Virtual Reality Enhanced Pink Dolphin Game for Children with ASD

Sandra Chan, Yiyu Cai, Andrew Lu, Nay Zin Tun, Lihui Huang and Indhumathi Chandrasekaran
School of Mechanical & Aerospace Engineering, Nanyang Technological University
50 Nanyang Avenue, Singapore 639798

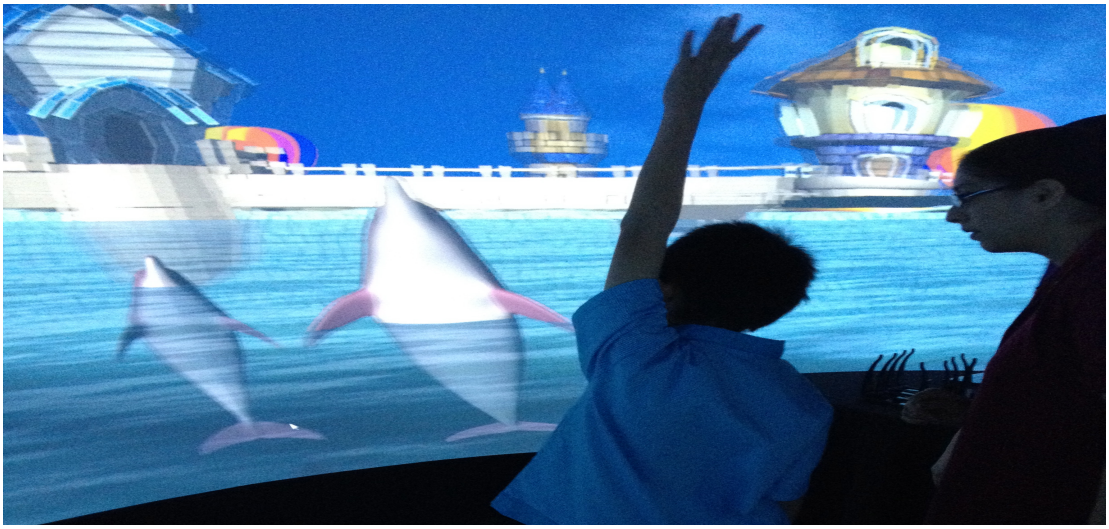

Figure 1: *Learning through gaming*

Abstract

Autism Spectrum Disorder (ASD) is a developmental disorder with different levels of severity. Although the exact causes of ASD is not yet known, nor is there a medical cure for ASD to date, special facilities and schools have been established to help individuals coping better and becoming more independent. With the advancement in Virtual Reality (VR) technology, there has been a greater depth of development of technology-enhanced game-based learning for children with ASD. This paper will describe our effort to design VR enabled pink dolphins game assisting children with ASD in their learning, at the same time, to avoid the use of physical pink dolphins which is a species endangered for animal assisted intervention. In particular, we will discuss the benefits of this VR technology enhanced and game based learning for children to follow direction, give direction and do hand-eye coordination.

Keywords: virtual reality, serious games, technology enhanced learning, autism spectrum disorder.

1 Introduction

1.1 Autism Spectrum Disorders

Autism Spectrum Disorder (ASD) is the diagnostic range of developmental disabilities which are characterized by slowness in social skills, as well as constrained or repetitive behavioural patterns and interests. These symptoms typically begin to surface early in the growing stages of a child. The characteristics can be classified in two broad categories: social and communication impairment, and repetitive and stereotyped behaviours. In cases of ASD, social and communication impairment refers to the deficiency in interaction skills. For some, language development may be slow and delayed. However, it must be noted that not all children have speech difficulties; some are even able to speak in perfect sentences. Such children still may not be able to keep an ongoing conversation because of difficulties in comprehending typical emotional cues. Repetitive and stereotyped behaviours may be presented in mild or extreme forms. In his case on 11 children with autism, Kanner observed involuntary, repeated actions by the children on a normal basis, such as jumping and spinning (Leo, 1943). On top of body motion stereotypes, children with ASD also work best with routine and do not adapt well to changes in their regular cycles. This inflexibility requires them to follow a strict regiment, such as always having to take the exact route to school. Repetitive behaviour may also take the form of a highly-concentrated preoccupation. While children with ASD may struggle to maintain focus on social activities, they can be excessively obsessed in things that interest them, such as bus routes and train schedules, in which they will memorize every single bus route of all bus services and train arrival timings.

