

A Design of Multipurpose Virtual Reality Game for Children with Autism Spectrum Disorder

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Abstract—Autism spectrum disorder (ASD) is a developmental disorder that related to brain development, affecting communication and behavior. Hallmarks of children with ASD are, they are not interested in communicating with other people and they find it really hard to focus on something they are not interested. Children with ASD need to learn some skills in order to increase their independence, including social skills, life skills, and focus. Some research studies have found that virtual reality (VR) is an effective tool for treatment in healthcare. In order to increase skills of children with ASD, we developed a system, based on VR and Leap Motion. We developed a game platform aiming to attract children with ASD to train their focus by placing balls with different colors in the box according to the ball's color, and increasing their social skills by training them how react with social situations and virtual people around them. Our design has been tested and it showed well running interface. Participants in this game had three sessions of training and they were engaged with the game environment and they were able to follow the game scenario well for focus training, signs learning, and eye gazing learning. Their accuracies for all games were increased. The accuracy increase was about 11.16% for Game for Subject Focus, 16.6% for game for Focus with Distraction game, and subjects could interpret the arrows better by reaching each destination 2 seconds faster on each training session. The accuracy of Eye Gazing game was 75% for each training session.

Keywords— autism, education game, Leap Motion, life skills game, serious games, virtual reality

I. INTRODUCTION

Autism spectrum disorder (ASD) is a developmental disorder that related to brain development, affecting communication and behavior. Hallmarks of children with ASD are, they are not interested in communicating with other people [2] and they find it really hard to focus on something they are not interested. Another characteristic of children with ASD are they have an inability to evaluate which task is more important, therefore they are likely to be unfocused [10]. Some autistic children also have motor impairment which could impact their academic performance [1]. To increase their academic performance and independence, children with ASD need to learn some skills, including social skills, life skills, and focus.

A research program has recently been started by the authors with the goal of developing a multipurpose game

based on VR and Leap Motion to help children with autism to learn. In this study, the games developed were tested in order to ensure that the function was running well and suitable for autistic children.

Computer games have been extensively applied as tools for children with autism to learn. Other than computer games, now games for iOS and Android platform are also widely developed for children with autism. However, little research to date is focused on developing computer games for autistic children based on Leap Motion device. Leap Motion is a new gesture and position tracking system with the accuracy level of sub-millimeter[1][4].

Recent studies have occurred in the field of games for children with autism. Zhu [1] developed a matching games based on Leap Motion. Noor [5] reviewed serious games for children with autism. Hopkins [6] improved social skills in students with ASD by computer-based intervention. Chang [8] developed a situated game for autistic children to learn daily activities. Qidwai [7] presented a digital gaming module, for therapeutic process of children with ASD. Barajas [9] proposed serious game for ASD children composed of a Tangible User Interface from physical Lego-like building blocks and a Graphical User Interface. To the best of our knowledge, most studies developed computer games for specific skills only, especially social skills.

Autistic children are often observed with difficulty to focus on something they don't interested, and they tend to be monotonous. Their ability to focus, will affect their academic performance. Therefore, they need to train to be more focused. Autistic children will also need to be focused when they are socializing with their interlocutors. One of the components of abnormal social functioning in autism is an impaired ability to direct eye gaze onto other people's faces in social situation [3]. Autistic children are not likely to gaze at their conversation partner's eyes, although eyes are really important for someone to understand the conversation. Therefore, they need to learn understanding what someone is intended by looking at their eyes. Life skills for children with autism are including interpreting signs, symbols, and following rules. Symbols and signs introduction to autistic children is important because they are included in survival skills.

The aim of the present work is to develop games that cover the need of children with autism with Leap Motion as the

