experts pertaining to neuroplasticity, the Face Matching game, and the Rabbit Adventure game. The Face Matching game is a facial discrimination intervention, which aims to strengthen the ability to recognise emotions in faces (Parvinchi, 2019). Rabbit Adventure targets a selective/inhibitory task, which involves the ability to selectively attend to a relevant stimulus and ignore distractions (Parvinchi, 2019).

Neuroplasticity is a term that is frequently used to describe modern approaches to autism therapy. The underlying concept is to approach aberrant neuroplasticity early, while the brain is still developing. Neuroplasticity refers to a neuron's ability to reorganize and alter their anatomical and functional connectivity in response to the environmental input (Desarkar, Rajji, Ameis, & Daskalakis, 2015). A well-cited neurobiological model suggests that an excitation-inhibition imbalance could be a key determinant of neuroplasticity abnormalities in ASD (Desarkar et al., 2015).

"As the brain develops, different connections are formed within the brain. These connections form a network, which manages a range of functions within the brain. During typical development, an optimal balance between the close range and long-range connectivity is required. This connectivity is what is being affected in children with autism" (Targeted Cognitive Training: Assessment and Plasticity in ASD | Diana Parvinchi - YouTube, 2017). "The best time to target changes in autistic children is between ages 3 to 7, while networks are being formed” (Targeted Cognitive Training: Assessment and Plasticity in ASD | Diana Parvinchi - YouTube, 2017). When the brain is young, it is open and receptive to change. Cognitive training involves the repeated exercise of the specific brain network over a couple of weeks by having the trainee carry out specific tasks that aim at specific abilities in order to complete the task. The idea is to train children to complete tasks by beginning with easy tasks that have incentives, encouragement and feedback. If the task is repeated over a couple of weeks there should be improvement. We expect to see gains “in not only on the tasks that they have been training but more importantly the ability we have been training. We expect to see transfer to other areas or performance generalization to other tasks” (Targeted Cognitive Training: Assessment and Plasticity in ASD | Diana Parvinchi - YouTube, 2017).

Other early behavior interventions, such as Applied Behaviour Analysis (ABA) or Developmental, Individual Difference, Relationship-based (DIR)/Floortime model, have been used to encourage social skills and language. ABA is the process of systematically applying interventions, based upon the principles of learning theory, to improve socially significant behaviours to a meaningful degree. The “ABA approach teaches social, motor, and verbal behaviours, as well as reasoning skills as part of their intervention” (ABA – Autism Canada, 2019). It is considered by many researchers and clinicians to be the most effective evidence-based therapeutic approach demonstrated thus far for children with autism (ABA – Autism Canada, 2019). However, as noted earlier, ABA therapy is usually very expensive requiring the therapists to work with a child individually for 20-40 hours a week. Skills are taught in a simple step by step manner (Jain, Tamersoy, Zhang, Aggarwal, & Orvalho, 2012).

These difficulties make the development of serious games (SGs), which can be used in a wider setting, and with less cost, an important area of research and development. Serious games (SGs) are games that do not have entertainment, enjoyment, or fun as their primary purpose (Christinaki, Vidakis, & Triantafyllidis, 2014). Playing serious games on mobiles or tablet devices has been shown to be effective in helping ASD children to express their feelings and improve the level of engagement with others (Zakari, Ma, & Simmons, 2014). Although they are designed to foster learning of targeted skills

(Fridenson-Hayo et al., 2017), they must also take advantage of game elements and mechanics to create engaging, fun, and challenging scenarios that motivate players to achieve the intended goals. Game elements can be developed to include immersive storylines, individualized training to target skill development, rewards and feedback, increasing level of difficulty, and the provision of choice (Fridenson-Hayo et al., 2017).

Serious games have progressed from entertainment technology to intervention tools for health and education (Kostkova, 2015). "Everything is affected by the digital revolution – the impact of new technology on improving the health and well-being of individuals, communities, and populations is unprecedented (Kostkova, 2015, p. 1)." Although serious games are gaining momentum in a wide variety of health-based applications, there are various problems that must be overcome before their use can become more widespread. One of the primary issues involves the fixed scenarios of most serious games that are customized to specific user needs and cannot be easily be overcome before their use can become more widespread (McCallum, 2012). Such a fixed-scenario approach can produce predictable, boring, and repetitive experiences after several sessions and this can negatively affect their effectiveness. More studies must be done in autism research for innovating technical tools, and a theoretical framework is needed to allow for making predictions, and organizing data (Alves, Marques, Queirós, & Orvalho, 2013).

1.2 Problem Statement

Within the scope of this research, it is hypothesized that therapists without prior programming experience will be able to develop more effective serious games for children with autism by using the ASGF since it provides a more usable, flexible, simple, and intuitive structure than traditional gaming engines.

Having a customized tool does make a difference for each child. DIR/Floortime states that the effects of autism is unique to each child. If a child has as specific problem recognizing faces, such as the happy face, the therapist can target this by creating a game with a happy face and another such as a surprise expression. In the Rabbit Adventures game, the system can use surprise to curb unwanted behavours. Also, by looking at the metrics for the Rabbit Adventures game, the therapist can import models to create an environment where there are challenges for the child. By changing the games, we can create interventions that motivate children.

Modern computer game engines allow for the creation of new games from existing prebuilt code and have a modular structure (Trenholme & Smith, 2008). These modular components allow the developer to create games that “fuse software engineering, architecture, artificial intelligence, 3D graphics, art and sound effects with dramatic performances, music and storytelling” (Trenholme & Smith, 2008, p. 6). The cost of developing a game engine is high and using an existing engine is what most developers do (Lewis & Jacobson, 2002).

Using game engines to develop games is not a trivial task, and it is very difficult to develop serious games to target autism research without prior programming experience. Most current game engines require the programming of specific functions, for example, adding two numbers together. Even in prebuilt engines, such as GameMaker, if the function required by the researcher to do task is absent, a programmer would be needed (Wang, Sourina, & Nguyen, 2010).

My autism serious game framework (ASGF) employs a WYSIWYG (What You See Is What You Get) interface which bypasses much of the intricacy of game development (Tang & Hanneghan, 2010). By creating a visual representation for the therapist and a logical connection, the therapist can understand what he/she is trying to develop. I have developed the system component-wise, such as adding a score label to the current level. The framework can determine, based on the settings and properties, how to “put the pieces together.” The ASGF framework “knows” all the components and all the interconnections of the components including their properties. When a game is built, such as the Rabbit Adventures game, the ASGF framework knows how to put the pieces together and create the finished game. It is similar to a compiler that takes input and processes it to generate code or the output. These assumptions allow the therapist to bypass the complex processes that occur within the code. The therapist is provided the option to focus on the problem and use the ASGF to create the solution, for example, a game to help teach autistic children to recognize faces. The framework enables the therapist to create a variety of games, which could raise the child’s confidence, motivate the child to follow through and succeed, and to potentially target different learning issues such as the need to inhibit repetition. The games to be developed with ASGF are intended for autistic children between the ages of three and seven, given that early diagnosis is very important and early treatment shows promising results (Grindle & Remington, 2005).

1.3 Rationale

"I am deeply grateful to the dedicated teachers and therapists who worked with me. They were responsible for my recovery, and their importance cannot be overemphasized. I was lucky enough to have the right people working with me at an early age. By the time I was 2 1/2, my mother realized there was something dreadfully wrong; I had no speech and screamed constantly" (Grandin, 1988, p. 1).

The development of a serious game platform that can be used in a variety of settings, using free open-source software (the AGSF will be freely available for download), and includes a detailed and intuitive user-friendly Graphical User Interface (GUI), is the goal of this research.

Without proper help at the correct age many things can go wrong (e.g., an individual may not learn to speak, or they may develop ritualistic behaviours). The concern is that if repetitive behaviours are not interrupted, the child's potential will be diminished, and the loss of neuroplastic freedom may prevent the child from the input of experiences necessary for normal neural and social development (Helt et al., 2008). "There is a critical need for cost-effective educational and treatment services for individuals with autism" (Whyte, Smyth, & Scherf, 2015 p. 10). Traditional techniques of treating autism, including ABA, are expensive, intensive and usually have long waiting lists (Jain et al., 2012; Sharpe & Baker, 2007; Renty & Roeyers, 2006). Successful ABA training involves early intervention and intensive treatment for as much time as possible (25-30 hours per week), well-trained practitioners and consistent ABA applications, at home and at school (Riva, Baños, Botella, Mantovani, & Gaggioli, 2016). ASD-specific education and support provided by services and schools are often dealing with long waiting lists (Renty & Roeyers, 2006).

Serious games offer a potential strategy for solving problems with autism. The structure/elements of how they are built, their effectiveness, the connection to new emerging technologies and cost are factors that will be important. ASGF is a serious game framework that uses the benefits of serious games. “Cognitive training is very accessible; you can train at home on a computer, so there is no wait list, there is no demand on clinicians, it is affordable and fun” (Targeted Cognitive Training: Assessment and Plasticity in ASD | Diana Parvinchi - YouTube, 2017). Through early intervention that stimulates communication between brain regions and helps connectivity, improvements in abilities that underlie academic achievement, and those that underlie autism such as inhibitory control, and reduction of repetitive behaviours should be evident (Targeted Cognitive Training: Assessment and Plasticity in ASD | Diana Parvinchi - YouTube, 2017).

Other areas of research are examining autism concerns such as transference and motivation. As long as several elements of serious games are present, the learning is more likely to transfer to real life situations or outcomes (Whyte et al., 2015). These game elements, which include immersive storylines, targeted skills and individualized training, rewards and feedback, increasing levels of difficulty, also include the element of choice. The application of these central elements has been shown empirically to improve learning and motivation in various learning domains (Whyte et al., 2015).

Relatively new to the autism treatment scene are the Microsoft Kinect visual-based depth sensor, Nintendo WiiMote, Playstation Move, augmented reality, and robotics (Boutsika, 2014). These emerging technologies will affect the future of serious game-based autism research. An example cited here (Taheri, Alemi, Meghdari, PourEtemad, & Holderread, 2015) uses the Kinect sensor to imitate autistic children using a robot and vice versa. “Imitation of the autistic patients’ behavior is an effective way of triggering their attention toward the therapist. Imitation and turn-taking games are considered as good therapy to improve social interactions, sense of self, creativity, and leadership in children and even adults with autism” (Taheri et al., 2015 p. 5). Microsoft’s Kinect visual sensor provides enhanced gaming and entertainment experiences by combining multiple technologies based on the use of RGB cameras, depth-sensing, and careful user interaction design (Boutsika, 2014). Kinect-based games allow children to work in teams, and encourage the cooperation and the development of oral expression. As children become familiar with the learning data and ideas, they may have increased self-esteem, self-understanding, autonomy and independence. Slowly these ideas and objectives may be slowly incorporated into their daily lives (Boutsika, 2014).

"Augmented reality can be described as an interactive visualization system (a head-mounted display, a computer, a game console, a smartphone, or a tablet) allowing the merging of digital contents with the real environment surrounding the user. In simpler words, AR allows the augmentation of our real experience blending both "real-world elements" and "virtual elements," which may involve not only the view but also hearing, touch, and smell" (Riva et al., 2016 p. 3). The exponential growth of smart technologies, such as smartphones, and the increase of processing capabilities, storage and interaction capabilities with the user, makes them suitable for autistic children and their families (Brandão, Cunha, Vasconcelos, Carvalho, & Soares, 2015). An example of a game that uses augmented reality (AR) and mobile technology is called the Augmented Reality Gamebook (Brandão et al., 2015). The child interacts with scenarios "by playing with one 3D AR avatar with different facial expressions" (Brandão et al., 2015, p. 1). "The GameBook presents the story of Tobias's adventure during a visit to a zoo park. The player can read the story by text or listen to it by audio. The story describes five scenarios and interactions with animals and real-world situations which will conduct the children to become involved on fictional contents associated with emotions. The child will have to interact on these chapters, by playing with Tobias and learning his five different facial expressions, choosing the appropriate one to each situation and environment described at any page of the GameBook" (Brandão et al., 2015 p. 3).

"Digital Games can change the way we behave – be it explicitly or implicitly, and whether we are aware of it or not. This bears great potential for serious gaming, where behavior change can be guided so as to be targeted, meaningful, and helpful for the player" (Whyte et al., 2015). Researchers are focused on the transfer of skills to the real world, gamification and social networks. Knowledge transfer and conveying educational content to learners so that they can make decisions based on an understanding of the consequences of certain behaviours, are important elements. A concern is whether changed behaviour can be generalized to the real world where it has to be applied. Pervasive computing may overcome this gap since it can be used in an environment where it needs to be applied. In current serious games, social interaction is rarely addressed although it has great potential in the field of autism (Malinverni et al., 2017).

The Oxford dictionary states that gamification is “the application of typical elements of game playing (e.g. point scoring, competition with others, rules of play) to other areas of activity, typically as an online marketing technique to encourage engagement with a product or service” (Gamification | Definition of Gamification by Lexico, 2019). “This industry practice quickly became known as gamification, which can be defined as the use of game design elements in non-game contexts” (Nacke & Deterding, 2017, p. 1).

Byrom (Byrom, 2016) states that gamification is able to drive behaviour because it leverages motivation through reinforcements and emotions. He describes a game platform, the Project:EVOgame, in his review that incorporates gamification in a variety of clinical trials around the world, to drive positive behaviour and encourage continued participation and compliance with study requirements (Byrom, 2016).

Virtual trophies, achievements, or other rewards may give intrinsic value through peer-recognition. In many on-line communities, the interface between real and virtual community, they may provide fertile ground to explore what influence virtual rewards may have on real world behaviours. Many online communities reward positive behaviors with such awards, and the interface between real and virtual community may prove a fertile ground for exploring how virtual rewards might be used to influence real world behaviors (Whyte et al., 2015).

As social networks are increasingly used, how these networks might best be understood and utilized to create models for social change is a topic of ongoing research. Gorini, Gaggioli, Vigna and Riva (2008) discuss the concept of interreality, which involves the creation of a hybrid augmented reality experience by merging physical and virtual worlds. P-health (Gorini et al., 2008) is a form of tailored immersive e-therapy involving interreality, where the goal is to convey greater involvement, positively influence cohesiveness in group therapy, facilitate communication and interpersonal trust between therapists and patients. Second Life (Gorini et al., 2008) has an island called Brigadoon that is specifically designed for people with Asperger's syndrome. Researchers are conducting studies to determine whether Asperger's is a form of high functioning autism or is a discrete category (Cuccaro et al., 2007).

The goal is to provide an ideal place to develop social skills through interaction with others who have the same difficulties. Many individuals with ASD, using the system, ventured out into the regular Second Life environment and are active participants in other communities, thus fulfilling a goal to allow autistic people a place to organize, be educated, and to advocate for themselves (Gorini, Gaggioli, Vigna, & Riva, 2008).

Analyzing players' behaviour, basic emotions, and more subtle "states" such as interest, confusion, frustration, or stress, can be of vital importance in a serious game. This analysis can also provide corrective feedback to keep the game motivational while adapting the level of difficulty (Whyte et al., 2015).

There are many challenges in developing games for autistic research and therapy. Therapists normally require access to a team of programmers and artists as they normally do not have the necessary skills. It is hard to obtain access to games/tools developed in prior studies in order to experiment with them. Most tools are not offered online or are available to the public. Effective communication is necessary and the process takes time. The goals of the researchers are important and some implementations (of those goals) could be difficult. Setting funding priorities for autism research is a daunting task. It is important to look at the types of studies that have benefited most from the recent funding boost and their impact (Singh, Illes, Lazzeroni, & Hallmayer, 2009).

By examining different game engines, design principles and also other games created for autistic children the literature allowed me to scaffold and learn from previous research. As part of my thesis requirements, I designed the autism serious game framework (ASGF) to allow therapists who had little or no programming experience to modify a set of games developed for specific interventions in autism therapy. The games can be created such that levels are tailored to meet individual needs in autism treatment, and record data for feedback purposes. Since symptoms vary across individuals, research indicates that interactive media including virtual worlds and serious games (that is, games whose primary purpose is education and training), can be effective. Designing virtual worlds is time-consuming and requires expertise in game development/computer science, education, and knowledge in ASD. As a result, serious games are often designed and developed to address one specific problem/scenario that cannot be easily modified. Changes to scenarios require the serious game's source code to be modified, a difficult and time-consuming process. The design I have made bypasses the need of expertise in computer science on the part of the therapist.

Prior to developing this ASGF, I contributed to the development of a series of serious games to help children with autism, such as recognizing facial expressions or preventing repetitive responses. These games were the basis for the framework presented in this thesis. I modified the idea of the games and recoded new software to create the framework. Using the autism serious game framework, a user (e.g., therapist) can modify the previously mentioned games, and create new combinations tailored to individual needs. Future work involves our content experts gaining access to the tool and learning our system by actually creating a game or a series of games. For educational purposes, I created a tutorial on how to use the functions of the ASGF. Future research involves using our system in clinical trials designed by our content experts.

1.4 Research Requirements

During the development of the Autism Serious Game Framework, which involved discussions with my team, the following requirements were devised to guide the research and development:

I developed the ASGF framework in a modular manner similar to how other game engines and software were built, such as the generic platform developed by Van Zijl & Chamberlain (2010). The framework must be intuitive to use by therapists. It must contain the necessary processes (e.g. the ability to load a card to create a Face Matching Game) and functionality. The goals of the therapists to provide individualized game interventions and the need for them to learn the tool within a minimal timeframe was required. I included tooltips to increase the learning curve, such as when the user hovers the mouse over the "score" button it displays a message that by clicking it, it will add a score label to the current game. The tooltips simplify learning the system. I supplied video tutorials to give extra valuable information about the tool. I am building on the current research of serious games and autism and anticipate there will be new discoveries and research theories that will help autistic children.

1.5 Methods

The methodology involves a description of the iterative process and an explanation of the development of ASGF. The autism serious game framework was developed in conjunction with two content experts. It was decided to develop the ASGF based on the games that we developed earlier. I included functionality within ASGF to recreate the games from scratch and to allow the therapist to specify the settings of these games. First, I reviewed different game engines that I could build my game tool on top of. This included Unity 3D, Monogame, Unreal Engine and the App Game Kit. Unity 3D was the best choice and I installed Unity 3D version 2017.3.1.f1. I also installed Visual Studio 2015, a development environment created by Microsoft, to create C# scripts to program code in Unity 3D. I acquired assets to use with Unity such as UniFileBrowser (UniFileBrowser - Asset Store, 2018) (a pop-up window to select a file for saving our reports, for example), the TriLib library (TriLib - Model loader package - Asset Store, 2019) (to load 3d models with animations at runtime), Json (JSON .NET For Unity - Asset Store, 2019) (to save C# structures to a file), and also several 3D (CGTrader - 3D Models for VR / AR and CG projects | CGTrader, 2019) models to use in our game (such as the main character in Rabbit Adventures, the sorceress). The coding process involved getting the different modules up and running, and then layering them while I added new functionalities. I used the iterative software design technique where I would analyze the problem, code it and then test it. If there were errors I would go back the analysis phase and find out what went wrong (Nielsen, 1992). I had to reference tutorials online to gain knowledge on Unity's methods of accessing objects, such as a dropdown combobox to access the current selected text (Unity Answers, 2015). After completing the code for the games, I presented to tool to our team of content experts.

1.6 Thesis Organization

This section included the Introduction, Motivation, Problem Statement, Objective, Methods and Rationale of the ASGF framework. Chapter 2 covers a literature review of the available literature on traditional and non-traditional techniques on treating autism. Traditional techniques include ABA, DIR/Floortime and TEACCH, the main methods of treating autism. Non-traditional techniques involve looking at literature on serious games for autistic children and of design of game engines which give background support. Chapter 3 is my development section. In it I discuss the development of my game framework, give use cases and system diagrams, describe the tools I used (i.e. Unity), comment on the processes, and identify my problems and challenges. Chapter 4 is my results/conclusion section. In it I state findings on my ASGF framework and suggest further research including adding other games to the framework.

Chapter 2. Literature Review

There are three traditional methods of therapy for autistic children mentioned in this section as they are the main ones used when dealing with children with autism. These include ABA (Applied Behavioural Analysis), TEECH (Treatment and Education of Autistic and Related Communication Handicapped Children) (Virues-Ortega, Julio, & Pastor-Barriuso, 2013) and DIR/Floortime (Developmental Individual-differences and Relationship-based model) (Greenspan & Wieder, 2008).

The non-traditional techniques section deals with serious games that look at a wide variety of emerging technologies. These include dealing with game principles, a game engine built for ASD children, using Augmented Smartglass technologies, using the Kinect sensor for gesture tracking and music composition, Exergames, and building an augmented game for ASD children with camera feedback.

Finally, there is an Others section describing robotics used in autistic research, including a robot engine developed in Unity3D. This section also includes mental-models and the development of another game engine that automatically derives executable code in an agile and inexpensive fashion.

The research was conducted from June 2019 to the current time September 2019. The search terms are included in Table 2.1. We used the Google search engine (Google, 2019) and Google Scholar (Google Scholar, 2019) to search for references. We also used the OntarioTech online reference library (Quick Search - Find Articles - Guides at University of Ontario Institute of Technology, 2019) for searching for articles.

Table 2.1 Search Terms for Literature Review.