The occurrence of the disorder is random, although certain factors can contribute to increased risks. For example, children who were conceived by parents advanced in years, or with a history of ASD in the family line, have proven to be more likely to acquire the disorder. Research has also led to several theories which have been used to explain the reasons of the certain characteristics of individuals with ASD. Theory of Mind (ToM) is the capacity to internally comprehend and distinguish subjective mental states like expectations and thoughts, of one's own and others' minds. ToM develops early in the developmental growth of children but there is a marked delay for those with ASD (Peterson, 2014). ToM encompass the understanding that different people have different wants, thoughts and feelings from one's own even though it may not be explicitly visible as well as the possibility for others to act according to what they believe in (Lowry). Fakhoury reviewed the theory of Impeded Plasticity, the Excitation and Inhibition Dysregulation and the ToM (Fakhoury, 2015). This Theory explains the abnormality in the development of the brain of children with autism. The imbalance that occurs

during the development of excitatory and inhibitory synapses can lead to various developmental malfunctions such as ASD. The exact causes of ASD are not known. While there is no cure for ASD, early and regular therapy can help both the child and caregivers to cope in their areas of limitations. Such therapy includes behavioural therapy, occupational therapy and medication. Special facilities, centres and associations are also set up so that support is provided for families with loved ones with ASD. Special education schools are commissioned with specialized teaching techniques, tailored programmes and adapted equipment to cater to children with ASD. Children are given a slower-paced curriculum to learn subjects such as language and mathematics, as well as skills. These are executed in the forms of book learning, role play, and educational toys.

1.2 Serious Games

Serious games are video games modelled for the purpose of learning or solving problems, as opposed to those entirely focused on entertainment (Djaouti, Alvarez, & Jessel, 2011). While there are entertainment video games branded as purpose-shifting games which carry secondary underlying motives, serious games are designed specifically for its intended purpose and audience. The use of serious games is common in fields such as the military, medical and educational sector. With the rapid advancements in technology, the virtual world is progressively infiltrating more areas of life. The tapping of technology in the education sector is no exception and one aspect of this is the use of serious games. The great array of benefits associated with learning through serious games include the possibility of players to learn effectively about an environment virtually without the need to be present at the actual environment as well as the high motivational factor embedded into learning (Mouaheb, Fahli, Moussetad, & Eljamali, 2012). With the current advancements in technology and greater engagement of electronic gadgets around the world, it is important to tap on the boundless opportunities technology presents to aid the learning of children with ASD (Göbel, Ma, Hauge, Oliveira, Wiemeyer, & Wendel, 2015). In this digital era where technological advancements are at unprecedented rates, the rife of gaming and the use of the internet has emphasized the need to produce various educational methods incorporating the use of (serious) video games (Freitas & Liarokapis, 2011). Consequently, the serious games sector has attracted the interest of steadily rising markets and a greater depth of academic research in diverse fields (Ritterfeld, Cody, & Vorderer, 2009). The exploration of the incorporation of serious games for an audience of children with ASD is on a progressive ascent today (Densmore, 2007). Educators and researchers are looking to digital teaching for the children to learn various skills- from communication, psychomotor training and social behaviour augmentation. An example of a website for autism games is the Whiz Kid Games site, www.whizkidgames.com. In a meta-analysis done by Sizmann and a research team, it was discovered that learning through simulation games resulted in 11% higher declarative knowledge, 14% higher procedural knowledge and 9% higher retention of training material compared to those who underwent traditional learning methods (Sitzmann, Ely, Bell, & Bauer, 2010). Serious games play increases the entertainment value to the player on top of the educational objectives trained (Csikszentmihalyi, 1990). This can help to deepen the sense of commitment and responsibility to perform well in the character (Yee & Bailenson, 2007).

This paper reports our effort to assist children with ASD by acquisition and exposure of learning skills through serious games. More specifically, Virtual Reality (VR) enabled pink dolphins game will be present. The idea is to develop low cost VR technology for the purpose to help children with ASD in their learning, at the same time avoid the use of physical pink dolphins which is a species endangered for animal assisted intervention.

2 VR Enabled Pink Dolphins Game

2.1 The game

Animal-assisted therapy is reported to be able to improve the social and communication skills such as being more receptive to stimuli, and to harness roles of responsibility in caring for the animals in the case of children with autism (Law & Scott, 1995). In particular, interactions with dolphins are said to have an impact of increased speech, a wider range of motion and increased periods of eye contact amongst those with ASD (Nutter, 2011). The virtual pink dolphin project is a joint initiative between Nanyang Technological University (NTU), Underwater World Singapore, and Asia Women's Welfare Association (AWWA) School for special needs. The motivations behind the development of the game apart from the learning objectives also include casting out of risks of children in the actual physical dolphin encounters such as drowning or unpredictable animal behaviour of the dolphins. Moreover, the game provides an alternative to dolphin-assisted therapy which may be harmful to the endangered creatures (Cai, 2013). Through modelling, simulation and programming, we seek to create a serious game with virtual pink dolphins to substitute live dolphin interactions. The virtual pink dolphin game is designed to engage children with ASD in their learning of social communication using gesture through immersive and interactive means of 3D virtual reality technology (Figure 1). This paper is interested to investigate the learning objectives for children with ASD with a focus on direction following, psychomotor skills and hand-eye coordination.