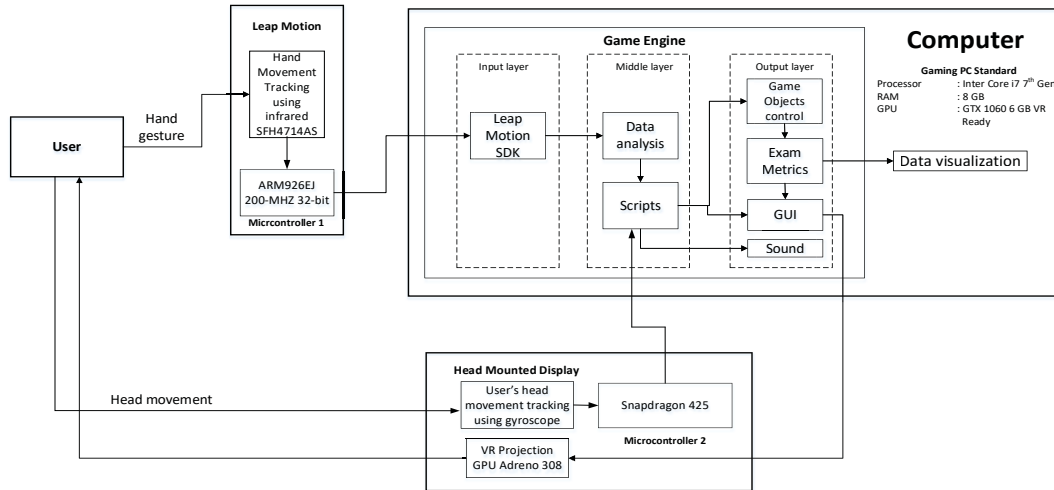


Figure 1. Block diagram of the system

game control tool. The results of the game are encouraging and show that Leap Motion can be used as more interesting game control tool in VR environment for children with autism. **Users that have some similar characteristics with autistic children had no difficulties using the system.**

II. METHOD

A. Block Diagram

The whole block diagram of the system is shown on Fig. 1. This system consisted of Head Mounted Display (HMD) device that was directly connected to Personal Computer (PC). Subject's hands were moved in front of the Leap Motion device while they were playing. Their hands were going to be read by the Leap Motion's infrared and directly converted to Leap Motion's rigged hand in the game engine.

B. Design

1) Hardware

Hardware of this study consisted of HMD and Leap Motion. HMD was used as a head tracking device for the subjects to look around at 360-environment. While Leap Motion function was to translate subject's hand movement in real environment into hand movement in 3D world.

2) Software

Software design in this study was done in the game engine. Software designs intended here including environment design, game scenario, and scoring system. There are four game designs that will be described below.

a) Game for Subject Focus

This game design is shown on Fig. 2. When Children with ASD presented with two objects and told to focus, they often cannot shift attention [10]. This is because of their inability to decide which task is more important. Another study explained that this inability stems not only from a developmental delay but also whether or not a child is interested enough to focus [10]. So, to train their focus we used fun and interesting object like balls with different colors. The balls were placed randomly in a place and the subjects were required to group the balls according to their colors. Scoring system for autistic children games is different from the usual scoring system. We used objects as our scoring system instead of numbers. Rewards in this game were bananas, grapes, and apples. Rewards would be given if the correct placements done by user were blue, yellow, and green respectively.