Autism serous games, autism spectrum disorder, Autism games
Serious games
Autism gamification
Autism ABA
Autism TEACCH
Autism DIR/Floortime, Autism DIR
Autism Augmented Reality, Autism Virtual Reality
Autism Kinect, Autism Kinect V2, Autism Kinect gesture tracking, Autism Kinect music therapy
Autism Social Networks and Serious games
Autism SmartGlasses
Autism Unity 3D, autism unity3D game engine
Autism game design principles
Autism game engines, autism game tools
Autism games for children, Autism behavioral interventions, building games for autism
Autism Second Life
Autism problems, Autism costs, Autism definition
Autism DSM definition
Software engineering and waterfall method
Software engineering and iterative design
Autism funding

2.1 Traditional Techniques

2.1.1 ABA and PRT Interventions REFS

Mohammadzaheri, Koegel, Rezaee, & Rafiee, (2014) examined the effectiveness of pivotal response treatment (PRT) compared to structured applied behavior analysis (ABA) to improve communication deficits in six to eleven-year-old children with autism. More specifically, they tested to determine which intervention provides greater gains in targeted language areas, such as mean length of utterance (MLU), and which would result in greater generalized gains in untreated areas as measured by a standardized communication checklist, the Children’s Communication Checklist (Mohammadzaheri, Koegel, Rezaee, & Rafiee, 2014), completed by each participant’s teacher and parent.

PRT and structured ABA fall under the umbrella of ABA interventions. Structured ABA approaches define discrete intervention targets where tight control over the antecedent stimuli, prompt hierarchy, and consequences are maintained and tokens or edibles paired with verbal praise are provided contingent upon correct responses. They use adult-selected materials that are presented repeatedly to promote success. Although structured ABA procedures are very effective, three main areas of difficulty are evident: gains are slow and often require thousands of trials to teach a single word; when gains do occur they often do not generalize; and children are often unmotivated and demonstrate disruptive behaviours. PRT is a naturalistic model, which targets core specific skills as well as core pivotal areas such as motivation, and has demonstrated widespread gains in joint attention, affect, and motivation, while decreasing untreated disruptive behaviour. PRT is based on the behavioural principals of ABA, but incorporates variables known to improve responsiveness, rate of responding, and positive affect (positive responses to stimuli). These variables include child choice, task variation, and reinforcement, and using direct natural consequences.

A randomized clinical trial design using two groups of children, matched according to age, gender, and mean length of utterance was used to compare the interventions. The data showed that the PRT approach was significantly more effective in improving targeted and untargeted areas after 3 months of intervention. More specifically, PRT was more effective at improving social communication skills, and the children demonstrated greater gains in MLU, and pragmatic skills, which include inappropriate initiation, coherence, stereotyped language, use of context, and rapport. The authors concluded that the motivational components of PRT were more effective in producing improvements in social communication. They suggested that the use of preferred toys as stimulus items, may have been more effective than artificial stimuli such as picture cards. Teaching sessions were presented in the context of natural play interactions, creating more interest, and resulting in greater communication skills.

Mohammadzaheri, Koegel, Rezaee, & Rafiee, (2014) mention that the study was conducted in Iran where few services are available for children so that no other ABA interventions were taking place at the time of the study.

2.1.2 TEACCH Interventions

Siu, Lin, & Chung, (2019) evaluate the application and effectiveness of a TEACCH (Treatment & Education of Autistic and Communication Related Handicapped Children) approach in teaching functional skills to young adults with ASD who have mild to moderate intellectual disabilities. Although the TEACCH approach has been widely used, most studies do not focus on children with intellectual disabilities.

The aim of TEACCH program is help people with ASD develop maximum independence by developing their strengths, skills, interests, and addressing their needs. It addresses neuropsychological deficits and strengths by using visual strategies and clear information, a structured teaching-learning environment and curriculum, appeals to special interests by engagement in activities, and as a reward for learning, and uses a social-pragmatic approach to develop meaning and self-initiated communication.

This Hong Kong-based study included 63 participants with ASD who were recruited for the most part from day activity centers. Participants ranged in age from twenty-one to forty years, had mild or moderate intellectual disabilities, and were in regular attendance at vocational or life skills training programs, and had not participated in TEACCH functional training programs in the previous six months. There were two groups, the experimental, and the comparison group. Participants of the experimental group attended 20 one-hour sessions of training using the TEACCH approach over a period of nine weeks, on top their regular training program. The participants of the comparison group attended their regular training program as usual. Training was provided by case managers who were either social workers or occupational therapists, and who had training in TEACCH.

Sessions were geared to the interests of each client, and included tasks that simulated work environments such as clerical, assembly line and craft work; leisure, and recreation activities such as applied arts, horticulture, table games and work-outs; and independent living skills such as cleaning, shopping and cooking. Training activities included teaching aids and materials to supply visual strategies.

Two assessment instruments were used: the TEACCH Transition Assessment Profile (TTAP), which was used to screen the strengths and limitations of the subjects in six areas of functional skills, and the goal attainment scaling (GAS), which is an individualized, criterion-referenced approach, were used. The training goals were evaluated at baseline, mid-program, and after the intervention program was completed. GAS scores indicated the goal attainment of the experimental group was significantly better than the comparison group in the areas of Independent Functioning and Functional Communication and marginally insignificant in the areas of Leisure Skills. TTAP scores showed no significant improvements, and the authors suggested this could have been due to the short duration of the sessions.

The authors concluded that results show that the TEACCH approach is effective in teaching specific functional skills to young adults with ASD and mild to moderate intellectual disabilities.

2.1.3 DIR/Floortime Interventions

Carpente (2016) examined, in an American study, the effectiveness of improvisational music therapy using a DIRFloortime framework to address social communication needs of children with ASD. He argued that there are concerns that traditional highly structured therapist-led behavioral interventions have not generalized to new settings, that gains were not maintained over time, and that over-dependence on prompts could result in a lack of spontaneity. As a result, interventionists now consistently incorporate Developmental Social Pragmatic (DSP) strategies, such as following the child's lead and teaching communication skills within a natural environment. The Developmental Individual Difference Relationship based model (DIR/Floortime) is one of several DSP models. It is a caregiver-mediated home-based intervention in which parents are trained to maximize interactions with their children to improve social reciprocity and pragmatic communication.

Participants included four children aged four to eight years, who were diagnosed with ASD, and were newly enrolled in a therapeutic day school. They had no prior experience in music therapy. Each child participated in twenty-four thirty-minute individual DIR-based improvisational music therapy (IMT) sessions over the course of thirteen weeks with treatment sessions lasting fifteen-thirty minutes. Two additional sessions involved pre and post testing by a DIR/Floortime psychologist. Sessions took place in in the school's music therapy treatment room, and all sessions were captured on a video recorder. The room was equipped with a variety of musical instruments that required no music knowledge to use. The Functional Emotional Assessment Scale (FEAS) was used to evaluate changes in social communication skills.

Results indicated improvements in areas of self-regulation, engagement, behavioral organization, and two-way purposeful communication. These skills usually impact the individual's ability to understand nonverbal and verbal communication, to experience shared attention, which affects peer relationships, and engage in social reciprocity.

The work of Carpente (Carpente, 2016) relates to the work described in this thesis as it aims to develop social skills based on the child's interests in order to foster communication. This acronym is an important way of organizing goals and skills development for games. The "D" is concerned with the child's developmental capacities. The "I" deals with the child's individual differences, and the "R" describes his/her learning relationships with others. The levels should also be considered when designing games: shared attention and self-regulation; relatedness and engagement; two-way purposeful communication; shared problem-solving; symbolic thinking, and bridging ideas.

2.2 Non-Traditional Techniques

2.2.1 Addressing Game Design Principles

Malinverni, Mora-Guiard, Padillo, Valero, Hervás, & Pares, (2017) address the weaknesses of poor game design applications, which fail to engage children or fulfill therapeutic objectives. They propose to make these objectives more effective by addressing these needs in the development of a Kinect-based game called, "Pico's Adventures," for high-functioning children with ASD. They define a model, which integrates the expertise of clinicians, the interests of children, and the experience of designers, with the goal of creating an engaging gaming for children that has therapeutic value.

The game, Pico's Adventures, is introduced to the child in phases. The sequences allow children to familiarize themselves with the game environment by playing alone in the first session. Then a familiar adult becomes involved in co-play, and finally another child who is also in the study, shares the play experience.

Before starting the study on a target group of children between the ages of four to six, the authors asked experts to define therapeutic goals, techniques and game structure for children with ASD. They then tested the game on an older group of male children between the ages of nine and ten with ASD who were of average cognitive ability, had functional language, and had been involved in social skills training. By observing these children, and eliciting their feedback, the authors were able to make adjustments to the game.

The authors then tested the game on the target group, comprising 10 children between the ages of four and six. Sessions were scheduled on a weekly basis over the period of one month. A psychologist, researchers and parents were present.

The story line involves Pico, an alien, who needs to repair his ship to return to his home planet. In the first session, the child plays alone to become familiar with game mechanics. In the second session a parent was present to help the child find items that Pico needs. In the third session the parent helps the child to navigate the ship, and in the fourth the child plays collaboratively with another child in the study to earn rewards. Thus, social engagement increases through the game. Malinverni et al. (Malinverni et al., 2017) report a good acceptance of the game based on observations of the children at play, parental feedback, and feedback from clinicians that the children wanted to play the game months after the exploratory sessions.

Malinverni, Mora-Guiard, Padillo, Valero, Hervás, & Pares, (2017) advise that games be designed with cooperative game mechanics, where the resources are pooled so that players need each other's help to achieve a goal. This would promote behaviour relating to social requests.

The game was initially tested on children in an older age demographic, so there could have been a bias for preferences and interests. Both groups were high functioning. The authors advocate more research to compare a child's baseline behaviour to their game behaviour. Also, more evaluation needs to be done to determine if there is transference of targeted social skills to everyday life, and if the game holds the child's interest over the long term.

The study groups all appear to be high functioning male children, although nothing is said about genders of children in the four to six age range. It would be interesting to see if girls would respond differently, or whether the social interactions in the game would change with mixed groups. Also, lower functioning children may benefit even more from early interventions such as these. In a short-term study Malinverni, Mora-Guiard, Padillo, Valero, Hervás, & Pares, (2017) may have chosen high functioning groups to get feedback, but the next step could include lower functioning children in baseline studies.

In their initial reach the authors mention that they wanted to create a character that the child could relate to, and for the high functioning children this seems to have been successful. They might want to try more concrete everyday scenarios of collaborative play for children who may not be able to relate to abstract ideas at an early age.

2.2.2 A Game Engine for ASD

Children with ASD usually find it extremely difficult to understand body language and innuendo, and computerized therapies from Europe and America can seldom be used in a South African context (Van Zijl & Chamberlain, 2010). Van Zijl & Chamberlain (2010), therefore proposed the development of a generic platform and extensible 3D virtual environment engine for the development of computerized ASD therapy and research tools, with the specific aim to provide free culture-independent software on a generic platform. The platform must be network capable, multi-threaded and have low financial resource requirements. It must provide a middleware interface for subsequent developments. Another objective of the project was to provide a platform for creation of educational games and ASD therapy tools, without the need for extensive programming knowledge.

The authors supported the premise, based on substantial published research, that structured goal-oriented virtual environments (VEs) enable participants to repeatedly practise skills, and that these skills can be transferred to real-life situations with relative ease (Van Zijl & Chamberlain, 2010) They took an inventory of the existing open-source game engines, such as Panda, Crystal Space, Open Game Engine (OGE), Enginuity Engine (EE), the Object-oriented Graphics Rendering Engine, and Second Life. All of these had some desirable features, but lacked flexibility in other areas.

After analyzing the options, they decided to build their platform with Object Oriented Graphics Rendering Engine (OGRE) and its add-ons as a base. The design was largely based on EE, using some desirable features from OGE, Panda3D and Crystal Space. The Enginuity Engine was modified to allow for multiple threads, thus improving better synchronization between video and sound, and reaction times in the therapy tools, among others.

They used a number of third-party libraries to manage tasks involving input from peripheral devices, playing audio, executing scripts and game logic, and rendering graphics. These included OIS for managing input, and Nvidia PhysX for physics and collision detection.

Their design paradigm consisted of a kernel, which managed a set of tasks. Tasks are divided into two categories, sequential and concurrent, and include tasks such as a timer an input, and a video. A management application programming interface (API), allows tasks to communicate via a message-passing-system. The game object is a hierarchy of classes, which starts with a generic and extensible base.

To address networking issues, a simple peer to peer-based network was implemented, allowing remote players to be added to the game as if they were local players with their own keyboards or mice. Lua, a scripted language, was chosen because the program does not have to be recompiled to change parameters, or fix errors. New content can be added as scripts, and to do this the authors used SWIG (simplified wrapper and interface generator), which allows one to link a C or C++ application to many different scripting languages using interface files to define the API of the application. Using SWIG, the authors created Lua, and Java wrappers for the engine, which can pave the way for middleware to simplify game development and therapy tools. To address feedback issues, a third-party library, MyGui, was used. An extensive data-capturing system was implemented in the engine to allow therapists to replay the actions a user took during the game. A language localization component was implemented to allow for multilingualism.

The platform was tested using two therapy tools, and one educational game. The first therapy tool, which computerized worksheets from a popular workbook for ASD, “I am special”, was programmed in Lua, and tested the scripting language interface, Graphical User Interface (GUI) and data capturing.

The developed game involved situations children might encounter in the classroom, and the target group involved first graders at a local school. All text was available in multiple languages, with audio for those who learners, who cannot read at a satisfactory level. Data-capturing enabled the researchers to capture all attempts and answers that the child gave. The game also tested the rendering capabilities of the engine, audio playback, input, language localization, and data capturing. In general no more than two users are in a session and the network infrastructure will be at least a 10Mbps reliable local area network. The authors stated in their conclusion that their intended goal to develop a generic open-source 3D virtual environment platform, was reached.

Now that the authors have provided a flexible game engine, a next step would be to design games specifically for children with ASD and test them on this population. They state there will be a need to develop more middleware to allow the platform to become more user friendly, and allow for the development of more therapy tools.

Current projects at the time of publication, included designing a visual programming environment to this middleware layer, and on the virtual environment platform, the creation of an avatar with definable neurological characteristics, and a rule-based reasoning system to control the avatar’s behavior, which can contribute to ASD research. The authors acknowledge that they received funding from two Foundations in South Africa.

2.2.3 SmartGlass Technology

The objective of Liu, Salisbury, Vahabzadeh, & Sahin (2017) was to provide a framework to fast-track the development of computerised ASD therapy tools (Liu, Salisbury, Vahabzadeh, & Sahin, 2017). The authors argue that current behavioral therapy resources are strained, and the ASD community has a great deal of difficulty accessing effective and timely therapeutic interventions. Based on their research, vital social information is transmitted through facial expressions, eye gaze, and other often nuanced social cues, and many people with ASD demonstrate deficits in facial processing. The BPS (Brain Power System) is a Smartglasses-based behavioral aid designed to help children and adults with ASD with emotional understanding, directed-gaze, eye contact, and self-control. The BPS is a combination of hardware and software add-ons that may be integrated onto a variety of Smartglasses platforms (Liu et al., 2017). The authors stated that to their knowledge, their paper was the first published report of the use of augmented reality Smartglasses, specifically Google Glass, as a behavioural guide in the pediatric population

BPS was used to provide a single session with two male children ages eight and nine who had a specialist-derived diagnosis of ASD. Assessment of the tolerability, usability, and behavioral changes was based on the aberrant behaviour checklist (ABC) as well as a subjective caregiver and user report. The applications reported on in the study provide coaching for emotion recognition, face directed gaze, eye contact, and behavioral self-regulation. The BPS system uses an array of inbuilt sensors to collect quantitative data about the user’s environment and interactions, and then analyze the data using artificial intelligence (AI).

Face Game and Emotion Game are two gamified BPS applications that are designed to help children improve their ability to engage in face and eye directed gaze and to recognize facial emotion, respectively. Face Game encourages users to attend visually to another person’s face while attempting to overcome issues of gaze indifference and gaze aversion. Gaze aversion is associated with a response to perceived threatening, or anxiety inducing behavior, and gaze indifference supports the notion that reduced eye contact may be a passive phenomenon, where the eyes of others are not seen as being engaging or a relevant stimulus. Face Game applies computer vision algorithms to a real-time camera feed and detects human faces anywhere in the user's field of view. When the attention is directed to a face, the face is overlaid by a cartoon, which engages the user's attention. Then the cartoon fades and the human face is visible. Points are rapidly tallied for the period of the directed gaze at the face. To prevent the user from being rewarded for staring, the points slow and then stop. The game can resume when the user looks away and then refocuses on the partner's face. There are more points given for focussing on the central area of the face (the eyes). Closed loop feedback is possible through the collection of in-app metrics and quantitative sensor-data provides a closed loop feedback, which allows for customization of game levels and rewards. In the Emotion game, the user identifies various facial expressions. Two emoticon choices are given, and the subject must choose the correct one with a slight tilt of the head. The BPS detects the head movement and awards point respectively. The experience can be modified to afford customized on-screen rewards, and can regulate activities based on a data-driven closed-loop feedback.

Initially, the children and their caregivers had a coaching session to become familiar with the system. Once the participants were comfortable with the device, they had periods of time to play both games. The games could be stopped at any time to allow for breaks. Thus, in addition to the use of the Smartglasses, in the games, a positive climate around their use was established. An ABC assessment was done prior to the session to provide a baseline, and also 24 hours immediately after the session. Both children completed the session without any adverse effects as noted by the study staff or reported by the participant and caregiver, and demonstrated a substantial decrease in the hyperactivity/ non-compliance subscale, the largest subscale contributor to their baseline ABC total score.

Liu, Salisbury, Vahabzadeh, & Sahin (2017) conclude that digital interventions such as augmented reality, may address some of the difficulties the ASD community has in accessing effective and timely therapeutic interventions. Augmented Reality (AR) may deliver visual and auditory cues while the user is simultaneously engaged in natural or structured social interactions. Additionally, wearable technologies contain sensors that can be used to record and quantitatively monitor a user's interaction. The quantitative data gathering from sensor-rich systems may allow for digital phenotyping and the refinement of social communication interventions. Because machine learning may allow researchers to adopt a data-driven approach to identifying optimal therapeutic and educational approaches for each individual user, the use of augmented reality Smartglasses promise a high degree of feasibility, usability, and tolerability. Overall results are encouraging, but should be considered in the context of the limitations outlined in the report.

Other technologies on the market, such as smartphone Apps, may not offer the flexibility afforded by Smartglasses. Rather than the user being immersed in a screen, the user of Smartglasses is free to move around, their hands remain free, enabling them to use their hands to engage in nonverbal conversation while undertaking educational and occupational tasks. This type of mobile device is mobile and lightweight, allowing users flexibility to use it in a variety of settings. It can be rapidly scaled to meet demands.

2.2.4 Augmented Reality Platform

Bhatt, De Leon, & Al-Jumaily (2014) explored the need for cost-effective activities to improve social engagement for children with Autism Spectrum Disorder (ASD). They used an augmented reality platform to develop the games, which targeted specific areas of need, such as communication, social interaction with others, and delayed motor skills. By improving social interaction and hand-eye coordination, they felt the children might become more at ease around unfamiliar people. The target ages were between eight and fifteen. Augmented reality games, which allow for colour detection and motion detection tracking and hand-eye coordination, may encourage concentration and imagination in children through activities that provide repetitive movement and emotional feedback. The games need bright colours, sounds, and familiar characters and an attractive Graphical User Interface (GUI).

The Adobe Flash Professional CS6 was used as it contains a broad range of multimedia development abilities. It allows development of web applications, games, movies and mobile phone applications, and is also Integrated Development Environment (IDE) for Actionscript 3.0. The Happy Minion Game, which involves motion tracking, was developed using the GreenSock Tweening Platform. The tweening-classes library enables Flash to automatically insert frames between key frames, allowing the developer to move an object from one point to another. To capture real time video-feed, an in-built laptop web camera was used. The video feed established the augmented reality feature, by overlaying virtual objects from the real world, thus giving immediate feedback on the child's reactions, and allowed for tracking of progress. To address the issues of hand-eye coordination and movement delay, the player controls the Mr. Minion character, by a waving hand movement from left to right. Scores are kept at the bottom of the screen, and the purpose to keep the character. In the Emotions game, a standard blue pen, or any suitable found object is used to control the character. The child can drag and drop facial features onto a blank face to create the required face, which is linked to a storyline. On the left side of the screen is the blank face, and the facial features are on the right. The virtual features are overlaid, allowing the player to see themselves in the background. The live screen gives feedback to the player, and well as to the person monitoring the game.

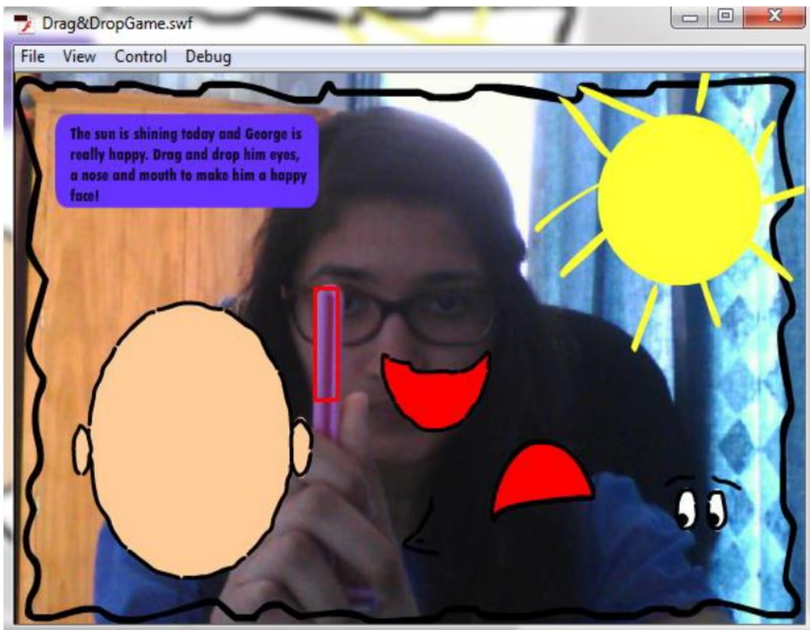

Figure 2.1 The Emotions game. Reprinted from (Bhatt, De Leon, & Al-Jumaily, 2014).