2.2 Game Play

In the game, the children will be dolphin trainers giving directions to the pink dolphins to perform tricks. By mirroring an avatar on the screen, their hand movements will be picked up by the motion sensing input device. There are three stages of the game, together with a warm-up round at the beginning. There are five sets in every stage. Upon executing the set correctly, the dolphin will perform a trick. The wrong gesture will trigger a prompt displaying, "Follow me!" with a buzzer sound. Likewise, the right gesture will result in a green tick, displaying a prompt of encouragement of "Excellent!" and accompanying victory bells ringing. The warm-up round starts with the avatar and a speech bubble with the exact instructions for the actions required. In the subsequent stages, only the avatar with performing the animated action will be shown without any worded hints. "Triangle" stage comprises of 1 action per set. Each set of level 2, or the "Circle" stage, is made up of 2 actions. The third and final stage, the "Square" stage, requires 3 actions in each set. After the warm-up round, the game will officially begin with level 1 Triangle stage, level 2 Circle stage and the final level 3 Square stage. At the end of the game play, the player will be rated on a 3-star scale for their speed and accuracy. The entire game consists of five actions, of which will be permutated in different sets in the Circle and Square stages. These five actions require the various movement of the arms, thus enabling learning using the correct hand and executing the action in the right position.

2.3 Game-based Learning

Firstly, the nature of the dolphin game being a virtual game will help children learn actions or skills more effectively as compared to traditional teaching methods through book or whiteboard. The virtual reality platform that the virtual pink dolphin game is conducted in would therefore reap such benefits as well. As the children play the role of the dolphin trainer with realistic graphics of the lagoon and the water splashing sounds and animation, the immersion into the environment leads to a greater sense of actuality and a more enjoyable experience (Csikszentmihalyi, 1990). This increases the entertainment value to the player on top of the educational objectives trained. The assumption of the persona of the dolphin trainer avatar helps the children to identify with their role and responsibilities better. This can help to deepen the sense of commitment and responsibility to perform well in the character (Yee & Bailenson, 2007). The hands-on approach involves the children to both follow the directions of the avatar and give directions to the dolphin. This contributes to the experiential learning of communicating through hand gestures. The children will be able to adapt what they have learnt in the game to real life, as well as to have a higher retention of the content. The virtual pink dolphin game may also reinforce other underlying learning objectives such as numeracy, colours and shapes. This is done through the subtle means of the game environment. Different colours are being presented in the background graphics such as the orange octopus holding the hula hoop. Numeracy is can also be practiced through the number of sets the player is left to complete, while the shapes at each stage are also used as the reward objects the dolphin proceeds to catch after each set is successful. However, the benefits and the game objectives have to be verified in order to test the true effectiveness of the virtual pink dolphin game as well as for future improvements and developments in using serious games as a teaching tool for children with ASD. The next section will discuss an experimental method to test the effectiveness of the Pink Dolphin game in teaching the children about following gesture directions.

3 Experiments of the Game

3.1 Research Question

In this experiment we would like to learn "whether children with ASD are able to learn to follow and give directions in the Virtual Pink Dolphin game"?

Game play data refers to the player's in-game movement and responses which are acquired by numerical variables (Loh, Sheng, & Ifenthaler, 2015). There are two ways to obtain players' game play records: ex situ and in situ methods. Ex situ data is data that is presented from the "outside" of the game through observation. The profile of the players such as the age, survey feedbacks and physical pre-test and post-tests are forms of ex situ data. On the other hand, in situ data is found from the "inside" of the system, in other words, the data that can be obtained from the internal software program (Loh, Sheng, & Ifenthaler, 2015). The effectiveness of the game may also require additional tests to be done, for example, to test the reaction time before and after playing, so as to compare the improvement as a result of playing the game. The theory of pattern matching may also be employed. Pattern matching is an attempt to relate a theoretical pattern with the actual observation. The theoretical pattern may be a hypothesis or a traditional theory derived by the researcher. Upon direct observation and measurements, the extent to which the patterns tally will reflect the support of the theoretical prediction. The pattern match is achieved through calculations of tests of significance like the t-test or ANOVA. The difficulties in these methods arise when there may be other factors which contribute to the differences or similarities between the groups in consideration (Trochim, 1989). Psychological tests may also be helpful in indicating the effectiveness of the game through the measurement of improvements to the individual's abilities.