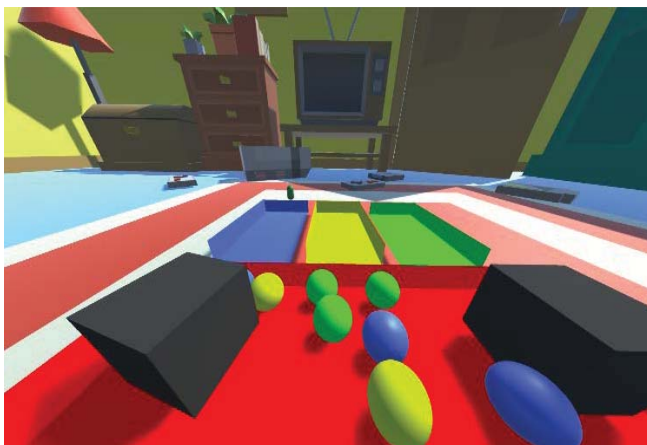


Figure 2. Game for Subject Focus

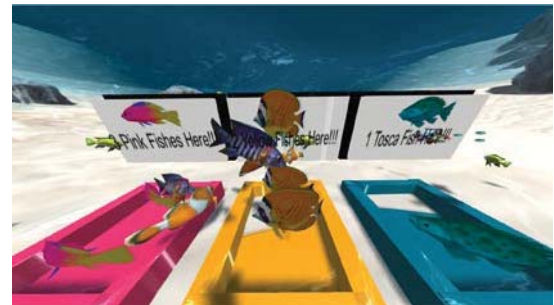


Figure 3. Focus with distraction game



Figure 4. Rules and signs game



Figure 5. Eye gazing game

b) Focus with Distraction

The game design in this section is shown on Fig. 3. This game is the next level of Game for Subject Focus. We used fish as our objects to engage children's attention. Subjects in this game were made like they were diving underwater so they could see many fish swimming around. There were three boxes with an instruction board behind each of them. Instruction words for ASD games should be made simple. Therefore, we limit the number of words we used [12]. Distractions here were the moving fish and the subjects were required to focus on the fish on the instruction boards and placed them inside the boxes with the same colors as the fish. We should not give children with ASD many distractions because they would lose their interest easily. Therefore, fish shown on the instruction boards were made immovable and they were already placed close to the correct boxes to reduce difficulties experienced by the subjects. Every correct placement done by the subjects were given a coin as a reward.

c) Rules and Signs

Rules and Signs game design is shown on Fig. 4. The purpose of this game was to teach children with ASD about arrows and directions. We used arrows as our learning materials here because we often found arrows in our environment as symbols of directions. In this game, the subjects were first notified about any rules of hand gestures for movement directions control : forward, backward, right, left, and stop in the game. They must move according to the direction of the arrows to meet virtual people in the game to obtain rewards.

d) Eye Gazing

Eye Gazing game design in shown on Fig. 5. Children with autism are known to have difficulties in sharing attention with others [2]. But, seeing the other person's eyes is important in communication to understand our partner of conversation. Therefore, we made this game aimed to train autistic children to focus on their interlocutor's eyes especially the gazing directions. In this game the subjects were required to focus on virtual character's eyes and saw which direction the virtual character's eyes were gazing. Around the virtual character, were placed several food and beverages as our interesting objects. The subject was required to give the virtual character the object that had been gazed at. For every correct answer, the gazing direction was changing

to another object and the subjects would obtain a stack of coins for their reward.

C. System Testing

1) Hardware

In order to validate the results, system testing was required. Hardware testing was related to the connection between Leap Motion and the game engine. This test was needed to ensure that the virtual hand in game engine was in the subject's view field. So, even though when the subject was looking at the environment as much as 180 degrees, the virtual hand remained legible and visible to the subject.

Based on testing, visibility of the virtual hands in the environment was related to the placement of the Leap Rig. The Leap Rig marker must be set to ensure that the virtual hand was visible to the subject even while subject's HMD was moving. This was because the Leap Motion device was stuck with the HMD. This test greatly determined the comfort of the subject while they were playing.

2) Software

a) Game for Subject Focus

At the time of testing, the location of the falling rewards was behind the red box on Fig. 2. However, if the rewards were located too far from the subject, the subjects were not going to be aware of obtaining a reward. So, to make the rewards visible, the rewards were placed inside the red box on Fig. 2 using an instantiate object with gravitational effect.

The key of this game was the balls inside the red box. Therefore, we also ensured that every single ball in the red box was able to be picked by the Leap Motion Rigged Hand by trying to pick the balls one by one.

b) Focus with Distraction

The key of this game was the immovable fish. The immovable fish should be able to be picked by the Rigged Hand of Leap Motion. Therefore, the Collider's shape was really important. In game for subject focus, we had fixed shape of objects (sphere). But in this game, fish did not have fixed shapes. Therefore, in our first trial, we used mesh collider as our collider shape. We enabled Convex for our Mesh Collider to make our Mesh Collider collided with other Mesh Collider. But Convex Mesh Colliders were limited to 255 triangles. Therefore, the performance of the immovable fish was not like we had expected before. The performance result was correct for Box Collider with small-enough size based on the grasping size of Rigged Hands. The size of this Collider was set by trial and error as our problem solving method.