Another goal was to provide cost effective activities for ASD children whose parents who may be carrying the burden of expensive therapy sessions. The objects used to interact with the screen can be familiar everyday items, and the child can use a laptop computer in their own familiar surroundings. The games are designed to be simple, and the prompts are designed to provide a context for the emotions. The webcam provides feedback, and imaginative play was encouraged.

Bhatt, De Leon, & Al-Jumaily (2014) noted that the children found the games easy to follow, and the idea of tracking objects in their environment got positive feedback from two of the four participants. The Happy Minion game provided the most fulfilling scoring system, and the Emotions game was appealing from the point of view of feedback from a live video.

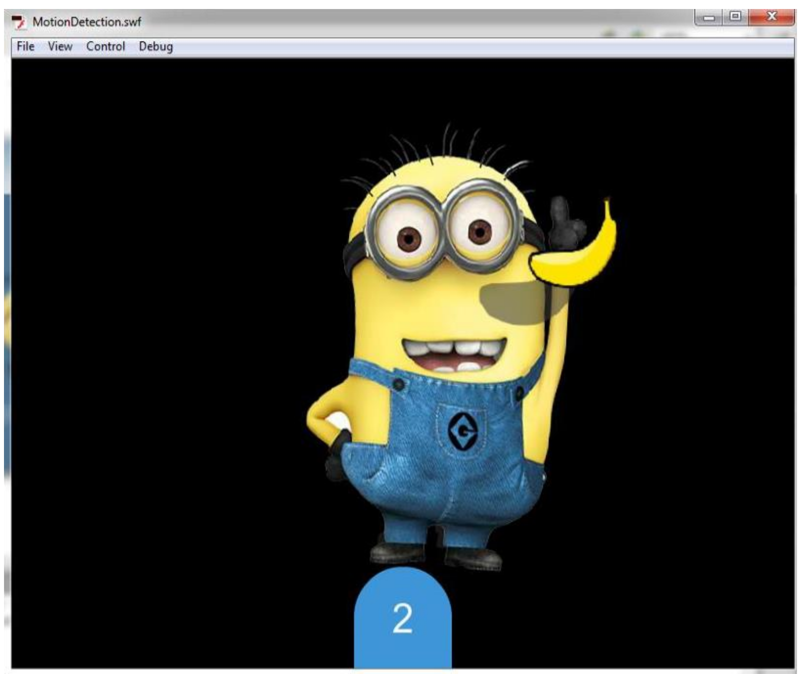

Figure 2.2 The Happy Minion game. Reprinted from (Bhatt, De Leon, & Al-Jumaily, 2014).

The games were tested on four typically developing children between the ages of ten and fifteen, and the instructions were easy enough for a ten-year-old to follow. There were only four children in the study, and their specific ages and genders were not noted. Tracking objects was more exciting for the older two participants, but there was negative feedback that the games became repetitive and boring. The authors concluded this was to be expected as they used typically developing children.

It is likely that modifications may have to be made to the instructions for children with ASD. Technical issues such as a blurry image of the player, and the fact that the Emotions Game was not fully completed, were works in progress at the time of publication. The authors have opened the door to further research and testing of game interventions for children with ASD. More trials would need to be done with children with ASD to determine if these games indeed foster more social interaction and whether improved hand-eye co-ordination is a factor in improving social situations.

The authors described some new technologies such as Socially Assistive Robotics (SAR), which is a new field of robotics being explored to treat autism. The robots can assist children with social interaction through coaching and motivating changes in their behaviour. They also comment on Virtual Reality (VR), which can create a captivating synthetic environment for the user. Some VR applications include; haptic devices, joysticks and wrap-around displays. VR applications can be extended to create an immersive environment from the real world with digital information, thereby augmenting the perception of one's reality. This concept, Augmented Reality (AR), may nurture imagination in a child who struggles with imaginary play. Their explorations with Augmented Reality are described in detail in this paper.

2.2.5 Gesture and Music Therapy

Magrini, Salvetti, Carboni, & Curzio, (2016) introduced a system for real-time gesture tracking, which can be used in assessment of well-being activities such as medical coaching, and music therapy. It is an interactive, computer-based system based on real-time image processing, which reacts to movements of a human body playing sounds. The system presented uses a gestural interface and a computer, which runs custom developed software. During the test the person moves freely inside a specialized room setting, and algorithms detect and extrapolate spatial position of the subject, such as arms and legs. The operator links this data to sounds. Movements are synthesized in real time. The underlying belief is that even profoundly impaired individuals can become expressive and communicative using music and sound.

Rather than use existing sensor-based interactive systems, which provide data to the computer with specially programmed software, the authors developed their system using real-time video processing with the understanding that extra sensors can be easily added. Video processing techniques add more parameters to localize and detail the gestures they want to detect and recognize and can be linked to sounds synthesized in real time using a custom software interface.

After considering two models, which address the needs of children with ASD, namely ABA (applied behaviour analysis) and Developmental Individual Difference Relationship (DIR), they chose the DIR approach. DIR (Stanley Greenspan MD) advocates involvement, communication and flexibility.

The system was developed in two steps using different technologies. The first was version based on real-time video processing where body recognition routines are software based. The system needed a controlled environment, and the presence of a technician. It used software developed in C++ on the Mac, using the latest version of Mac OS X. The video camera is connected through a Firewire digitizer, Imaging Source DFG1394. As an output audio card, the authors used the Mac's internal one, and a couple of TASCAM (TASCAM, 2019) loudspeakers were added. The system architecture involved several specialized core software modules, including a sequence grabber, a video processor, a skeleton reconstuctor, a data and a sound synthesizer. The system was installed in a special empty room with wood walls, designed to create a relaxed environment. As system parts were hidden to avoid being distracting, and the ambient light was soft and indirect, to avoid shadows, which could interfere with motion detection.

After having success with the first version, they implemented the second version, which relied on the Kinect v2, as it provided more flexibility in tracking, and could be installed in the user's home. The intuitive interface could easily be used by the children's families. The Kinect V2 is based on Time-of-Flight principles (T o F), which allows the device to compute a depth map of the environment. In the home version the authors used a set of predefined pre-sets, easily accessible from a drop-down list, which covered a broad range of interaction modalities and gestures. Two special modes designed to improve motor coordination were used. Anticipating that parents who are using it at home may require technical support, a video chat mechanism in the software was installed, so that a technician could be reached by pressing a button. As well, a record button was also included so that movements are recorded on a disk for off-line analysis by a psychologist.

Experiments were carried out in a school environment, on four male subjects aged five to seven, who had a diagnosis of low-functioning Autism. The weekly intervention lasted about thirty minutes. The children were evaluated in a cross sectional and follow up pilot study. Teachers completed the Short Sensory Profile, and parents responded to a questionnaire on motor control and sensory elaboration. Three clinical psychologists not previously involved in the study, analyzed the first eight videos and completed an observation grid for each session. The grid was produced ad hoc by the research team based on DIR Floortime model and from a questionnaire of Politi and colleagues (DATE), with the aim to assess music sensitivity in children affected by ASD. Nineteen items that related to the child's behaviour during sessions were measured in terms of Arousal, Attention, Affection, and Action. The person who conducted the sessions had formal training in DIR Floortime.

There was a moderate to good concordance rate between the evaluations on the observation grid completed by the psychologists. Overall skills improved over time, as recorded by the psychologists. The positive results of the pilot study indicated that children developed skills in communicating with gestures and symbols, imitating the caregivers, and establishing joint attention. The authors suggest that since they did not evaluate outcomes, such as increased cognitive skills and school performance, this may be an interesting area of research for the use of accessible technology-enhanced environments. The authors' new objectives are to include a video component and they are exploring possibilities using Unity and Processing frameworks to enhance the visual experience. In one demonstration, they use an avatar to replicate the subject's movements, with the idea that the avatar and the scenario can be customized to prove a sense of immersion in an imaginary world. In the second demonstration, the subject needs to correctly replicate the movements of a trainer in a video. In the third demonstration, aerial painting, the subject waves his hands in the air and those movements are mapped to brush strokes on a virtual canvas.

2.2.6 Exergames

Caro, Tentori, Martinez-Garcia, & Alvelais, (2017) proposed that exergames, which combine game technology with exercise activity (Caro, Tentori, Martinez-Garcia, & Alvelais, 2017), can offer children with severe autism a natural interaction using multisensory stimuli to keep them focussed during motor therapeutic interventions (Caro et al., 2017). Children who exhibit poor eye-body coordination skills, may have limitations on independence, on abilities to take part in sports, and on developing age-appropriate social skills. Traditionally, therapists use paper-based visual supports such as images or coloured markers to represent visual targets and guide the limb movements. These visual supports may be unclear, confusing, unengaging, or in completion with other visual stimuli in the environment.

Caro, Tentori, Martinez-Garcia, & Alvelais, (2017) found little research, which supported the impact of exergames on motor skills development and hand-eye coordination. Most were found to support behavioural disturbances and improve cognitive control, and assist in social interactions. They therefore set out to develop a game called FroggyBobby, as a tool to improve hand-eye coordination in children with autism. They applied an iterative user-centered design methodology, which involved interviewing, observation, and participatory design sessions. FroggyBobby uses the Kinect sensor to monitor and track which arm a child is using at a particular moment. It was implemented as a 2D game in C++ using the Microsoft XNA framework.

The goal of the game is to encourage participants to use their upper limbs to perform different eye-body coordination exercises. Children are to help the frog avatar to eat as many flies as he can. Their limb movements, which involve moving their right or left arm to reach a visual target, control the frog’s tongue. A yellow start button located in the upper screen area, indicates where the limb movement starts, and a red end button located at the bottom of the screen indicates where it ends. Children are to catch as many flies as possible that are in the path between start and finish, by swiping their arms between both buttons. There are six levels of difficulty, based on motor therapeutic goals. In levels one to three children practise lateral exercises to control the tongue. In level one children use their right arm, in level two, their left arm, and in level three, they alternate between left and right arms. For levels four to six they practise cross-lateral exercises which vary their use of arms. Each level has ten repetitions and children earn points and coins. The children can later use the coins to buy accessories for the avatar, such as shoes, hats, and eye glasses.

Caro, Tentori, Martinez-Garcia, & Alvelais, (2017) presented a seven-week evaluation study using exergames to support the practice of eye-body coordination exercises. Seven children with severe autism ranging in age between seven and ten years, one of whom was female, and three female psychotherapists participated in the study. All parents and psychotherapists consented to the study, and agreed to be interviewed, observed and video-recorded. All psychotherapists from the facility, Pasitos, received a one-day training session of how to use the game. Based on their suggestions, game levels of FroggyBobby were introduced slowly to avoid cognitive overload in the children.

A small playroom was equipped with a Kinect sensor, a multimedia projector, two cloud video cameras, a keyboard and a mouse. The Kinect sensor tracks body movements to control the game. Speakers play FroggyBobby music, and video cameras, one in front, to monitor user interactions, and one in back to monitor reactions and movements. A red tape rectangle mark was placed on the floor three meters from the Kinect sensor, to indicate where the children are to stand. During the first week of the study, adjustments were made to determine correct standing distances from the Kinect, in order to get reliable body tracking data. Twice a week during the next six weeks, the children progressed through the six levels. To avoid fatigue, each child was limited to seven trials, and the physiotherapists selected the levels for each child to suit their needs. Weekly interviews were conducted and recorded, and as the children were non-verbal, the psychotherapists acted as their proxies. Each session was done individually in the presence of the therapist. Total time of observations was just under twenty-eight hours, including videos obtained from front and back cameras. six hours of thirty-minute interviews with psychotherapists, involved discussions on how the system went that week. To provide a controlled setting each child was supported by the same psychotherapist, and variations in the supports were limited. They all received the same therapies and classes- three days a week of cognitive, social and language therapies, and two days of thirty-minute physical exercise geared at control and flexibility. None of the children were taking medications during the study.

Data analysis involved a mixed approach. Qualitative data was analysed using techniques to derive grounded theory and affinity diagramming. Quotes or events obtained from interviews and videos were grouped to uncover emergent themes, and to code the data, they used atlas.ti. Quantitative data analysis involved sequential analysis techniques, which quantified children's behaviours and interactions with the game. A coding scheme based on other available codes for autism, allowed for systematic coding of behaviours, such as attention, expression, motor performance and prompts. Two researchers applied the coding scheme to the videos of each child, using an excel spreadsheet. (CITE)

Psychotherapists found FroggyBobby easy to use during eye-body coordination sessions. Results indicated that children with severe autism maintained their attention for the total duration of the therapy, reduced their aimless limb movements and developed aimed limb movements as a result of weeks of usage. The authors felt that research is needed to fade out the guidance children receive when doing the eye-body exercises. Their concern is that assistive technologies may jeopardize a child's independence when using too many stimuli and step-by-step guidance. They chose not to use an eye-tracking device to investigate the amount of time the child was looking at the visual stimuli. They were concerned that placing a sensorial device over the eyes could result in sensory problems.

Their paper contributed qualitative and quantitative empirical evidence to show how exergames help in the development of eye-body coordination. Caro, Tentori, Martinez-Garcia, & Alvelais (2017) concluded there does not seem to be any evidence to support the use of exergames to improve eye-body coordination as compared to benefits offered by traditional motor therapies, but they are conducting an evaluation study to determine in what situations FroggyBobby excels compared to traditional therapeutic motor intervention.

2.3 Other Works

2.3.1 Interactive Robots

Baraka, Melo, & Veloso (2019) developed a robot with autism-like behaviors, as a tool for better understanding and evaluating Autism Spectrum Disorder. Although the initial goal was to provide therapists with better tools for diagnosis, they also saw the potential benefits of such robots to complement existing therapist training as well as to enable novel tasks. To the best of their knowledge, the use of social robots in the context of professional therapist training has not yet been investigated. They scaffolded (Baraka, Melo, & Veloso, 2019) this research on a previous paper that dealt with the application of the ADOS-2 model (an ASD diagnostic tool) to control the behaviours of an NAO robot which exhibits behaviours similar to children on the spectrum. “The NAO is a humanoid robot developed by the French company Alderbaran Robotics”, (Kulk & Welsh, 2008, p. 2). Baraka, Melo, & Veloso (2019) make it clear they are using the term autism-like behaviour as it applies to robots, so as to not reinforce erroneous assumptions about how the autistic mind functions.

To address the diverse behavioural profiles of individuals with ASD, Baraka, Melo, & Veloso (2019) utilized the behavioural characteristics defined in the ADOS-2 diagnostic tool, which is a state-of-the-art standard of ASD assessment. Normally, in a semi-controlled setting, therapists go through a series of ten tasks with the child using standardized objects and procedures. They then code the behaviours they have observed during the session in the form of discrete values on a set of features spanning several dimensions of behaviour. The typical session takes forty to sixty minutes to administer. Different modules are available depending on the child’s age or language ability, and for the purpose of this research, the authors chose module two, which is suitable for children with speech abilities, because it provides a richer set of behaviours.

Using the ADOS-2 model, they designed autism-like behaviours of varying severities along four behavioural features, which include verbal and non-verbal features, in an autonomous agent running on a NAO robot. The result was a customizable interactive robot with autism-like behaviours, which can interact with a human in response to a predefined set of stimuli. The user can customize the robot in one of 256 unique ways.

The validity of the reactions was evaluated through video and in-situ studies with certified Autism therapists.

Therapist training relies heavily on videos, theoretical material, and observations of real-life diagnosis sessions run by a trained expert. Although the training covers a wide range of behaviours, and stresses the rigorous nature of coding and task procedures, it largely ignores the interactive and embodied component required for a successful tool. The therapist must interact with the child, while observing behaviours, adapting tasks in real time, and do feature coding. Mistakes may result from poor mastering of these skills. Robots, which are capable of exhibiting autism-like behaviours, may be used to complement existing training. The robot is capable of emulating the structured interactions of the ADOS-2 session, to a limited extent. It can also give customized behavioural profiles, which can increase diversity and the number of feature combinations. Video play-backs of real-life interactions can allow the therapist to review different sessions, as the robot can actually repeat a behaviour.

Baraka, Melo, & Veloso (2019) detailed how the robot was programmed, what behaviours were simulated and how the programming architecture was implemented. In the evaluation process, the authors ran a video-based evaluation with trained ASD therapists. The aim was to investigate whether therapists would assign the same value to the designed behaviours as they would for ADOS ones, and whether they would agree with each other in evaluation. The participants, after watching a video were asked to diagnose the robot, based on three tasks. Then when these were completed, the participants were asked to go through a further three pre-randomized robot behaviours. Questionnaire answers were rated on the Likert scale, and over-all, participants provided high ratings for the three applications suggested.

Results of the study indicated generally satisfactory levels of accuracy and agreement for most behaviours. Although the ADOS-2 has systematic coding structure, the authors found considerable levels of subjectivity in coding for some behaviours. Subjectivity can be a problem in behaviour-based diagnostic procedures in general. There was also a discrepancy between results from the video based diagnostic behaviours, and real interaction with the robot, even though the robot behaviours were largely identical. They speculated that the cognitive load of embodied interactions affects the therapists.

Because the robot in this study is capable of simulating simplified versions of a real ADOS-2 interaction, the authors suggested they should focus on procedural training, as opposed to coding training, for which videos are more adequate. Questionnaire results suggest that Autism experts are willing to use robotic tools professionally.

Although the focus of this study was to use robots to complement therapist training, the authors see huge potential for the use of their robot to unlock novel autism tasks, and to educate and sensitize the general public about the diversity of the behavioral aspects of ASD. An autonomous, customizable, and adaptable robot, which is able to match its behaviour to that of the child, may demonstrate desirable behaviour for the child to imitate. The robot could also be used in learning-by-teaching scenarios, where a child could teach the robot a skill that the child has mastered but one in which the robot needs to be programmed. The authors state that this possibility would need empirical investigation, as some children at the higher levels of ASD may find this challenging. Robots that can be programmed with different severities may open the door to a number of applications for training, treating, and educating a wide range of individuals with ASD.

2.3.2 A Robot Engine based on Unity 3D

Bartneck, Soucy, Fleuret, & Sandoval (2015) introduced a new approach for animating and programming their interaction with users, using a Robot Engine, TRE. They used existing powerful animation and programming tools of a game engine to give interaction designers the tools they need. They believe that TRE has the potential to bridge the gap between the diverse fields of study needed for successful Human –Robot Interaction (HRI).

They explored different platforms, programming languages, tools for animation, and games engines. The authors chose Unity3D for TRE because it met their requirements, and had a strong developer community. The plug-in architecture of the Pro version allows developers to expand core functionality. The authors felt their main technical contribution was to develop a plugin to communicate with sensors and actuators within Unity 3D.

They integrated several plugins such as a speech recognizer and computer vision library to enable the robots to process sensory information. They thereby have established proof that Game engines can be used for controlling interactions between humans and robots.

TRE consists of the Mainscript, ModelScript, Serial CommunicationScript and the AnimatorScript. The Mainscript manages all other scripts, modules and graphical interface elements. It controls modules such as speech recognition, text to speech, TTS and a computer vision module. Speech recognition is based on Microsoft Kinect, and requires the installation of Kinect SDK. The TTS system uses Microcoft Windows Voice, and the vision module is based on OpenCV. Many more modules such as Leap Motion, a device to track hand gestures, can be integrated.

The ModelScript translates the constraints that the physical robot has into a virtual robot. This means that the virtual robot will not perform movements that would be impossible for a physical robot to execute. In TRE every part of the robot in the 3D model is a game object.

The AnimatorScript manages Unity3D's Mecanim Animation System, which manages animations and sends positions and angles of the GameObjects to ModelScript. Keyboard presses are caught and mapped on the graphical user interfaces. TRE includes two scripts, one for debugging and the other for control, which are executed on Arduino boards.

Robots can be made using a variety of programs. The first robot developed using TRE, was a Lego fireman torch, where all the internal components were removed and replaced with servo motors in the torso, head arms, and legs, which allowed six degrees of freedom. A USB webcam with a microphone was placed in the head. They mounted the fireman on a base, which enclosed an Arduino microcontroller and speaker. They then created a 3D model in Blender, and imported it into Unity. After the TRE modules were configured, the robot could be animated using the virtual robot.

Originally robotic hardware was expensive to produce and required expertise. Now, with 3D printers, and the availability of easy to use micro controllers, such as Arduino boards, enthusiasts can build their own robots. The authors chose the InMoov robot, which is open source robot, where anyone can download the 3D files and blueprints. Printing was a big undertaking, and some of the moveable parts had to be printed of a professional 3D printer. The robot they produced has 25 degrees of freedom, two cameras, a Microsoft Kinect and a speaker. They imported the 3D files into the Blender software, and then exported it to a format compatible with Unity. Following the pattern of the Lego fireman, they configured the TRE models to fit this specific hardware configuration. They were able to fully control the InMoov robot using Unity 3D.

Bartneck, Soucy, Fleuret, & Sandoval (2015) did not run a controlled user study but developed a set of tutorials, which allowed a user familiar with Unity 3D to install and use it. Two colleagues, who were not in the original development study, followed the instruction manual and gave feedback with suggestions for better directions. Although this does not substitute for a usability study, they found the feedback informative, and plan other forms of future evaluation. The authors feel that their Robot Engine, TRE, has met their objectives to enable users with little to no programming experience to animate robots, and to control interactions with humans. They recommend TRE as an ideal tool for the democratization of robot development.