3.2 Experiment Design

The experimental design would split the participants into the experimental group (EG) and the control group (CG). Participants in the EG are those who have been exposed to the Pink Dolphin game before, with the game in their curriculum. On the other hand, the CG would contain those who have not even seen the game before. With an EG and a CG, we are now enabled to directly compare the results of two groups of participants with regards to their circumstance. It lessens the margin for error stemming from particular individuals.

Both the EG and CG will take a test and we will compare their results. Since the objectives of the dolphin game were 1) Follow Directions 2) Communicate by giving directions and 3) Train psychomotor skills and hand-eye coordination, we designed a test to measure the capabilities of the students in these three aspects. The test is split into two main parts, the 'Grid Game' which would encompass the first two objectives, and the 'Do As You See' game which would fulfil the last objective.

The grid game will be set up on paper in a 3x3 grid (Figure 2). The 3 grid side will be facing the instructor with the participants opposite. A toy will be placed in the possession of the participants. By listening to a set of instructions in the directions of 'move the toy straight', 'turn left', and 'turn right', the aim of the game is to reach the other side of the grid following the path chosen (path is fixed for all participants). If a wrong step is taken, they would have to start from the beginning, with the number of attempts being recorded. Next, the instructor would place sweets on his end of the grids. The participants are supposed to give the instructor instructions to follow to reach other side of the grids in accordance to the path that is marked. The three instructions available to the participants are the same as the previous part. If a wrong instruction was even, the participants would have to start from the beginning. The number of attempts will be recorded and measured for participants.

"***Do As You See***" game is to test the participants' hand eye coordination. With the sweets and toys hidden from sight, when they see the sweets, they must raise their right hand. When they see the toy, they must wave their left hand. This will be used to test their hand eye coordination, and they must get it right 3 times. Number of attempts will be recorded and measured. The toy or sweet shown should be fixed to avoid errors. Three different situations will be tested by the instructor, raising the sweets with his left hand, raising the toy with his right hand, and raising the sweets with his right hand. The test will be conducted with the objects hidden behind his back. The reason for the last action is to ensure that the participants do not second guess the answer by looking at which hand is about to be raised.

A local special school was gracious enough to allow us to do the EG/CG test at their school. A total 12 children participated the research with 5 for the EG and 7 for the CG. Out of the 12 children available, 2 of them were unable to complete the experiment due to a lack of attention span/ the lack of ability. As

such, in order to not affect the experimental samples, they were each allocated the worst results of the respective categories.

A one tailed T-test was done and it was found that the t ratio was greater than the t critical one-tail. This shows that we can reject the null hypothesis that the results of the CG and EG are the same, proving that they are fundamentally different, where the EG outperformed the CG (Table 1).

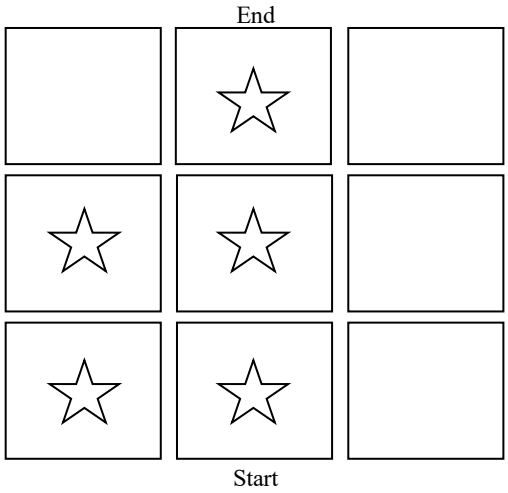

Figure 2: *The grid game*

Table 1: *T-test results*

	Variable
Mean	16.57142857
Variance	133.6190476
Observations	7
Hypothesized mean difference	0
Degree of freedom (df)	7
t ratio	2.130858355
P(T<=t) one-tail	0.03529034
t critical one-tail	1.894578604
P(T<=t) two-tail	0.070580681

4 Conclusions

Virtual pink dolphin game is a VR enhanced serious game designed to help children with ASD in learning of social communication and interaction by serving as dolphin trainers. This research looks into the benefits of playing virtual pink dolphin games for children with ASD to learn specifically following directions, giving directions and hand-eye coordination. Through the conduct of the experiment of the virtual pink dolphin game, the statistical analysis based on the experiment data shows that the game is effective in the helping children with ASD learn to follow directions from the avatar and give directions to the dolphins. These directions included pointing with the correct hand. From the t-tests analysis, it is obvious that the EG showed better results than the CG. However, there were certain limitations in the experimental methods.

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