2.3.3 Creating a Game Engine and Mental-Models

The objective of Guana, Stroulia, & Nguyen (2015) was to develop a domain-specific language (DSL), PhyDSL-2, to enable a diverse variety of game developers to autonomously define gameplay mental-models, and automatically derive executable code in an agile and inexpensive fashion. They defined that the role of the game-engine architects is to provide adequate development interfaces, and also enable game designers to specify gameplay designs, using semantics analogous to their gameplay mental model. Based on the concept of mental models, they proposed that mental models are key in capturing human perception, imagination, and structural understanding of reality.

Because building video games is an intensive and error prone software development task, the authors advocated building on existing modern model-driven technologies, to overcome the complexity of the engine design and to systemize maintenance and evolution. They presented a set of lessons learned during the design and construction of PhyDSL-2, an engine for 2D physics –based games.

They defined DSL(domain-specific languages) as tools to capture the specification of a software system using semantics that belong to the system's domain. These allow developers to reflect about their gameplay mental models, and guide the specification, study, and optimization of game designs.

In the context of Phy-DSL-2, the authors detailed their approach. They wanted to provide a game-development language for non-programming experts, which would also appeal to professional developers, and decided to limit the scope to 2-D games. Phy-DSL-2 builds on PhyDSL, but provides new camera behaviors, new on-screen control constructs, and manipulative gameplay objects. Their PhyDSL-2 editor is built as an IDE (integrated development environment) plugin for Eclipse2.

Guana, Stroulia, & Nguyen (2015) considered essential five gameplay questions: who is the player (external or internal); what are the possible actions available; where does the player live; what are the goals, and challenges? The ultimate scope of the language is to provide a set of related constructs, using semantics close to the level of abstraction of their gameplay vision. The authors' belief is that these questions can be generalized to help in the scope definition of any game development interface.

Guana, Stroulia, & Nguyen (2015) other major undertaking was to define a set of components that a game engine needs to support such as scene and management, collision and rigid control, collision and rigid body mechanic, human interface input, and sound and haptic feedback management. The life-cycle manager is the main orchestrator of the game. The game-view manager restores the state of game views, the player-input manager controls the different interactions for the player, and the score manger evaluates the game's reward and punishment rules. The physics engine is used to compute the position of all game elements; the rendering engine provides the game view; the sound and haptic feedback controller gives tangible feedback using sound and device vibrations. The collision detector filters out the collision events detected by the physics engine.

With these elements in mind the main goal was to design a highly cohesive software design, following a 5-step iterative process: implement concrete components, which conform to the architecture; identify code segments; conceptually group code segments according to their roles; and refactor the component implementations.

The third area of focus was on model-driven engineering technologies: Model to model (M2M) and model to text (M2T). Using these technologies, such as ATL, information contained in a model can be split or augmented, and template –based M2T technologies such as Accelo, can be translated into text. In PhyDSL-2 the authors used a 3-step model-transformation composition. Initial input is split into four independent game models: game layout, game dynamics, game scoring, and game controls.

Their fourth area of focus, that model transformations are hard to build and maintain, the authors have developed ChainTracker, a visualization and trace analysis tool, which allows developers to assess the impact of changes in evolving systems. It enables developers to track tangled aspects along architecture implementation and transformation implementation.

The authors learned first-hand how the engine scope definition evolves to satisfy the needs of different developers and gameplay models. They also established that game engines need flexible architectures since they need to react with new game deployment platforms such as new controllers, or sensors etc. They became aware of the fact that the more scattered the feature implementations are in the architecture, the more likely they may get tangled with features to be added. This increases the potential maintenance and evolution costs. For example, the introduction of on-screen controls in DSL-2 cross-cuts the mechanisms of gameplay specification, and they had to redesign how game actors reacted to events, how buttons were included in the game and how they had to be modelled without impacting other game elements. They found that by minimizing how scattered gameplay elements were, they could add new gameplay features more efficiently. In addition, they could quickly identify modifications needed in order to keep PhyDSL ‘s domain specific language in sync with the developer’s evolving model.

In regard to their approach to model-driven technologies, the modularization strategy has eased the transition of PhyDSL into PhyDSL-2. The camera management and on-screen features were limited to one game-plate component, and language changes were progressive. Developers experienced less severe cognitive challenges while executing tasks, and spent less time trying to understand the entire transformation architecture, and could focus on maintenance. Using ChainTracker, they were able to effectively react to the evolutionary nature of gameplay model definitions, and code implementation requirements.

The authors conclude that their model, which was developed in a modular manner, assures that language changes only affect small scopes of transformation rules. Through development and experimentation with PhyDSL-2 and ChainTracker, they have empirically validated how model-driven technologies can be effectively used in the construction of video games. They are confident that the use of PhyDSL-2 will facilitate the development of gameplay mental-models by allowing developers to autonomously define, and automatically derive executable code in an agile and inexpensive fashion.

2.4 Implications of Open Problems

My research papers were carefully chosen to offer insight into current areas of study in interventions for autism. They offer a varied approach, which considers traditional and more modern approaches. As technology becomes more available as a global vehicle for delivering services and information, it can offer cost effective and creative interventions for autism research. In this section I am offering some of my insights into the articles presented in the literature review.

2.4.1 ABA and PRT Interventions (Mohammadzaheri et al., 2014)

Video games are played in real time and usually involve instantaneous feedback. Rewards, similar to ABA’s operant conditioning, are also present in video games. Games offer the ability to learn over many trails, with the learning objective created by the game designer. My Autism Serious Game Framework (ASGF) holds promise as it is flexible enough for researchers to adapt to their purposes in a simple and intuitive manner.

2.4.2 TEACCH Interventions (Siu, Lin, & Chung, 2019)

The learning environment is important and can be further explored in VR (Virtual Reality) worlds with aims to make the child comfortable and willing to learn. The goal-based structure (GAS) is important and should be incorporated into games. An example would be to eliminate inappropriate types of behaviour such as perseverating on task.

2.4.3 DIR/Floortime Interventions (Carpente, 2016)

Games use sound and background music that could also help the child's mood and feel connected to the game. It would be interesting to see the impact of sounds or music in encouraging a child to get involved in video games.

2.4.4 Addressing Game Design Principles (Malinverni et al., 2017)

Developers need good design principles when making games. Being educated helps create more choices and be better able to target the audience of the game.

2.4.5 A Game Engine for ASD (Van Zijl & Chamberlain, 2010)

One of the objectives of the project was to provide a platform for creation of educational games and ASD therapy tools, without the need for extensive programming knowledge. This resonates with my research in particular, and provided motivation for my own unique angle. This paper was very specific in its use of current technologies, which makes it of particular interest to my studies. In my opinion, building on another language and adding a scripting language is smart as it allows for scaffolding ideas on previously established work. Documentation for the engine and add-ons is important information.

2.4.6 SmartGlass Technology (Yu, Li, Li, & Liu, 2016)

The work of Liu, Salisbury, Vahabzadeh, & Sahin (2017), focuses was on the delivery of technological interventions in a controlled setting, and therefore, modifications potentially could be made for a variety of uses. If the study on the use of Smartglasses for ASD is expanded, then variables such as gender, age, and cognitive ability levels should be addressed. The use of Smartglasses and Augmented Reality show great potential because they allow for the delivery of visual and auditory cues through sensors, while the user is simultaneously engaged in natural or social interactions.

It is necessary to experiment with Smartglasses technology, such as Oculus Rift and the HTC Vive. These are the main Smartglasses on the market and would be promising to use in autistic research. I believe this will be a big area to watch as it will likely evolve fairly fast and be adopted by consumers.

2.4.7 Augmented Reality Platform (Bhatt et al., 2014)

This technology uses a webcam and the development a free library that is accessible to any developer for use with Augmented Reality is important. By offering a free library, developers could scaffold their work on previous research and expand on established ideas. By using more detailed models, like those used in commercial videogames such as Final Fantasy, realism (to create immersion) in the augmented world can be increased.

2.4.8 Gesture and Music Therapy (Magrini, Salvetti, Carboni, & Curzio, 2016)

I find it helpful to read an article that incorporates the musical or fine arts in the development of new ways to stimulate, and evaluate children with autism. Background sound may be an important element of any interventions.

2.4.9 Exergames (Caro et al., 2017)

It is of interest to my research that the authors did not recommend the use of eye-tracking devices for hand-eye coordination exercises in traditional therapy sessions. Also, the authors express concern that assistive technologies may jeopardize a child's independence when using too many stimuli and step-by-step guidance. They state that from a clinical point of view, more research is needed to investigate how to fade out the assistance children get from the technology, and that independence is a primary goal when caring for children with autism. I think the concerns they express are valuable guideposts when developing game interventions, and should be given serious consideration.

2.4.10 Interactive Robots (Baraka et al., 2019)

Programming a robot that can imitate autism-like behaviours, or can help a child to recognize a range of emotions, and assist in social interactions, seems to have great potential as far as my research is concerned. Allowing a child direct interaction with a robot, which could adjust feedback, has potential. Using the Kinect with robotics is also an area to explore.

Subjectivity can be a problem in behaviour-based diagnostic procedures in general. There was also a discrepancy between results from the video based diagnostic behaviours, and real interaction with the robot, even though the robot behaviours were largely identical.

2.4.11 A Robot Engine based on Unity 3D (Bartneck, Soucy, Fleuret, & Sandoval, 2015)

For my part, the use of robots holds great potential for interventions with children with ASD. This study seems to offer a segue into the development of a robot that could incorporate specialized software to address children's needs. Of use for my thesis is the development of an engine that targets Unity3D.

2.4.12 Creating a Game Engine and Mental-Models (Guana, Stroulia, & Nguyen, 2015)

My initial idea for developing the ASFG, was similar to an event type language (see Appendix A). Converting it to a domain-specific language (DSL) would be important as it may simplify the language. Developing mental models would give researchers an edge as it would help them to understand the structure of designing games.

Chapter 3. Development Section

I developed the Autism Serious Game Framework (ASGF) to allow therapists or other professionals who have little or no programming experience to modify existing game interventions for children with autism. ASGF also tracks gameplay through customizable metrics that can be recorded and saved after each session. Thus, ASFG is an intuitive tool which includes feedback for the therapist, such as tooltips, so further modifications and research can be done to improve the delivery of serious game interventions.

Prior to being involved in the development of the ASGF system, I worked on the development of five games intended to assist children with autism, under the direction of the autism research experts, whose fields of expertise are in neuroscience and behavior. It was determined that the next steps would be to develop a framework so that therapists could modify games to the needs and specifications of their client base. I met with the team of experts both physically and remotely via Skype to determine the expected functionality of the framework.

I developed two games, which could be modified to suit the purposes of ASGF. I rewrote these games based on earlier work I did with the team of content experts. The Face Matching game is a game for autistic children to discriminate faces by identifying the correct emotion on a face, such as happy or sad. This aims to help them to understand social communication. The Rabbit Adventures game is an inhibitory game which aims to curtail unwanted behaviors. The child must press the space bar when they see a rabbit only, and not when they see another character such as a wolf. I developed the game interventions to modify certain behaviors at an early age as part of a neuroplasticity study for young children with autism (Targeted Cognitive Training: Assessment and Plasticity in ASD | Diana Parvinchi - YouTube, 2017).

In my research, it was helpful to consider how other researchers dealt with the task of building a flexible game engine, as discussed in the literature review The Robot Engine (TRE) (Bartneck et al., 2015), which is developed on top of the Unity 3D engine, differs from ASGF in the application. The autism game engine developed by Van Zijl & Chamberlain (2010) requires programmers to program the Lua language and have extensive knowledge of their underlying system. Assets would either have to be created, or purchased online, and integrating them may be a difficult.

3.1.1 Needs Analysis

There is a need to have flexibility in game delivery to match the needs of the users, and the therapists delivering the interventions. As the content experts were involved in neurobiology research, the focus has been on developing game interventions that can positively alter some thought processes that may impede typical brain development in children with autism (Parvinchi, 2019).

My supervisors and I met with the content experts early in the process. We exchanged ideas from the very beginning. In conjunction with my supervisors, I edited and expanded on ideas that the content experts sent us. The games interventions were their ideas, which included concepts such as face recognition, inhibition control and set shifting. The modifiable aspect of the ASGF framework was the next logical step. I had a professional relationship with the content experts and felt they had a good grasp of the capabilities of technologies such as the Microsoft Kinect, Eye trackers, and understood what a game engine (such as Unity 3D) was. They requested I use the Unity 3D engine, as they believed that it held potential for meeting their needs for a flexible game framework.

3.1.2 Task Analysis

I propose that the therapist begins by starting the ASGF application. The first option is to watch the videos, which explain the game (that will be developed using the ASGF), in detail, or view terminology from the introduction screen. This option is the best method for understanding the function of the buttons within the graphical user interface (GUI) and the steps involved with the program; it is imperative that the function of the buttons is understood by the framework users (therapists). The “Build Game” button will give appropriate feedback if there are errors in building and finalizing the game. The Help View feedback window will give tips when undertaking game building activities such as creating cards. Also, when the therapist hovers over a button, tooltips popup showing what the button does.

Should the therapist choose to bypass the instructions because they understand the function of the buttons, they may start at the main screen by pressing the “Start Autism Tool” button. They may choose to start the process by creating a card game (or a Rabbit Adventures game) and would press the create “Face Matching Card Game” button three times to create the cards. Then in the popup properties panel they may select the Happy and Sad Expressions and set the number of trials per block to two. A new level can be created by pressing the “New Level” button on the main screen. If level Two is selected in the Level dropdown screen, the therapist presses the “Load Level” button on the Cards or Load Game panel located on the main screen. In this panel they may select Rabbit Adventures Game in the dropdown and select Load Level to create a Rabbit Adventures Game on Level 2. The “Events” button can be selected to load the properties menu for the Rabbit Adventures Game. In the end, the therapist must understand conceptually what the buttons do in the ASGF framework, to develop a game.

The main character may be replaced with another FBX model in the Rabbit Adventures settings panel. By pressing the “Build Game” button (on the main screen), the instruction and metric screens load. This is easy to understand and labels describing the screens give feedback to the therapist. On the instruction screen is the option of playing back a short movie to reward the child after completing the current level. After clicking next on the Metric Screen, the Play Game menu shows. The therapist can then select the “Save Current Game” button to save the games that he/she built.

The next step is for the therapist to run a study with the game he/she just built. On the introduction screen, she/he can press the “Load Previous Game” button to load a game. The Play Games Screen will then load. Also, a game from the Play Games Screen can be loaded by pressing the “Load Previous Game” button located on this screen.

When each game level finishes the optional movie, selected previously by the therapist, will play giving a reward to the child. At the end of a game(s) the ASGF system reloads the Play Games screen. The therapist may select the “Save Report” button to save out the metric data, such as response time or player scores. It is necessary to understand that the process goes on until the “Exit Application” button is pressed. The therapist may load more games in if she/he chooses to do so or repeat the trial using the current game (and run more studies).

3.2.1 Face Matching Game

The Unified Modeling Language (UML) Diagram for the Face Matching game is shown in Figure 3.1. When starting ASGF the introduction screen loads. The therapist has the option of loading a previously saved game, viewing the terminology, viewing the video tutorials and starting to create games. In Build Mode the therapist may build a game by creating three cards and setting the properties, such as selecting the happy or sad expressions to be played. They can also set up the score and level objects and add a timer. Next the therapist may set up the instruction and metric screens. An example of a metric is response time, how long it takes for a child to select a card. In the Play Game(s) screen the therapist can save the current game. The child may then play the games created by the therapist. The instruction screen loads with verbal feedback screen and after clicking next the Face Matching game begins. When the child (user of the developed game) has completed the level, audiovisual feedback in the form of a movie is played for the child for a reward. At the end of the game, the Play Games screen loads. The therapist can then save out the report data. The game can then be played again with another child. When the therapist has finished, they can select Exit Application from the Play Game(s) menu to end the game. The save game feature allows the therapist to save the current game. Should the therapist need different features, they can then create a new game and then save with a different name. This allows the therapist to have a choice of what game they want to address specifically with the child when they run the trials. This is done by reloading a previously saved game.

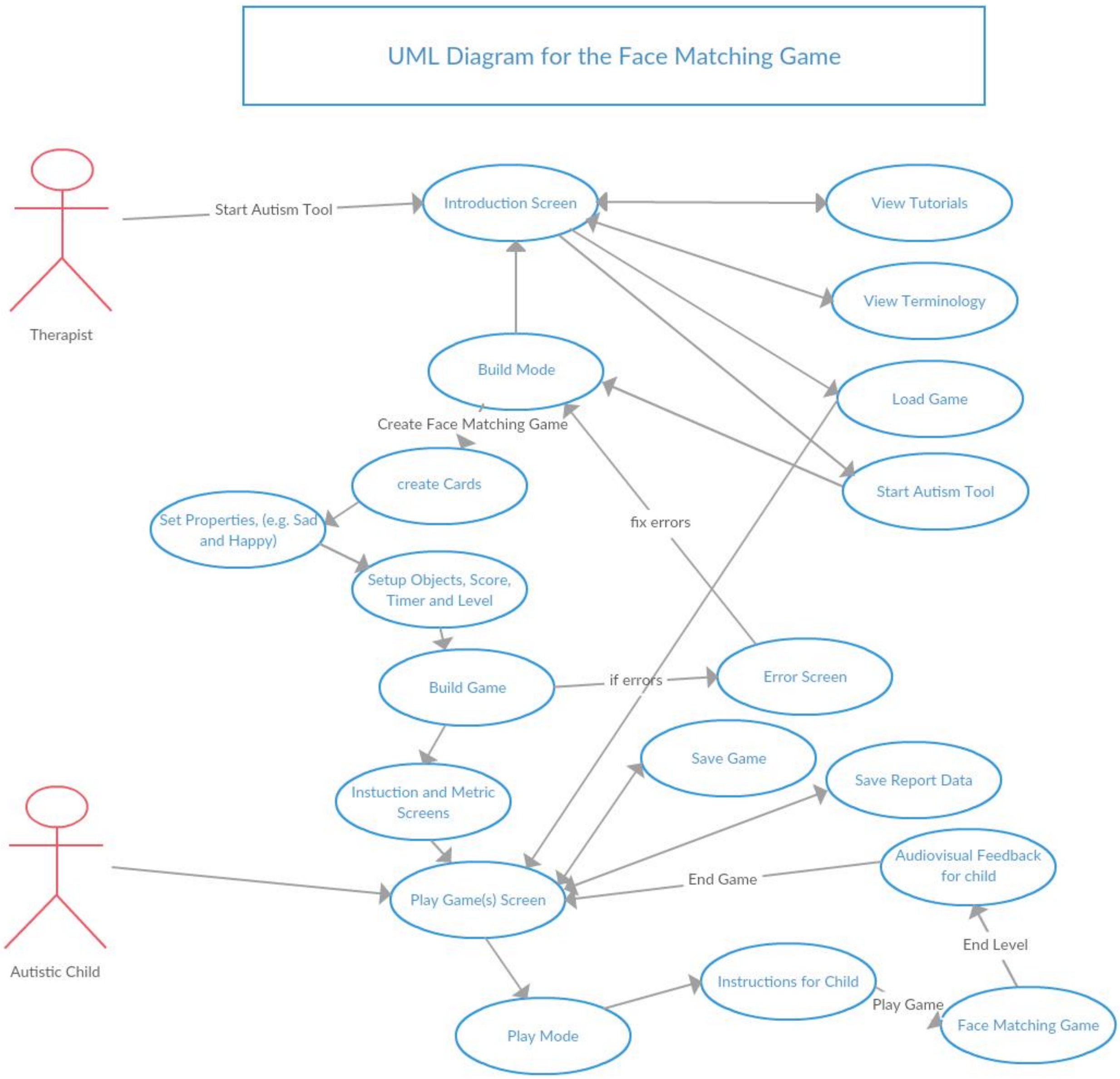

Figure 3.1 UML Diagram for the Face Matching game.

3.2.2 Rabbit Adventures Game

The Unified Modeling Language (UML) Diagram for the Rabbit Adventures game is shown in Figure 3.2. When starting ASGF the introduction screen loads. The therapist has the option of loading a previously saved game, viewing the terminology, viewing the video tutorials and starting to build games. In Build Mode the therapist may create the Rabbit Adventures game by selecting the Rabbit Adventures item in the dropdown of the associated screen and pressing the “Load Game” button. In the Events panel the therapist can change the settings of the game, by changing the helper character, for example. The score, level, and timer objects are automatically created for the therapist. Next the therapist may set up the instruction and metric screens. An example of a metric is player scores (representing how well the child did in the game) which outputs to the report the child's score for the Rabbit Adventures game (e.g., 11/15 or 73%) In the Play Game(s) screen the therapist can save the current game. The child may then play the games created by the therapist. The instruction screen loads with verbal feedback screen and after clicking next the Rabbit Adventures game begins. When the child (user of the developed game) completes the level, audiovisual feedback in the form of a movie, is played for the child for a reward. At the end of the game the Play Games screen loads. The therapist can then save out the report data. The game can then be played again with another child. When the therapist is finished, they can select Exit Application from the Play Game(s) menu to end the game.

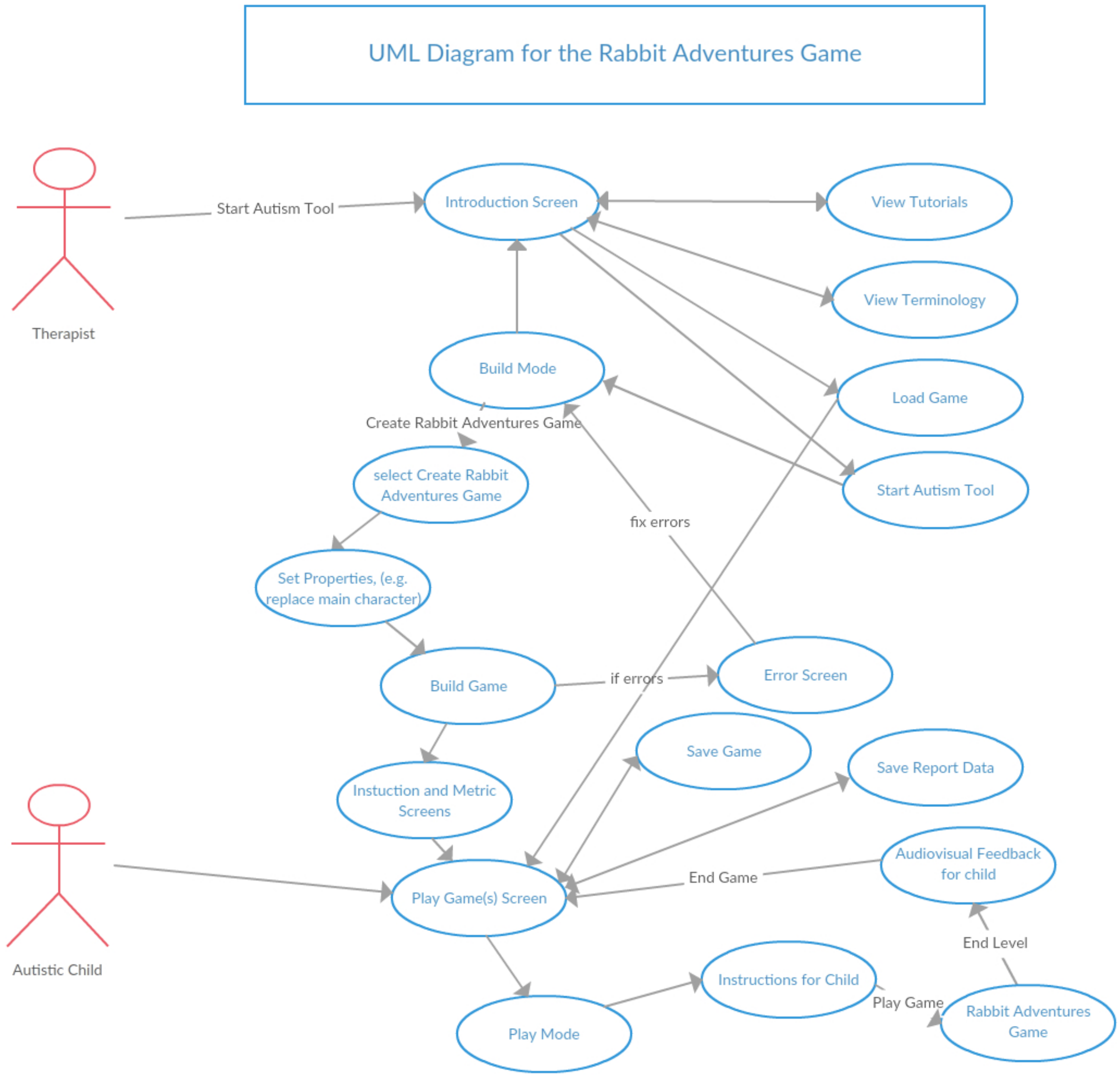

Figure 3.2 UML Diagram for the Rabbit Adventures game.

3.3.1 System Architecture

A graphical overview of the ASGF system architecture is provided in Figure 3.3.

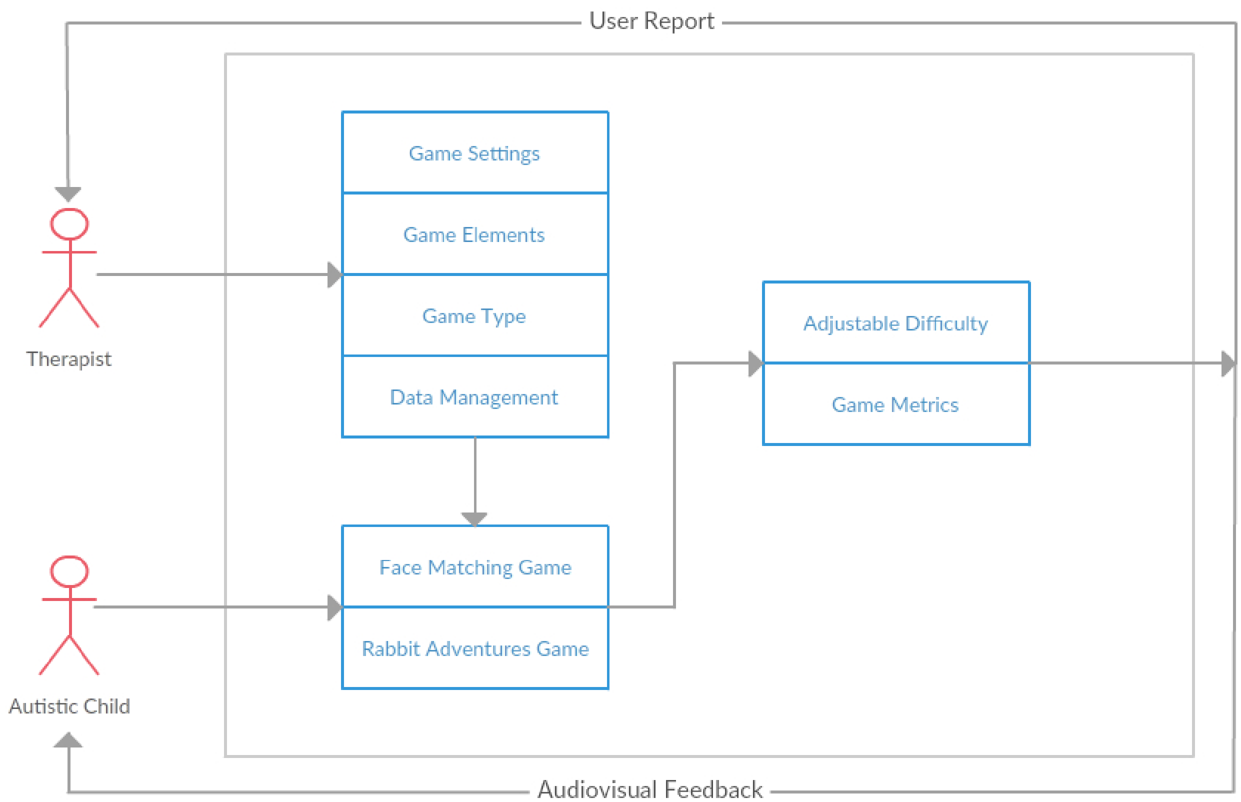

Figure 3.3 System architecture of the Autism Serious Game Framework (ASGF).

Therapist, User 1:

With the understanding that a person trained in the administration of the ASGF may be from a number of educational backgrounds, in this section, I use the term Therapist, as principal user, since it is he or she who will be modifying the games to suit the needs of the child user. The therapists are the stakeholders who develop or modify the customizable games to target the desired behavior interventions for their clients.

Child with ASD, User 2:

The content experts set the parameters of the age range for children using the game interventions, as between three and seven years. It is felt that specific, directed activities to improve behaviors such as social awareness, and flexibility in thinking can have a greater impact during the early years (Targeted Cognitive Training: Assessment and Plasticity in ASD | Diana Parvinchi - YouTube, 2017). The idea is to engage the children in motivational activities that are fun and start out easy. As the children improve in their skills, the games are meant to be more challenging. Hence the need for flexibility in using the ASGF is paramount.

Games with multiple levels can be created within the ASGF. To create a new level, one presses the “New Level” button in the main screen. On one level you could have a Face Matching game and on another you could have a Rabbit Adventures Game. In the dropdown on the Level Panel, you can select the level you wish to work on. The current level can be deleted by pressing the “Delete Level” button. When the game runs in play mode the game associated with level one runs first and then the next and so on until the last level is reached.

3.3.2 Adjustable Difficulty Subsystem

The ASGF is set up to provide challenges of the “right” difficulty level, which matches the child’s abilities (Vahldick, Jose Mendes, & Jose Marcelino, 2017). The difficulty level can be set in the main interface by selecting the “Difficulty UI” button (which loads the Difficulty Panel). This is saved in internal structures; one difficulty value for each level. The therapist can select the difficulty level from a dropdown combobox, such as a value from 50% to 90%. If a specific value is needed the therapist can select a toggle and a textbox becomes active. The difficulty can then be entered into the textbox. The difficulty level in the Rabbit Adventures adjusts the number of correct responses to pass the level. If the difficulty is 50%, 10 (normally 20) consecutive responses are necessary to pass the level. If the difficulty in the Face Matching game is 50%, the child must get 50% of the expressions correct to pass the round. The time value, which reduces or increases the time required, can also be lowered to create difficulty in the Face Matching game.

Levels of difficulty are a way to adjust the game experience based on achievements (Vahldick et al., 2017). If one considers other gaming interventions, based on data collected, difficulty levels can control elements such as enemies, bonuses, sounds, and environment. Early in the game, opponents can be slower and have less fighting potential. It is easier to find items such as health. Later in the game, with increased difficulty, the enemies can move faster and have greater fighting potential and items can become rare and harder to find. Adjusting the difficulty, allows for more engagement, and avoids boredom or frustration (Vahldick et al., 2017).

Game calculation elements:

Pseudo code to determine if a child passes a turn per block is shown below:

```
PASS LEVEL VARIABLE = CARDS (RESPONSES) CORRECT DIVIDED BY
NUMBER OF ROUNDS TIMES 100 //20 ROUNDS PER TRIAL PER BLOCK
```

Algorithm 3.1 Pseudo Code to determine whether or not the child passes the turn per block in the Face Matching game.

If PASS LEVEL VARIABLE is greater than or equal to the difficulty level the child will pass the round. If it is the last round the child will pass the game.

The pseudo code to determine score in the Rabbit Adventures game is shown below:

```
SCORE ON LEVEL = HELPER BUNNIES CORRECT DIVIDED BY NUMBER
OF ROUNDS TIMES 100 // // NUMBER OF_ROUNDS set in
properties of Build Mode by therapist.
```

Algorithm 3.2 Pseudo Code to determine Score in the Rabbit Adventures Game.

The child plays until there are a certain number of consecutive correct responses in the Rabbit Adventures game. When the difficulty is decreased, the the number of consecutive correct responses to pass the level also decreases.

3.3.3 Game Element Subsystem

Below are the elements of the Face Matching game (Table 3.1) followed by the Rabbit Adventures game (Table 3.2). Each object opens a panel (e.g. Sound Object) when the object is created for setting the properties. After the panel is closed it can be reopened by selecting the object and pressing the Properties UI object in the main screen. All this information is stored in an internal list structure.

Table 3.1 Face Matching Game Elements.

Game Element	What it does:
Card	This is a picture object (using an expression) that appears on the screen. This stands for an expression the child clicks on, such as a happy face. If this is the Target Card (a property the user can select) it stands for the card the child is meant to match.
Sound Object	Is an object for playing sounds at the beginning of the level, when the child is successful, or gives an incorrect response. There is no graphic associated with this object when in Play Mode.
Timer Object	Keeps track of the time in milliseconds. The therapist can select a toggle in the panel to count up or down. If counting down the therapist can set a time in the time value textbox in the panel. If counting down and the timer is less than zero, the child loses the round.
Level Object	Shows the Label with the current level in play mode. You may set a picture (.jpg or .png) for this object. You may also set text in the panel. (e.g.) “Level:” The level will be appended to this text. (e.g. for Level 1 it would be “Level 1”.
Score Object	Shows the Label with the current score in play mode. You may set a picture (.jpg or .png) for this object. You may also set text in the panel. (e.g.) “Score:” The score will be appended to this text.
Text Object	Shows static text within the game and can be set in the text panel (e.g. “The Rabbit Adventures Game:”)
Graphic Object	Shows a picture (.jpg or .png) with static text within the game
FBX Object	A 3D model using Autodesk’s FBX format. It includes animations that (optionally) play at the start of the level or when the child is correct or incorrect. These can be set in the associated panel.

Table 3.2 Game elements of the Rabbit Adventures game.

Game Elements	What It Does:
Timer Object	Keeps track of the time and only counts up. It measures the time in milliseconds. This object is made for the therapist in this game.
Level Object	Shows the Label with a standard picture and the current level in play mode. This is made for the therapist in this game.
Score Object	Shows the Label with a standard picture and the current score in play mode. This is made for the therapist in this game.
FBX Object	A 3D model using Autodesk's FBX format. It includes animations that (optionally) play at the start of the level or when the child is correct or incorrect. These can be set in the associated panel.
Sound Object	An object for playing sounds at the beginning of the level or when the child is successful or gives an incorrect response. Supported files are ".MP3" or ".WAV" sound files.

These objects, once created, can be deleted by selecting the object and pressing delete on the keyboard (including FBX models). The therapist can also press the Del UI Object in the main screen under the Events Panel (except for FBX models).

All the objects except for an FBX 3D model can be scaled in the Events Panel by selecting the "Scale Object (xyz)" button. The current scale values are 100 by 100. They can be changed (for the x and y coordinates) to values between the ranges of 60 and 300.

The FBX 3D models can be scaled, rotated and transformed by pressing the "Ruler" button (which loads the associated panel for manipulation) in the Difficulty Panel. The FBX model, when created, also has a drag script associated with it so the therapist can directly move the model (left to right and vice versa and up and down and vice versa).

Below is the code for creating a model and playing the animation when the child successfully matches a happy expression card in the Face Matching game.

The code for creating a model and playing an animation is shown below:

```
Create myModel as new Game Object
Create Array of myAnimations as List
Load Wolf Model myModel and pass myAnimations as
parameter//myAnimations store the animations for the model
While child is playing game:
If Therapist has selected Play Animation on Success
     If Child selects "Happy" when the Target Card is
Happy
          Play Successful Response Animation
                //First Animation on Model
     End if
End If
```

Algorithm 3.3 Simplified code for creating model and playing success animation.

3.3.4 Game Setting Subsystem

The settings are the elements that are changeable in the games. First the Face Matching game (Table 3.3) settings are listed, followed by the Rabbit Adventures game (Table 3.4).

Table 3.3 Face Matching game settings.

Game Settings	What it does:
Happy expression	Adds happy as an expression to the game.
Sad expression	Adds sad as an expression to the game.
Angry expression	Adds angry as an expression to the game.
Surprise expression	Adds surprise as an expression to the game.
Fear expression	Adds fear as an expression to the game.
Disgust expression	Adds disgust as an expression to the game.
Number of trials per block	If you have 2 trials you have 2 * 20 (cards per level)

All these settings can be set in the Events Panel of the Rabbit Adventures game.

Table 3.4 Rabbit Adventure game settings.

Game Settings	What it does:
Set Helper Property:	This is the character that crosses the path of the main character and is the correct response for the game. By default, it is set to "Rabbit". Pressing the space bar when the child sees the Rabbit (if it is the helper character) would give the correct response.
Set Main Character Property:	This is an option to replace the main character with another fbx model. The default is the Sorceress model.
Add an additional character to cross the path of the Main Character Property:	The therapist may wish to include more models that cross the path of the main character. Additional characters can be added in the events menu.
Key Property:	The therapist may wish to change the response key pressed on the keyboard to another key. The therapist can change this setting to the "A" or "C" key. The default is the space bar.
Set Number of consecutive correct responses to pass the level Property:	If this is set to 20 you need 20 consecutive helper characters (default – bunnies) to pass the level.

3.3.5 Gameplay Metrics Subsystem

The metrics were determined from consultations I had with the content experts. Response time is necessary to determine how long it took for a child to respond. The player choice including the correct answer was recorded as a metric. Is the child understanding the emotions on the faces is a question we may ask? Future work would include recording the specific card that was the target card. Scores determine how well the child did. If the response time is good and the score is high, we can determine that the child is doing well. The difficulty metric outputs to the report what the current difficulty on that level is. It makes it easier for the child if the task is difficult. It is a way to cross reference or show the data in the report.

The metrics for the Face Matching game (Table 3.5) are followed by the Rabbit Adventures game (Table 3.6).

Table 3.5 Face Matching game metrics.

Metric	What it does:
Response Time	How long in milliseconds does it take for the child to respond?
Card Load Time	How long between the child selecting a card or the start of the level (for the first card) does it take to load the next card?
Player’s Choices	The child clicks on a card and the card contains the current expression. The target card and the selected card are saved for the report. Also, it saves whether the child got the correct match or an incorrect match.
Difficulty	What is the current difficulty of the level? This will be displayed in the report file.
Scores	What is the child’s score for the Face Matching game e.g. 18/20 or 90%

Table 3.6 Rabbit Adventures game metrics.

Metric	What it does:
Response Time	How long in milliseconds does it take for the child to respond?
Character Load Time	How long does it take to load a character?
Player’s Choices	What character is the child pressing the spacebar on? This also stores the correct or incorrect response.
Difficulty	What is the current difficulty of the level? This will be displayed in the report file.
Scores	What is the child’s score for the Rabbit Adventures game e.g. 11/15 or 73%

3.3.6 Audiovisual Feedback Subsystem

The goal of using computer games for educational purposes is to allow the encoded knowledge to be internalized, thus allowing it to be transferred to from the learning environment to the real world (Oberdörfer & Latoschik, 2019). Game mechanics should present, demonstrate, and require the learning content to support the building of mental models in an audiovisual way. Mental models by definition, are mental representations of a particular knowledge, which allow for internal visualization, problems solving, and transfer of knowledge (Oberdörfer & Latoschik, 2019).

The audio feedback is loaded through a sound object. MP3 and WAV sound files are supported and are saved in data structures. The therapist can select a sound to play at the beginning of the level, when the child is correct in their response, e.g. selecting the happy card when the target card is a happy expression, and playing a sound on an incorrect response. If there is more than one sound, e.g. on startup, a random number will be generated selecting one of these sounds. Also, the therapist can set a sound for the playback of the instructions. Audio visual feedback helps the child connect to the game. Upon completing the level, an optional video can play providing reinforcement to the child. The therapist can select a movie to play from the instructions menu.

Figure 3.4 shows the feedback for the therapist in Build Mode. As he/she works with the system, feedback is shown in this window (at the top left of the main screen). In this case the therapist has just created a card for the first Face Matching game.

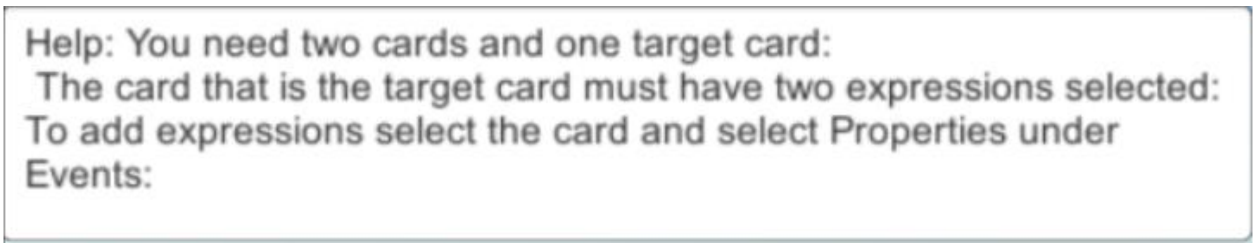

Figure 3.4 Help Menu Feedback.

Figure 3.5 shows an example of tool tip feedback for the system as the therapist hovers the mouse over the top left card in the Cards or Load Game Panel. Every button in the ASGF system has an associated tool tip that will show when the therapist hovers over the button. This reduces the confusion of using the system by creating text (tool tip) feedback that helps the therapist understand the tasks she/he is carrying out.

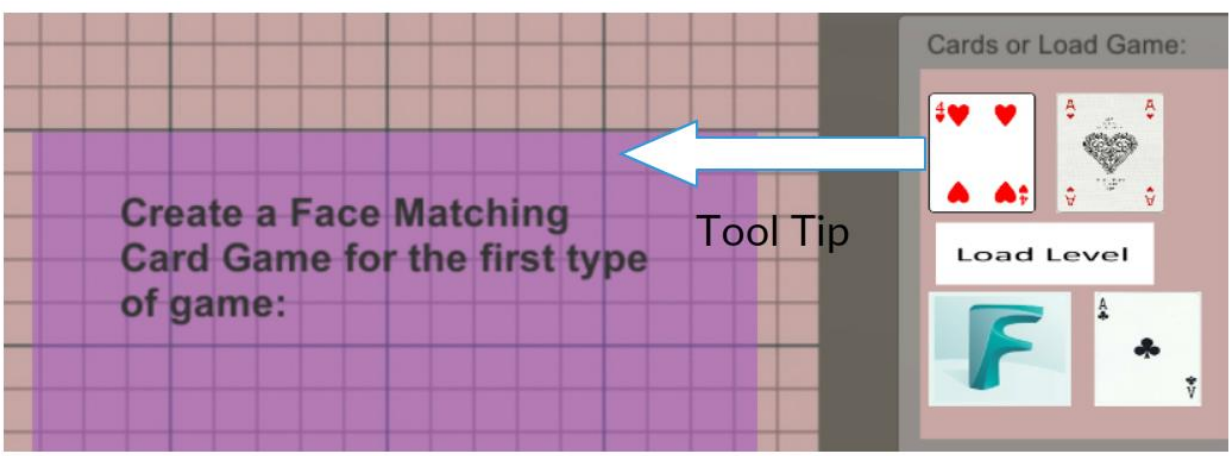

Figure 3.5 Tool Tip Feedback.

On the introduction screen there is an option to go to the terminology screen. The first screen explains what Build Mode and Play Mode are. The second screen gives a review of the two games.

3.4.1 Development Tools

Prior to developing the ASGF, I examined and compared several game engines and development tools, including Unity, AppGameKit, MonoGame (with DigitalRune), and Visual Studio using DirectX or OpenGL, Unreal and Construct 2. Except for DirectX and OpenGL these are languages for creating video games. A summary comparison of the examined engines and tools is provided in Table 3.7.

Table 3.7 Game engine and development tools comparison.

Tools	App Game Kit	Pro Tools	Digital Rune	Monogame	Unity3D	OpenGL C++	Unreal	Construct 2
License	Yes	Yes	Yes	Free	Personal Free	Free	Free	Yes
3D	Yes	Obj Export	Yes	Yes	Yes	Yes	Yes	No
2D	Yes	No	Hard	Yes	Hard	Yes	Hard	Yes
Use as Engine	No	No	Yes I think	Yes	Yes	Yes	No	No
UI	Yes	No	Yes	Empty Keys	Yes	Windows	Yes	Yes

Pro Tools is a 3D level designer for Unity and exports the result as an .obj file. The .obj file stores mesh and texture information and is a file extension for 3D models. “The obj file format is a text based, open file format developed by Wavefront Technologies (now Alias|Wavefront). The format has been adopted by other 3D graphics applications vendors and can be imported/exported by a number of them” (McHenry & Bajcsy, 2008). Construct 2 does not have 3D support. C++ with OpenGL or DirectX would require everything to be built from scratch. Monogame with Digital Rune sitting on top of it would have been my second choice. During the development of this project a UI (User Interface) library would have been needed and there is little support for UI in Monogame.

AppGameKit also requires a UI library. Unreal would have been my third choice and not all platforms would have been supported.

I developed the ASGF developed on top of the Unity game engine. Unity 3D supports over 20 major platforms such as workstations, mobile devices, game consoles, and web applications, to name a few. It has advanced graphics support which utilizes and optimizes modern hardware to the fullest extent (Harshfield, Chang, & Rammohan, 2015). As a multimedia (game) engine, it offers built-in features such as materials and shaders, rendering, lighting, physics, advanced animations. It offers audio and video support, and powerful UI-development tools (Harshfield et al., 2015). Using Unity, users have the ability to create games and experiences in both 2D and 3D. The engine offers a primary scripting API (Application Programming Interface) in C#, for the Unity editor in the form of plugins and games, and a drag and drop functionality (Thesis, 2018). The plugin architecture allows developers to extend core functionality in the pro version. And once the design of the animations, behaviours and interactions are complete, the Unity 3D project can be compiled into and executable file (Bartneck et al., 2015). A designer who has a console license, can use Unity to export the project to licensed console platforms such as XBOX, SWITCH, and PLAYSTATION 4 (Buyuksalih et al., 2017).

According the CEO of Unity, half of all games are built using Unity 3D (Unity CEO says half of all games are built on Unity | TechCrunch, 2018). This very popular game development language (Xie, 2012) is used by indie game developers and many large studios. It is used for rapid prototyping for generating and pitching ideas. It is also popular because it has a strong developer community supporting its progress (Bartneck et al., 2015). It is one of the best documented Game Engines and there are many tutorial videos and community support forums (Bartneck et al., 2015).

Unless raised funds and annual revenues exceed $100k, the personal version of Unity is freely available for Windows (Powerful 2D, 3D, VR, & AR software for cross-platform development of games and mobile apps., 2019). However, this version does not include personal services, training and additional support (Powerful 2D, 3D, VR, & AR software for cross-platform development of games and mobile apps., 2019). Unity is freely available for research and education and supports multiple operating systems (Windows, Mac OSX and Linux) (Bartneck et al., 2015).

3.5.1 Acquired Assets for ASGF

I used a camera follow script in the Rabbit Adventures, Enchanted Apples, and Mysterious Islands games (Camera Follow Player Position & Rotation in Unity 3D - YouTube, 2019). It was placed behind the main character and followed the main character as they were moving.

I used the endless runner tutorial in the Rabbit Adventures Game to create the scene as the main player (the Sorceress) runs forward (Unity Endless Tutorial • 6 • Spawning infinite tiles [Tutorial][C#] - YouTube, 2016).

I also used algorithms from Jim Adam's book, Advanced Animation with DirectX (Adams, 2003). I used the code to transform a character along a path and also a curve. These were used in the Enchanted Apples and Mysterious Island games.

I used some online code that contained the functions setTop, setBottom, setLeft, and setRight (Access 'Left', 'Right', 'Top' and 'Bottom' of RectTransform via script - Unity Answers, 2015). This code allows us to move the work area into focus during the play mode of the Rabbit Adventures game.

I also purchased the following models that include animations online at CGTrader. "CGTrader is the world's largest source for licensable stock and custom 3D models. CGTrader Marketplace features more than 800,000 3D models and a managed community of close to two million users, including highly-skilled 3D designers" (CGTrader - 3D Models for VR / AR and CG projects | CGTrader, 2019).

- The Royal Sorceress and the Female Woman Warrior
- Anita (Wolf), Rabbit, and Tiger

The next asset that I used was UniFileBrowser (UniFileBrowser - Asset Store, 2018). This allows for selecting a file in an Open File Dialog or Save As Dialog. I could use the Save As Dialog, for example, to give the therapist a unique name to save out the report data.

I loaded in sprite assets (e.g. PNG loaded onto a card) at runtime using the code from this site (Generating sprites dynamically from PNG or JPEG files in C# - Unity Forum, 2013).

3.6.1 User Interaction Storyboard

The Introduction Screen is the first screen the therapist sees. In it, the therapist can view the terminology used in the game and view tutorials on how to use the system. The therapist also has the option of loading a previously developed game. The last option is to start the autism tool where the therapist can start building the games in Build Mode.

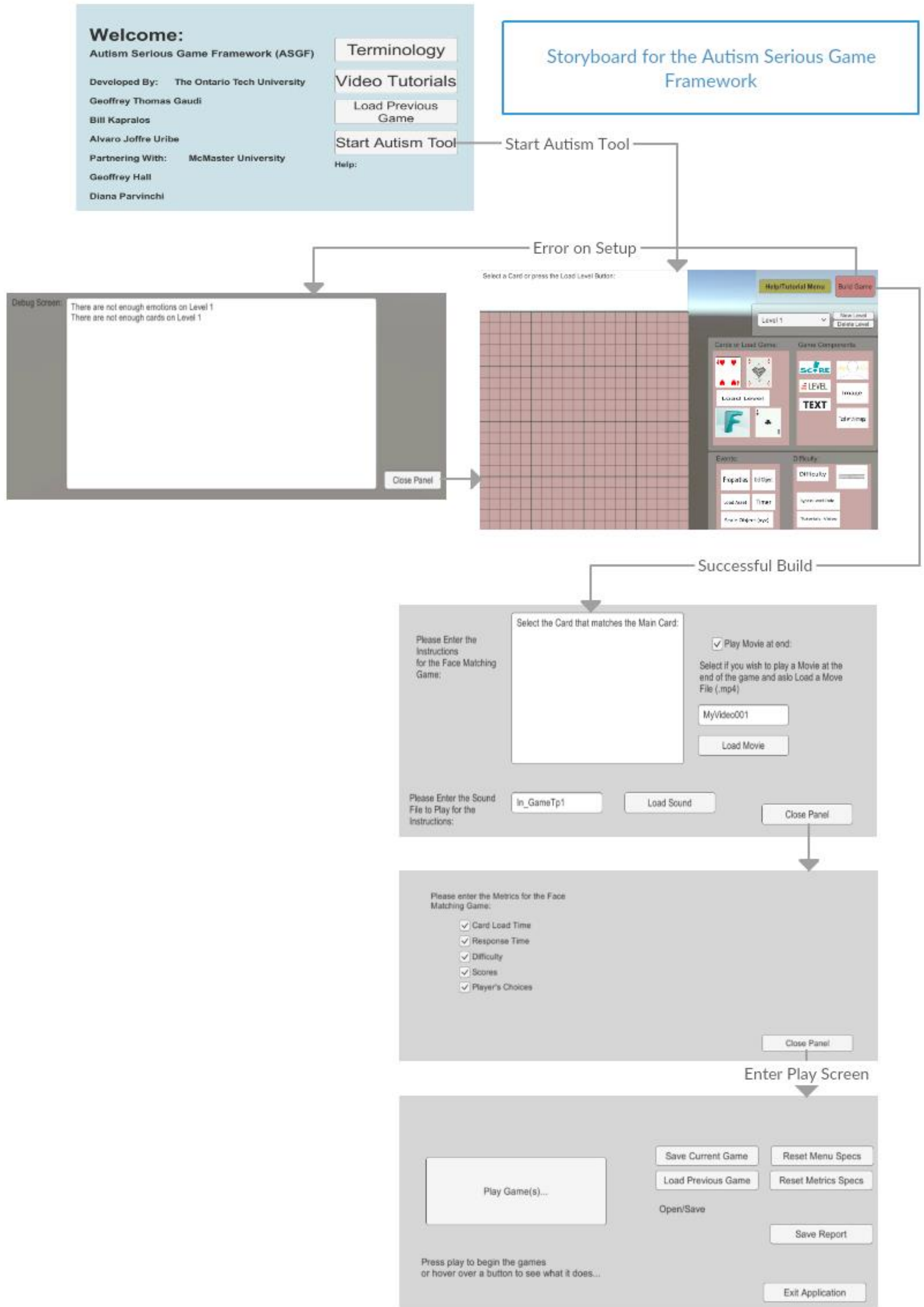

Figure 3.6 Storyboard for therapist using the Autism Serious Game Framework.

Once in build mode, the therapist can then develop the games as an intervention for children with autism. By pressing the "Build Game" button two things could happen. First, if there are errors, such as not enough cards in the Face Matching game, the system goes to a debug screen window. The therapist can then click Close Panel to close the message window to go back to the main screen to fix the errors. If everything is set up correctly there is a successful build. The therapist then moves on to the instruction screens for the Face Matching game. The therapist can write a message, select a sound, and (if the toggle is set) select a movie file for reward. If there was another level with a Rabbit Adventures game there would be another instruction screen for this type of game. The therapist can then select Close Panel to go to the metrics screen. The therapist can set the metrics for reporting such as recording response times of the child. After finishing the metrics screen the system then loads the Play Game(s) screen. From here the user can reset the metrics and instructions. The therapist can also load another previously saved game. The child can then start the game by selecting the "Play Game(s)" button. When the child is finished with the games, they will return to the Play Games screen. The therapist can then save out the report data to a file with a .RER extension. Also, a .REN file is saved with the JSON output of the data structures. These are unique file extensions I made to distinguish between different file types. The therapist can then exit the system by pressing the "Exit Application" button.

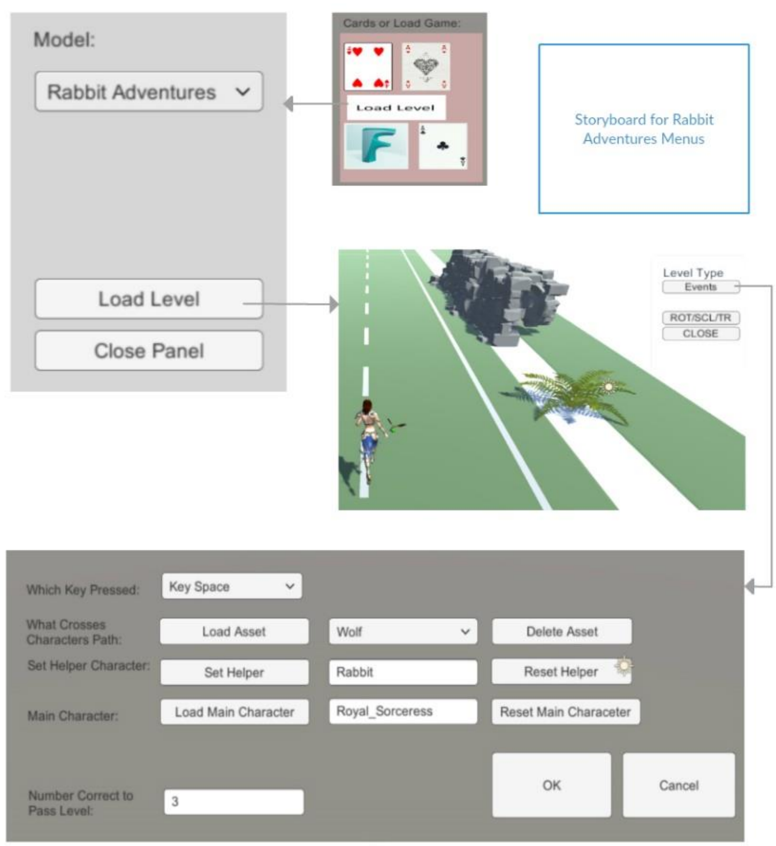

Figure 3.7 Storyboard for the therapist building a Rabbit Adventures game.

Figure 3.7 shows the storyboard for the Rabbit Adventures game. In the main screen the therapist selects Load Level from the Cards or Load Game panel. The next panel loads and the therapist then selects Rabbit Adventures game from the dropdown combobox. On this screen the therapist can select Load Level to load the Rabbit Adventures game on the current level (out of all the games). The Rabbit Adventures game screen then loads. The therapist can then select the "Events" button to go to the Rabbit Adventures Properties screen. In it the therapist can change the properties for the game such as (the child) pressing the "C" key instead of the "SPACE" key. The therapist can select "OK" to save the changes or "CANCEL" to undo the changes. After pressing either of these buttons the therapist returns to the Rabbit Adventures game screen. The therapist can then select the "CLOSE" button to return to the main screen.

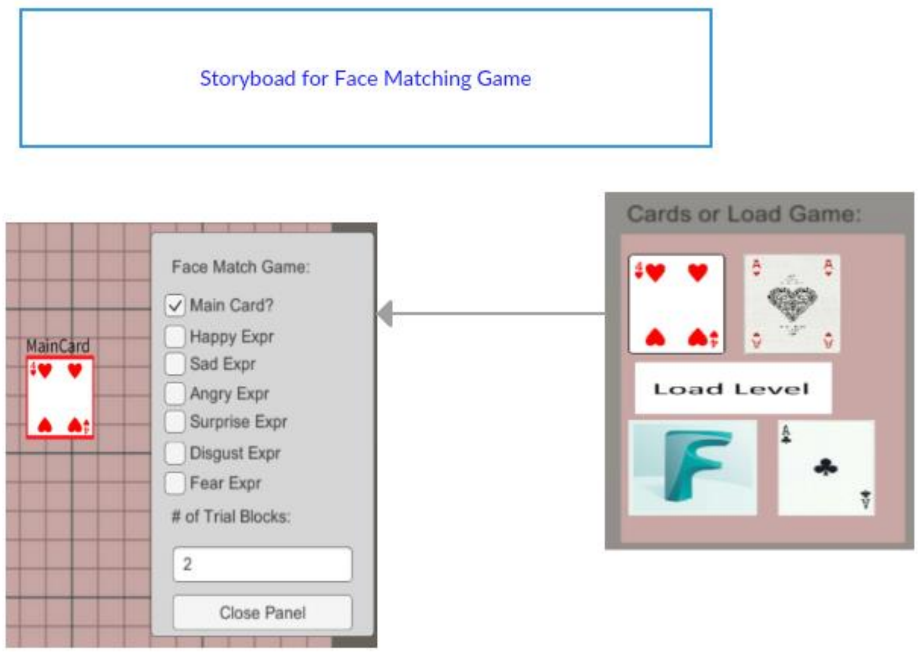

Figure 3.8 Storyboard for the therapist building a Face Matching game.

Figure 3.8 shows the storyboard for the Face Matching game. In the Cards or Load Game panel located in the main screen the therapist can select the red card (top-left) to create a card. The therapist can create as many cards as he/she chooses. After selecting the card, the properties for the card appear. The therapist can select the expressions that happen in the game such as Happy. The therapist can select the number of trials per block. There are twenty cards per round and if the trials per block is two there would be two × (twenty cards) or forty cards or expressions to be matched on the current level.

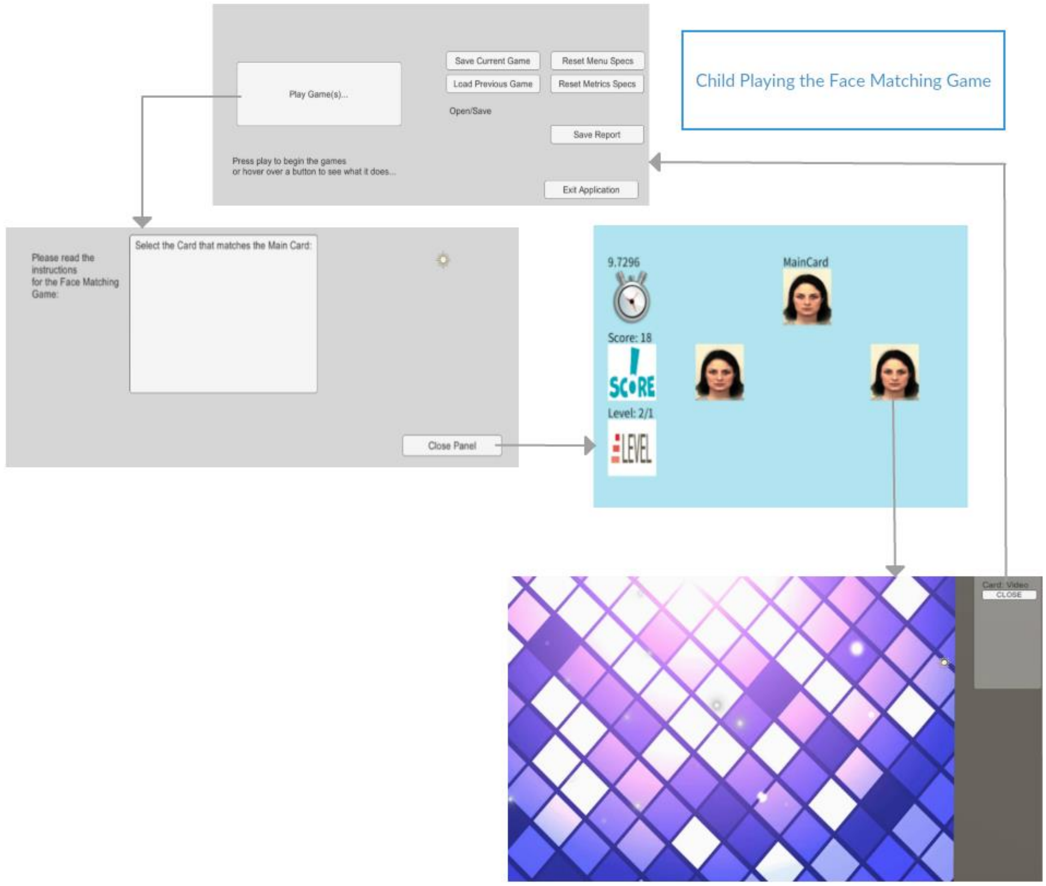

Figure 3.9 Storyboard of child playing the Face Matching game.

Figure 3.9 is the storyboard for playing the Face Matching game. The child selects play games and the instructions menu shows. There is verbal feedback included with the instructions in case the child cannot read. After the child selects the “Close Panel” button the game begins. After finishing the game, the movie playback for reinforcement begins. It will loop the video until the “CLOSE” button is pressed. On pressing the “CLOSE” button it will return to the beginning Play Game(s) screen. The reports can be saved and then the games can then be run with a different child. Also, a previously saved game can be loaded by clicking the “Load Previous Game” button. If a Rabbit Adventures game were present it would follow the same process as the Face Matching game. There can also be multiple levels. The game loops through the levels and shows the instructions for each one and then runs the games. After each one the reward movie screen will show and then move on to the next game until all of the levels have been run.

3.7.1 Framework Development

I developed the ASGF system over the course of my thesis. I developed ASGF in conjunction with content experts. It was decided to create the game tool based on the games that we developed earlier. I included functionality within ASGF to recreate the games from scratch and to allow the therapist to specify the settings of these games. First, I reviewed different game engines that I could build my game tool on top of. This included Unity 3D, Monogame, Unreal Engine and the App Game Kit. Unity 3D was the best choice and I installed Unity 3D version 2017.3.1.f1. I also installed Visual Studio 2015, a development environment created by Microsoft, to create C# scripts to program code in Unity 3D. I acquired assets to use with Unity such as UniFileBrowser (UniFileBrowser - Asset Store, 2018) (a pop-up window to select a file for saving our reports, for example), the TriLib library (TriLib - Model loader package - Asset Store, 2019) (to load 3d models with animations at runtime), JSON (JSON .NET For Unity - Asset Store, 2019) (to save C# structures to a file), and also several 3D (CGTrader - 3D Models for VR / AR and CG projects | CGTrader, 2019) models to use in our game (such as the main character in Rabbit Adventures, the sorceress). The models were purchased online at CGTrader, which according to their website, is the world's largest source for licensable stock and custom 3D models. Its Marketplace features more than 800,000 3D models and it has a managed community of close to two million users, including many highly-skilled 3D designers (CGTrader - 3D Models for VR / AR and CG projects | CGTrader, 2019).

The coding process involved getting the different modules up and running, and then layering them while I added new functionalities. I used the iterative software design technique where I would analyze the problem, code it and then test it. If there were errors I would go back the analysis phase and find out what went wrong. Using the iterative process, a problem is understood at the conceptual level, and then must be broken down into understandable working objects, and developed further until an outcome is achieved (Chapman & Pinfold, 1999).

I had to reference tutorials (Unity Answers, 2015) online to gain knowledge on Unity's methods of accessing objects, such as a Dropdown combobox to access the current selected text. Unity has a coding syntax that is not intuitive.

3.8.1 Graphical User Interface (GUI)

The GUI of the ASGF was set up so it would be intuitive to navigate. It uses the What You See Is What You Get (WYSIWYG) user interface (Ridge, Industries, Livermore, & Office, 2017). This user interface involves an approach that is utilized in computing and image processing. The content displayed during editing appears very similar to a final output. A rendered document, a web page, a slide presentation or even a lighting for a theatrical event would fall under this usage (Ridge et al., 2017).The layout was planned so that each screen enabled a specific function in the system. There is an introduction screen setup to run when ASGF is first started. Build Mode is mainly associated with the main screen (Figure 3.10) Panels were used on other screens, such as the Instructions screen where input was required by the user. It is meant to keep most functions necessary at a specific step contained. An example is the Play Game(s) Screen which implements a panel with the necessary buttons on it such as the "Play Game(s)" button to start Play Mode. Also, when loading FBX models, they can be positioned and remain in the same location during Play Mode.

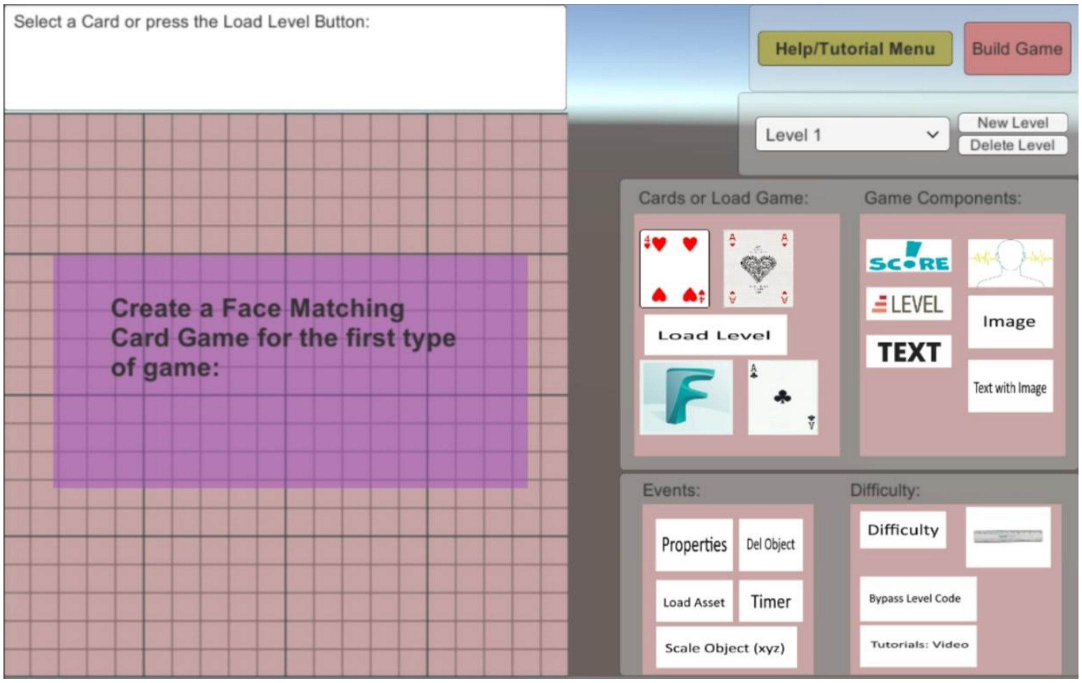

Figure 3.10 Main screen of the ASGF.

3.9.1 Media Import

The ASGF allows assets, such as sounds, movies or 3D models, to be imported. The assets are used in the two featured games and are loaded at runtime.

The Face Matching game uses sounds (.MP3 and .WAV files) for feedback, which can be loaded into the game. Instructions to the child user in the same format above can also be imported. ASGF also allows for the graphic elements to be changed (which is a property) using either .JPG or .PNG images. An example would be to load “Score.jpg” into the properties panel of the Score Object. Models with animations (Autodesk’s FBX extension) can also be loaded (by the therapist) to give feedback to the child, such as playing an animation when the child gives the correct answer. The therapist has flexibility to determine how they administer instructions and rewards based on the needs of the child. They can load a Wolf FBX file, or another runtime FBX character, and play a success animation as determined by their needs.

The Rabbit Adventures game also uses the same systems as above, except that the Timer, Score and Level Object are made by default and cannot be changed. The Rabbit Adventures game also adds additional functionality necessary for this specific game. It allows for the importing of models to replace the main character, to add more characters to cross the path of the main character and to set the model for the helper character.

Both these games allow for the importing of a video as a .MP4 extension to play back a reward scene for the child.

3.10.1 Game Creation

When the system starts, the welcome screen appears, while default variables are loaded. The therapist has the option of viewing the tutorials, going to the terminology section, loading a previously saved game and entering Build Mode. If the therapist selects Load Previous Game, and there are no errors, they go to Play Mode and can begin the games. If the therapist selects Start Autism Tool, they enter the main application screen (Build Mode) and are ready to start building games. The first option is to select the type of game he or she wishes to build (see Figure 1-3). In this menu you may start a specific game on the current level by pressing the card or the "Load Level" button.

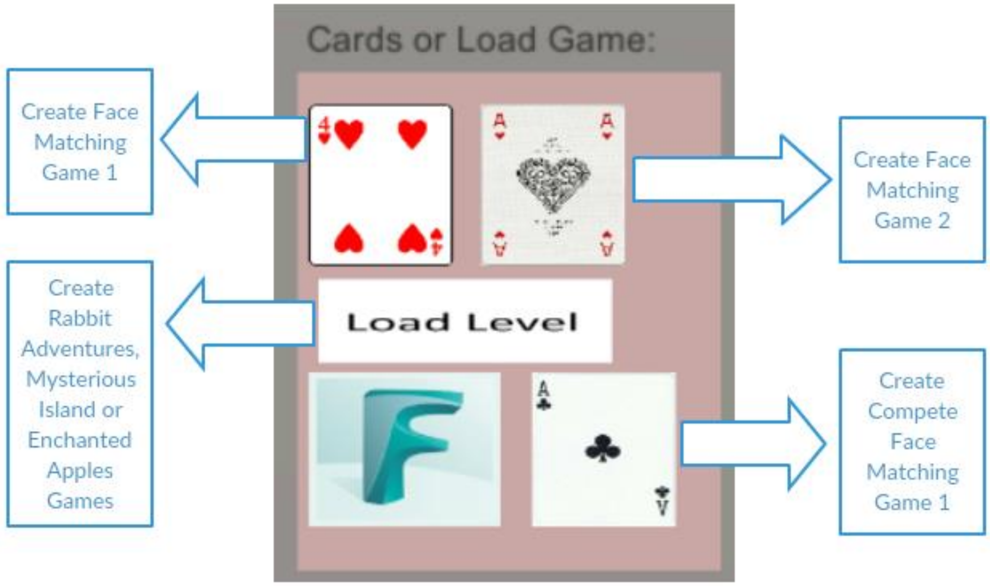

Figure 3.11 Select the type of game to create in the ASGF.

3.10.2 Create Face Matching Game

After pressing the "Create Face Matching Game" button (Figure 3.11) above (upper left), a card is created in the work area and the properties show for the card object

(Figure 3.12). Internal structures are created with default values. At least three cards need to be created for the Face Expression Matching Card game. Only one of these may be designated as the target card within the properties. The other settings are the expressions that happen in this level of the game. If you choose the happy and sad expression during Build Mode those are the only expressions from which the child playing the game will be able to select. There are 20 card expressions per level, times the trial block value, which is the number of turns. If there are two turns during this card level, there will be 2 ×20 cards at the current difficulty.

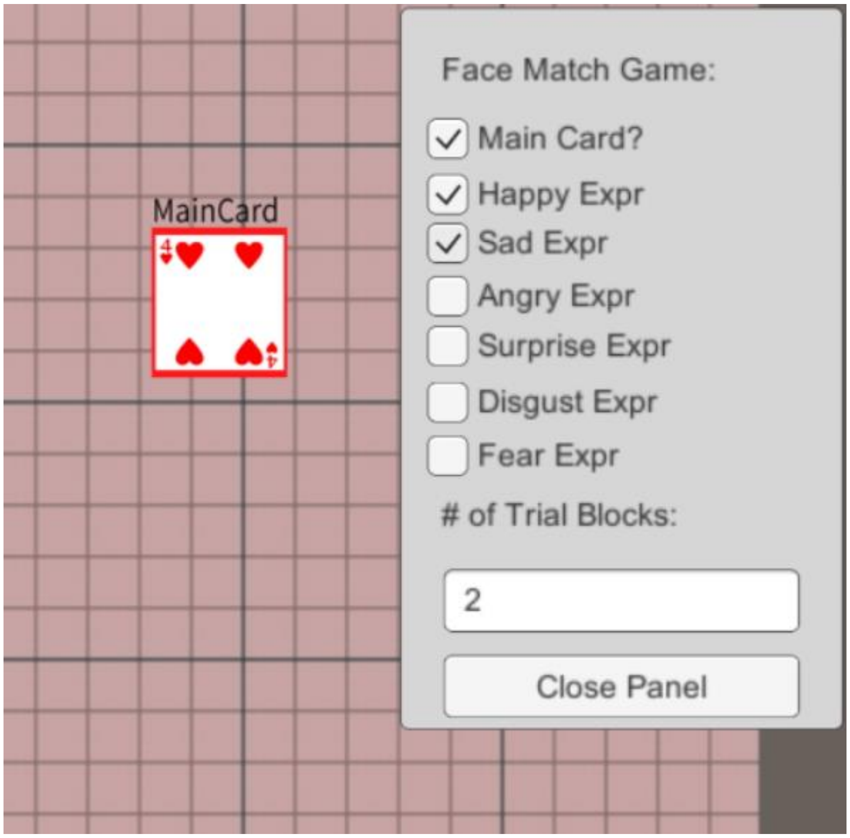

Figure 3.12 Card Loaded with Properties Panel showing.

Below is the pseudocode for creating a new card object in code. It uses a global list array and adds the components at runtime. When switching levels, all of the current cards are turned off using myObject[index].SetActive(false) and the cards on the new level are turned on (if there are any).

The newest card created will be set as the target card and all other cards will be set to non-target card. To change this, the therapist can select another card and select the

Properties UI object. Then the therapist can select the target card toggle in the Properties Panel and the first card will be disabled as the target card.

The code to create a card for the Face Matching game is shown below:

```
Create Global array object myObject
Begin Function CreateObject
     Create a new myObject as List
     Add an Image Component to new myObject
     Set the Image Component to new myObject//e.g.
"CARD.JPG"
     Add a Drag Script to new myObject
     Add a Click Script to new myObject
     Set the name of myObject //e.g. "Card01"
     Create a second myObject as List //Second Object
     Add a Text Component to second myObject
     Set the Text Component to second myObject//e.g.
"Target Card"
     Set the name of myObject//e.g.  "TEXT01"
     Parent second myObject TO first myObject// "TEXT01"
TO "Card01"
End of Function CreateObject
```

Algorithm 3.4 Code for Creating Card.

3.10.3 Create Complete Face Matching Game

After pressing the "Create Complete Face Matching Game" button (Figure 3.11 bottom right) a complete card game is created. Internal structures are created with default values. Three cards, the top one being they target card, are created in the work area, and a Timer Object, Level Object, and Score Object are created. After this process the properties show for the target card object. The therapist can then change any of the settings, such as changing the default expressions to surprise and anger (See Figure 1-13).

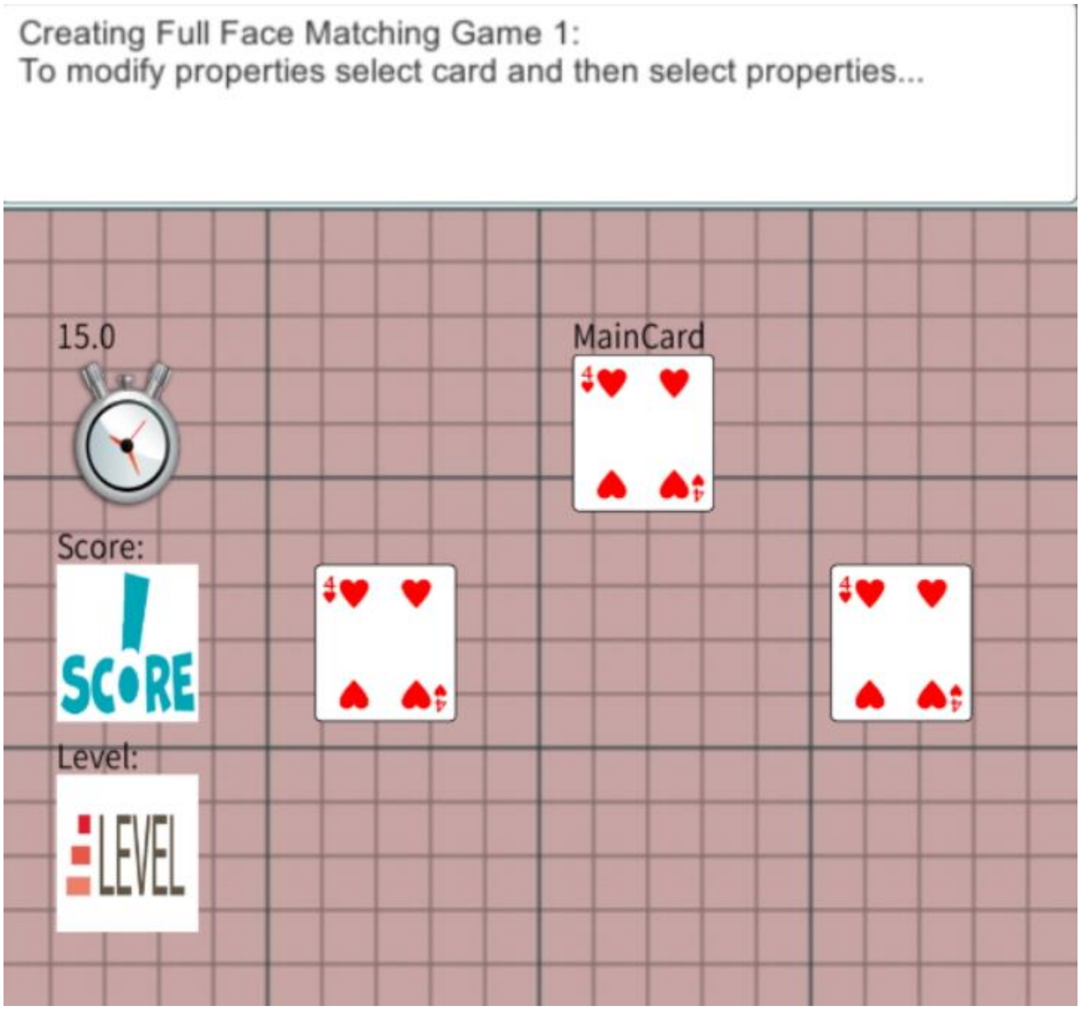

Figure 3.13 Create Complete Face Matching game.

3.10.4 Create Rabbit Adventures Game

The therapist would select the "Load Level" button shown in Figure 3.14 and the associated panel will load. From a dropdown combo box they can then select the Rabbit Adventures game and then press Load Level from this panel. The main interface is then hidden (main screen). Internal structures are created with default values. A road and objects such as trees, are loaded. The sorceress main character is loaded. In this type of game, the Score, Level and Timer Objects are created for the therapist. The timer counts up. On the screen there is a menu. The therapist can select the "Events" Button to load the menu for customizing the game. The therapist can click the "Close" Button to return to the main interface (main screen). If another game is created on this level, such as the

Mysterious Island game, a message will display in the help message window saying another game is present (and the Rabbit Adventures game will not load).

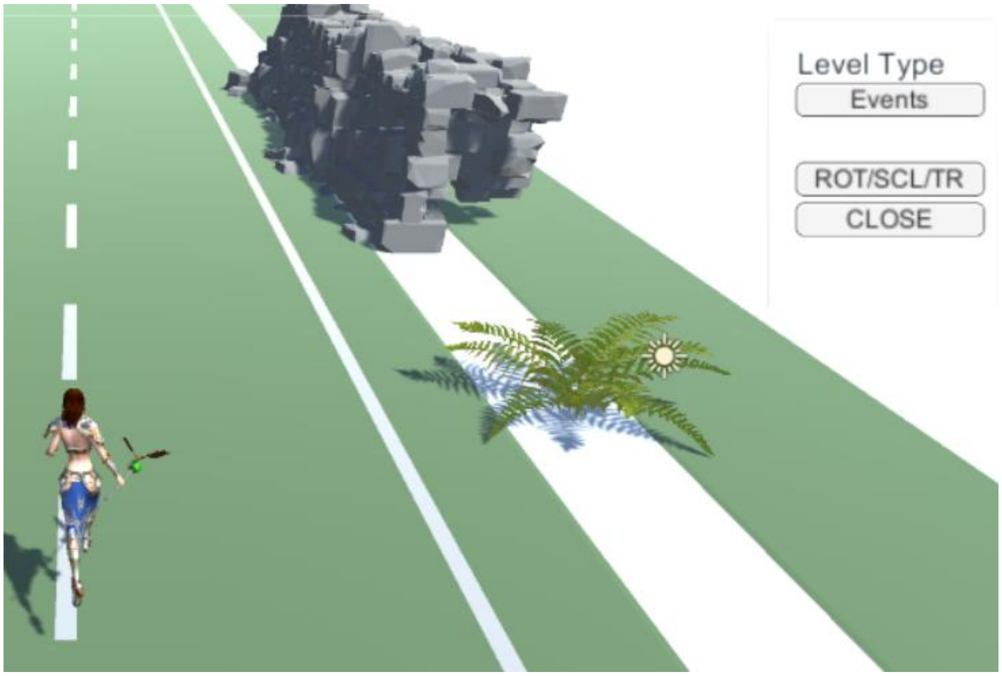

Figure 3.14 Rabbit Adventures game.

3.11.1 Game Customization

There are several differences compared to the original games developed with the content experts, and more specifically, these games are customizable. I also changed the bunny to a rabbit, for example, in the Rabbit Adventures game, as this was the model available to me for purchase, and it didn't affect the game. In the original games there were no customizations. I expanded the system so that several levels could be created (e.g., Level 1: Face Expression Matching game and Level 2: Rabbit Adventures game). The customizations in the Face Matching game include the ability to select specific facial emotions to target, the ability to change the target card, have as many cards as you want, and given 20 cards per round, you can set the number of trial blocks you want on that level, with a minimum of one trial block. The customizable difficulty parameter was added that sets, measured as a percentage, the number of matched cards that must be correct for the child to move to the next round.

In the Rabbit Adventures game, various parameters and aspects of the game can be replaced including the main character or the helper character, the key to be pressed for responding (e.g., the “A”, or “C” key), the number of consecutive correct answers, and additional characters to cross the helper character’s path can be added. When the difficulty is decreased, the number of consecutive correct responses to pass the level also decreases. The two games developed include customizations, such as adding a Score Object, a Level Object, Graphic and Text Objects and the inclusion of Timer Objects. These allow for the inclusion of the necessary serious game mechanics, such as displaying the current score on the screen.

3.12.1 Game Data

Internal structures save all the game data. Examples include the difficulty for each level, what type of game is on each level, what models are on each level and the animations that play on those models. Also, structures are filled with, for example the score object, the graphic file and the display text.

Reports are generated by the system after the child has played the games and they give feedback to the researcher or therapist. This is saved with a custom .RER extension and is a text file. Also, a .REN file is saved with all the report data and is exported from the structures to a file using JSON (JSON .NET For Unity - Asset Store, 2019).

The therapists can view the data and run statistical calculations to determine if the interventions are effective. If, for example, the child is getting low scores it means they are having trouble with the specific game intervention.

Sample data results:

Below is a sample of the tables generated by ASGF for the Face Matching game (Table 3.8 and Table 3.9).

Table 3.8 Level information for the Face Expression Matching game.

Level	Pass Level	Percent Right	Trial block	Difficulty
1	True	100	1	60%
1	True	80	2	60%

Table 3.9 Level data for the Face Expression Matching game.

Level	Card (Yes/No)	Player Choice	Player Answer	TRIAL BLOCK	ROUNDS	LOAD TIME	RESPONSE TIME
1	True	Sad	Sad	2	20	0	2.136722
1	True	Happy	Happy	2	19	0	1.634009
1	True	Happy	Happy	2	18	0	3.967283
1	True	Happy	Happy	2	17	0	2.847707
1	True	Sad	Sad	2	16	0	4.664196

3.13.1 Colour Management

Colour is a necessary element in serious games. “Colour is also considered as an ‘international language’ allowing people to express their preferences, their choices, and their emotions” (Saes, 2019, p. 1). “The design features need to be child friendly; encouraging participation with the availability of modern animations and vivid colours” (Howard & Crotty, 2017, p. 6). “Colour has the ability to impact student attention, behaviour, and achievement” (Howard & Crotty, 2017, p. 6). It is important to know if a child is sensitive to colours, hypersensitivity, or the opposite, hyposensitivity (Ludlow, Heaton, Hill, & Franklin, 2014, p. 1). Consultations are necessary with the content experts to determine the colours or colour scheme to be used with ASGF. Also, the colours used in the cards, including the pictures used, were determined by our experts. I highlighted the introduction menu button using color differentaton (Olykaynen, 2016, p. 49) to make it clearer for the therapist. Future work is necessary, with consultations with our experts, to differentiate the UI elements.

3.14.1 Problems Encountered

Some of the programming methods could be altered in the program to make it easier for programmers. For example, every object (e.g., a panel) that must be disabled using myObject.SetActive(true/false), must be made global. Once you turn the object off Unity has no knowledge of the object. I suggest that the best model of UI interfaces are Rapid Application Development (RAD) interfaces, such as those used in Visual Basic or C#.NET. It is difficult to set up a complex UI menu system in Unity. Also, Unity does not allow for external Dynamic Linked Libraries (DLLs) to be added to the project. This prevents the user from using code developed in other languages and forces developers to buy plugins made for Unity.

Another problem is that the current version of the TRILIB library (used to load 3D models and their associated animations) runs all the animations on the model and it is not possible to select a specific animation. This was fine for loading in the Rabbit, Tiger and Wolf models as they only had one animation stored on the model. Work would need to be done to strip models of their animations if a specific model (with multiple animations) were required.

3.15.1 Chapter Summary

In this chapter, I have described the development of the Unity-based ASGF system The ASGF framework was developed over a period of several months, using an iterative approach, which meant building everything layer upon layer. Once a task was completed, it was tested for errors and then if the module was sound, I could move on to the next stage. The context experts set the initial parameters of what they wanted and I reused assets from the original games that they had worked on.

I found the UI very tricky to code and it was difficult to build such a large and complex application. Programing a complex GUI is not intuitive in Unity. There were many panels in ASGF that contained UI elements such as comboboxes or textboxes. Including the necessary code to load and save these panels was tricky, especially if you are loading an index of a structure in memory when there are multiple indexes. The framework required additional resources or plugins.

I purchased the Trilib model loader plugin, which allows for loading of models at run time. It was suitable for my purposes, but it needs to be updated by the author as there are some technical problems with it described above. When the ASGF framework is available as open-source, this and other licensed paid for plug-ins would have to be purchased by the user, as it does not compile to an executable program, and runs in the Unity editor. Future work is necessary to ensure that it compiles.

As mentioned, Unity is free software (under certain conditions), and there is a lot of user feedback through forums. I feel Unity is better suited to 3D applications.

Chapter 4. Discussion

The goal of my research thesis was to develop the ASGF and provide a platform for ASD therapists to develop games to help children with ASD, in a simple and intuitive manner. The ASGF was developed to help therapists with no programming or 3D modeling experience (complex game design skills). After developing the ASGF, I wanted to determine whether the ASGF is easy enough to use in order to reach its objectives (i.e., allow for the simple development of games to help children with ASD). Part of the ASGF is to provide a reporting mechanism so the therapist can study the results of the system after running the study with autistic children between the ages of three to seven. Prior to the development of the ASGF, I worked with the content experts on games which supported research in brain plasticity. The ideas of these games were incorporated into the ASGF. I re-developed two of the five games (the Facial Expression Matching game and the Rabbit Adventures game). These games have modifiable properties that allow therapists to target their goals. Validation of the ASGF occurred through consultation with two ASD experts rather than conducting formal testing with ASD therapists who would use the ASGF and develop a game as part of the test. Such an approach was taken due to the difficulties associated with recruiting ASD therapists to participate in the study.

There are two modes used in the system as described in Chapter 3; Build Mode and Play Mode. In Build mode the therapist creates the games for the study. In Play Mode the autistic child plays the games created by the therapists. The validation involved building several games in Build Mode and running them in Play Mode. Different types of games can be created by using multiple levels or saving a game and then starting a new game.

Below is a picture of the Face Matching game while it is running in Play Mode:

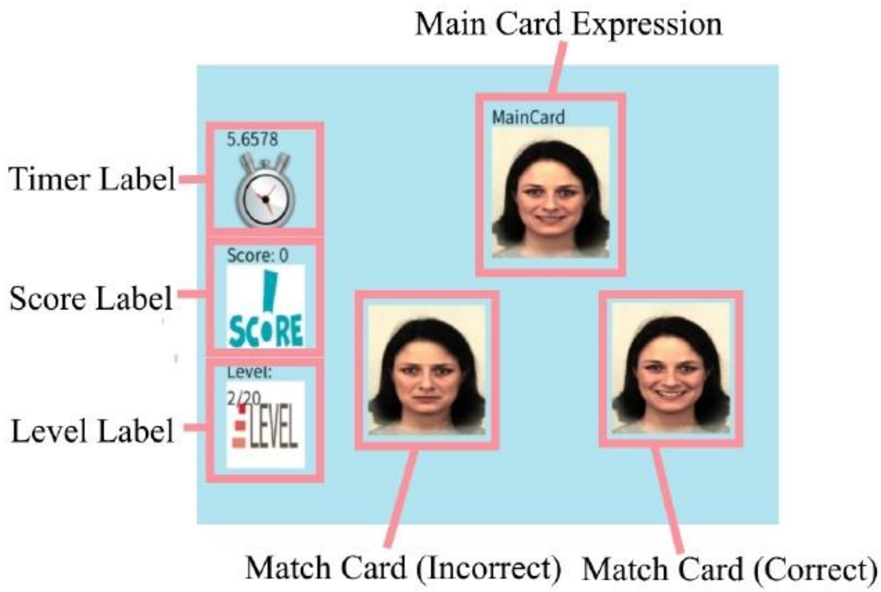

Figure 4.1 Face Matching game screenshot.

In the Face Matching game (Figure 4.1), the child is asked to select the emotional expression that matches the target card (top card). For example, if the target card shows a happy face, the child is asked to identify the card that also shows a happy face.

A graphical example screenshot of the Rabbit Adventures game while it is running in Play Mode is shown in Figure 4.2.

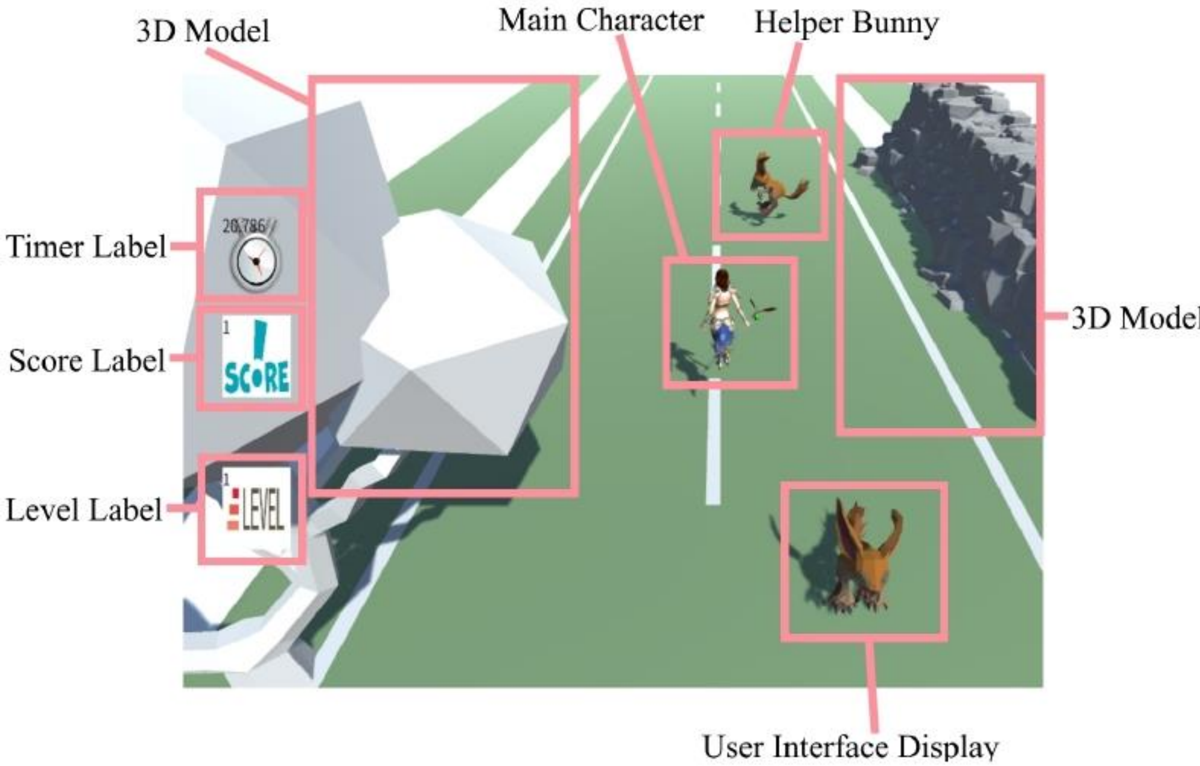

Figure 4.2 Rabbit Adventures game screenshot.

In the Rabbit Adventures game (Figure 4.2), which is a response inhibition game, the goal is for the player to catch as many rabbits as they can. When the game starts, the main character runs forward on the screen. When a rabbit crosses their path, they must press the space bar to catch the rabbit, and if a wolf crosses their path, they should not respond (i.e., they should not press any key). If they respond and press the space bar, they will catch the wolf who will steal the captured rabbits. The variable parts include: replacing the main character, setting the helper character that crosses the path (of the main character), setting a different key other than the space bar (e.g., the "A" or "C" key to respond), the number that must be correct to pass the level, and adding more characters that will cross the main character's path. When the difficulty is decreased, the the number of consecutive correct responses to pass the level also decreases.

4.1 Work in Process

The following descriptions include the games that are a work in progress and are the partially developed games. These games are complete in Build Mode except for saving the properties menus, and need to be completed for Play Mode (i.e. for the autistic child to play the games).

Face Morphing game: Use the slider to morph the face into the expression as shown on the target card. Then select the “Check” button to accept your answer.

Enchanted Apples game: Enchanted apples are hidden behind green bushes around an interesting scene. The user must look for the apples behind the green bushes except when they are given a magic wand in their hand. When they have a magic wand, they must look behind the golden bushes for enchanted apples.

Mysterious Island game: First take a raft, which has 5 rabbits on it. The middle rabbit always shows the correct way, and the other rabbits are confused and may point the wrong way. When the raft comes to two possible channels, the middle rabbit will point either left or right. If the rabbit points left, press the left arrow key and if it points right, press the right arrow key.

4.2 Modifiable Aspects of ASGF

There are several differences compared to the original games developed with the content experts —more specifically, these games are customizable. I also changed the bunny to a rabbit, for example, in the Rabbit Adventures game. In the original games there were no customizations. I expanded the system so that several levels could be created (e.g., Level 1: Face Expression Matching game and Level 2: Rabbit Adventures game). The customizations in the Face Matching game include the ability to select specific facial emotions to target, the ability to change the target card, have as many cards as you want, and given 20 cards per round, you can set the number of trial blocks you want on that level, with a minimum of one trial block. The customizable difficulty parameter was added that sets, measured as a percentage, the number of matched cards that must be correct for the child to move to the next round.

In the Rabbit adventures game, various parameters and aspects of the game can be replaced including the main character or the helper character, the key to be pressed for responding (e.g., the “A”, or “C” key), the number of consecutive correct answers, and additional characters to cross the helper character’s path can be added. When the difficulty is decreased, the number of consecutive correct responses to pass the level also decreases. The two games developed include customizations, such as adding a Score Object, a Level Object, Graphic and Text Objects and the inclusion of Timer Objects. These allow for the inclusion of necessary serious game mechanics, such as displaying the current score on the screen.

I developed the games with an end in mind "– each one targets a specific ability that is known to be affected in autism, such as the ability to shift attention, given an aspect in a task or the ability to read emotion from the face" (Targeted Cognitive Training: Assessment and Plasticity in ASD | Diana Parvinchi - YouTube, 2017). "We want the kids to think they are playing video games so they won't give their parents a hard time and their interest will be maintained" (Targeted Cognitive Training: Assessment and Plasticity in ASD | Diana Parvinchi - YouTube, 2017).

"We want them to view it as fun so they want to play" (Targeted Cognitive Training: Assessment and Plasticity in ASD | Diana Parvinchi - YouTube, 2017). "As they play and become better the difficulty increases matching their level of ability" (Targeted Cognitive Training: Assessment and Plasticity in ASD | Diana Parvinchi - YouTube, 2017).

4.3 Contact with Content Experts

I met with our two content experts and we came up with the ideas for the games. Two games were completed in the ASGF system, the first game being the Face Matching game and the second the Rabbit Adventures game. The results stem from the feedback of our two experts. On July 12, 2019 I presented through Skype the final framework to the content experts. The Skype meeting was recorded for further analysis. I also sent them a set of PowerPoint slides of what had been covered in the interview and the experts provided comments on them. I also found a video (by one of our content experts) online on YouTube (Targeted Cognitive Training: Assessment and Plasticity in ASD | Diana Parvinchi - YouTube, 2017). In it she discusses the cognitive strategies or the reasoning behind their studies on the set of games we developed prior to the ASGF system. As of the date of the video she had tested the earlier games on typically developed children and had positive feedback.

4.4 Conducting a Future Study with ASGF

My research question would involve the validation of ASGF in clinical trials. I will first recruit a group of therapists and have them download the ASGF software and then I will ask them to run the ASGF system. When they start the system, they start at the introduction screen. I will ask them to click on Video Tutorials to watch the videos. They can also view the Terminology screens and return to the introduction screen once they are finished. Next, I will ask them to press Start Autism Tool to go to the main tool screen where they will attempt to develop a game with the option of multiple levels. If they need help, they can hover over each button and tooltips will appear explaining what each button does. They can also return to the introduction screen to watch the videos from the main screen. I want the therapists to develop a conceptual idea of the framework and understand the system, and to get them comfortable with the system and familiar with developing games. One of the goals is for the therapist to be able to save the game they developed and be able to load it back when they run a study. I will also use two questionnaires with the therapists. The first questionnaire is comprised of a subset of questions from the Questionnaire for User Interaction Satisfaction (QUIS) (Cindy Lu, 1998) and the second is the System Usability Scale (SUS) survey (Brooke, 1996). The QUIS provides information regarding specific aspects of the human-computer interface and the SUS gathers information about usability. I would also want to get their opinions on the system.

4.5 Recommendations (ASGF)

From my meeting with the content experts on July 12, 2019, I received feedback on the ASGF. They have suggested that I export the report data to a Microsoft Excel Worksheet to make the data easier to read and to allow calculations to be run on the data. Since Unity does not support external custom controls, we would have to send the data to a text file and then parse the report data into Excel. The ASGF is also set up to save the report when pressing the “Save Report” button. This data should be saved automatically. The content experts also mentioned that the games should be labeled in such a way so they would include info about the goal or purpose - so the user, the therapist, will be able to select according to need. Currently there is an option to add a text label for this purpose. I was also recommended to update my terminology. For the Face Matching game, I should refer to the main card as the "target card" and the other two at the bottom as "choices". I was also recommended to “use the wolf model as a way of building rewards in[to the games] and this should this be a consistent character used in all [the] games” (Parvinchi, 2019). It should be introduced at the very start of game play along with the reward music and an excited animation (Parvinchi, 2019). It should also be clear that each individual level has its own difficulty value.

In my analysis, a report name and unique id should be saved with the data. To further enhance the system, I could upgrade the version of Unity to 2019.1 and also update the TRILIB model asset importer library. The developer of TRILIB will eventually solve the problem of all animations playing on the Autodesk FBX model as described in the development section. I also want to know whether the content experts want to add more default models to the games or extend our library of models (e.g., a Cat model) and if necessary, strip any animations they don’t want to use on the model. I also want to change all the graphic images for buttons (e.g., the “Difficulty UI” button image) to what our content experts require using their professional knowledge. This means all the pictures for the UI need to be changed and have the UI reorganized. Also, the colour schemes will need to be changed to target children between the ages of three and seven.

The content experts were confused by some of the pictures on the buttons (e.g., “Create Face Matching Game” button), and it is suggested that these get replaced to make it clear as to what the buttons do. I also want to replace the tooltip text in keeping with future feedback from our content experts, and also need to record several short movies to play for the reward at the end of each game level.

I could also update the (.png or jpg) target expressions for the Face Matching game or change the expressions so that a 3D model with an animation for each expression is used. I could also change the path colour in the Enchanted Apples and Mysterious game to red (so it is easier to see).

Future work would involve multiplayer games for children with autism. I would suggest multiplayer serious games for older children with autism or higher functioning children with autism. We must understand how anxious a child becomes when interacting with other children. In Pico's adventures the last level is played with a typically developed child and is a new experience (Malinverni et al., 2017). They had to work together on tasks. "Multiplayer games have been shown to encourage sociability and communication among players to accomplish shared goals" (Boyd et al., 2015, p. 4)."Collaborative virtual environments, including games, successfully encourage partnership by requiring users to use offline skills to carry out activities within a virtual environment" (Boyd et al., 2015, p. 4). "Much of the "fun" of games may actually come from the relationships among players as they navigate game activities" (Boyd et al., 2015, p. 4). Collaboration would be necessary with our content experts to determine the goals of multiplayer games and determine the targeted learning or neuroplastic change within the brain.

The ASGF was developed to enable the content experts to develop a series of games to use in their studies of autistic children. I anticipate the ASGF framework will meet their goals of developing a game building environment that is natural (easy) to manipulate.

Chapter 5. Conclusions

The goal of my research was to develop the Autism Serious Game Framework (ASGF) to allow therapists to create serious games to assist children with autism without any prior programming experience. The ASGF provides a more usable, flexible, simple, and intuitive structure than traditional gaming engines, since it allows a non-programmer to develop games, and modify their parameters. The ASGF is designed to address changes to multiple scenarios and does not require the framework's source code to be modified which is a difficult and time-consuming process. The ASGF framework is intended to be intuitive and contains help feedback though the help window and tooltips.

The ASGF addresses the need for more collaboration between clinical and computer/game design experts (Grossard et al., 2017). Through close collaboration with content experts, I designed ASGF to meet their needs. The framework enables the therapists (users of the ASGF) to develop a variety of games, which could raise the child's confidence, motivate the child to follow through and succeed, and to potentially target different learning issues such as the need to inhibit repetition.

The ASGF provides a safe and cost effective solution (Chaffin & Barnes, 2010). Future work will involve the content experts becoming proficient with the ASGF and using it to conduct a series of usability studies that will examine the usability of the ASGF with ASD therapist participants (who will use the ASGF to develop a series of serious games for autism treatment). Results of the ASGF will guide its refinement and ultimately improvement. Future work will also involve using the ASGF system with therapists in clinical studies. A case study, which could provide a rich description of the therapist's work, would be an excellent first step.

On a larger scope, robust studies are required which include large samples of subjects, control groups, longer treatment studies and follow-up to determine if the changes are stable (Grossard et al., 2017).

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APPENDICES

Appendix A. Sample Event type language for the Rabbit Adventures Game

```
START > Rabbit Adventures Game
//GAMEOBJECT FOR ALL (HAS SCORE, LEVEL)
CREATE OBJECT MyGround(MYGROUND.FBX)
          MyGround.Position(CENTER)
CREATE OBJECT MyTREE(TREE.FBX)
CREATE DUPLICATE myForest(MyTREE, 100)
          //Position them in a row on each side
CREATE PLAYER MyPlayer1
          MyPlayer.Positon(CENTER)
          MyPlayer.Movement(FORWARD 50)
          EVENT: Movement.STOP{
               MyPlayer.Positon(CENTER)
               MyPlayer.Movement(FORWARD 50) //Reset the
level
          }
          MyPlayer.ANIMATION = TAKE1
CREATE SOUND MyBackgroundSound, GoodJob, TryAgain
CREATE OBJECT MyBunny(MYBUNNY.FBX) //Duplicate later
          MyBunny.Visible = FALSE
CREATE OBJECT MyFox(MYFOX.FBX) //Duplicate Later
          MyFox.Visible = FALSE
CREATE INVENTORY MyBunnyInvetory(5)
          //Use bunny model
CREATE TIMER MyTIMER(RANDOM(50MS, 200MS) //BETWEEN
CREATE KEYBOARD MyKEY("SPACE")
PLAY MyBackgroundSound
PLAY >
TIMER MyTIMER EVENT:
{
     IF(RANDOM(0,1) == 1
     {
          CREATE DUPLICATE MyFOXCHAR(MyFOX)
               MyFOXCHAR.POSITON(MyPlayer.Location)
               MyFOXCHAR.POSITION(FORWARD 10, RT 90,
FORWARD 20, RT 180)
               MyFOXCHAR.Movement(FORWARD 40)
               EVENT: Movement.STOP{
                    DELETE MyFOXCHAR //will skip if
already deleted
               }
     }ELSE{
          CREATE DUPLICATE MyBUNNYCHAR(MyFOX)
               MyBUNNYCHAR.POSITON(MyPlayer.Location)
```

```
                MyBUNNYCHAR.POSITION(FORWARD 10, RT 90,
FORWARD 20, RT 180)
                MyBUNNYCHAR.Movement(FORWARD 40)
                EVENT: Movement.STOP{
                     DELETE MyBUNNYCHAR //will skip if
already deleted
                }

     }
     MyTIMER.INTERVAL = RANDOM(50MS, 200MS) //RESET THE
INTERVAL
}
MOUSE MyKEY EVENT:
{
     IF(CLOSEST(MyPlayer, MyBUNNYCHAR){
          GAME.SCORE++;
          IF (SCORE >= 40)
          {
               //CODE FOR NEXT LEVEL
               LOAD GAME2
          }
          PLAY GoodJob

          MyBunny Movement.RESET(RT 90, FORWARD 60)
          MyBunny Movement.STOP Event:
          {
               IF(MyBunnyInventory.Count < 5)
               {
                    CurrentIndex =
               MyBunnyInventory.Add(MyBunny)

     MyBunnyInventory[CurrentIndex].Position… //Position
Behind Player

     MyBunnyInventory[CurrnetIndex].Animation = Take2
               }
               DELETE MyBunny
          }


     }ELSE IF(CLOSEST(MyPlayer, MyFOXCHAR)
     {
          GAME.SCORE = 0;
          PLAY TryAgain
          MyBunnyInvetory.Clear()
     }ELSE
     {
```

```
                DEBUG.LOG("NO MATCH")
        }
}
```