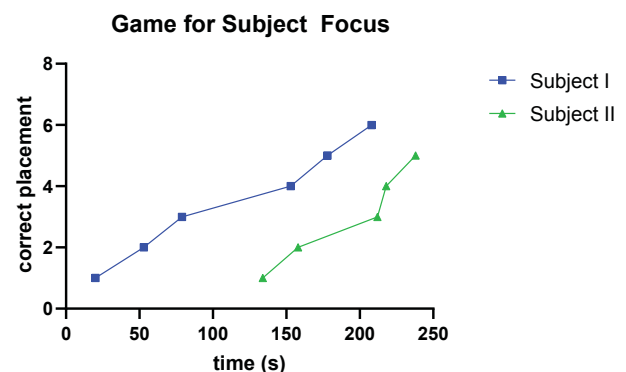


Figure 6. Game for Subject Focus Result

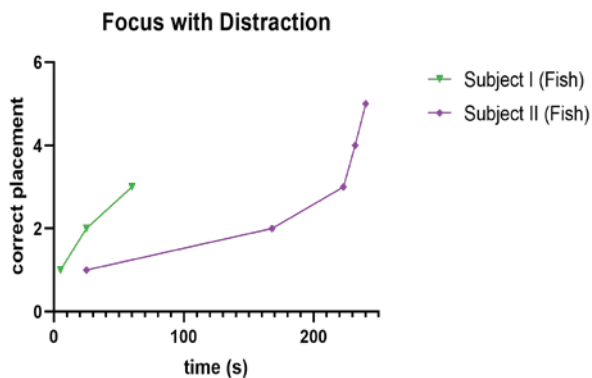


Figure 7. Focus with distraction game result

c) Rules and Signs

In testing, this game was relatively more relaxed than two previous games. Because, for the previous system, the subjects were required to be really concentrated so the objects could be taken. But in this game, what was important was the hand gestures. The subjects were able to walk following the directions and reached to the designated destination with the gestures. Only three destinations in this game were made because too many destinations would give the subjects mundane feeling. To reach these three destinations, the subjects duration were measured.

d) Eye Gazing

The distance of objects in this game is really important. Because it affects the Subject's interpretation about the gazing directions. Short distance between two objects tended to confuse the subjects about where actually the virtual character's eyes were looking.

D. Experimental Method

1) Participants

Two subjects with similar characteristic as autistic children were chosen. Subject I had better motor skill but with focus that could be distracted easily, whilst Subject II had motor impairment. Both subjects were arranged to have three times of training sessions for each game.

2) Setting and the system

Gaming system consisted of a gaming PC with the Windows 10 operating system, and graphics processor GTX 1060 VR Ready, a 24 inch curved LCD Monitor for displaying game result while subjects were playing, and a Leap Motion device. In order to prepare the system, teachers or parents should help the children and the use of the system should be accompanied by them.

III. RESULTS AND DISCUSSIONS

A. Game for Subject Focus

Result for this game is shown on Fig. 6. Based on the results obtained in Fig. 6, Subject I had better motor skills than Subject II but had the characteristic of hating noise because of difficulties in concentrating, obtained more correct results when compared to Subject II.

From the graph in Fig. 6 it shows that Subject I had successfully placed the ball in the first 50 seconds, which means, with better motor skills, the subject could adapt faster than Subject II. For Subject II, she started making a score in 125s and above but with the number of balls placed nearly the same with Subject I.

Overall, Subject I could put the ball correctly as many as six balls, while Subject II was managed to put five balls correctly. In [2] it was explained that motor skills would influence the subject's academic abilities at school.

From the results obtained, Subject II who had a motor impairment but has a better focus, needed more time to be able to adapt to the game. Subject I who had better motor skills, from time to time could add the number of balls that were accurately put into the correct place, but for the same number of balls as Subject II, Subject I required more time.

Overall, the accuracy of both subjects were increased gradually. On the first training session Subject I had 88.8% rate of accuracy then 100% for the next training session and 100% for the final training session. The accuracy of Subject II was 77.7% for the first training session, then 88.8% for the second training session, and 100% for the last training session.

B. Focus with Distraction

Result for this game is shown on Fig. 7. Fig. 7 illustrates that Subject I who had better motor skills could only concentrate at the beginning of time. For the rest of time, the subject did not score a new score because he was paying attention to the moving fish around him. Meanwhile, Subject II, despite the motor impairment, but from time to time the subject's score was increasing. At the end of the game the subject had the ability to focus on completing the game with more correct placement scores than Subject I. From the results on Figure 7, it could be known that Subject II required time to adapt to the game longer than Subject I. Subject I could immediately adapt with the Leap Motion but his focus was lost easily. Even though the difficulties of this game was already reduced by placing the immovable fish close to the correct boxes. Therefore, in designing game for children with autism, we should reduce the distraction as much as possible.

Generally, the accuracy of both subjects increased. Subject I's accuracy on the first training session was 50%, then increased to 83.33% on the second training and on final training session he had 100% rate of accuracy. Subject II who had better focus than Subject I, had 83.33% rate on the first training, then 100% for the second and the third training session.

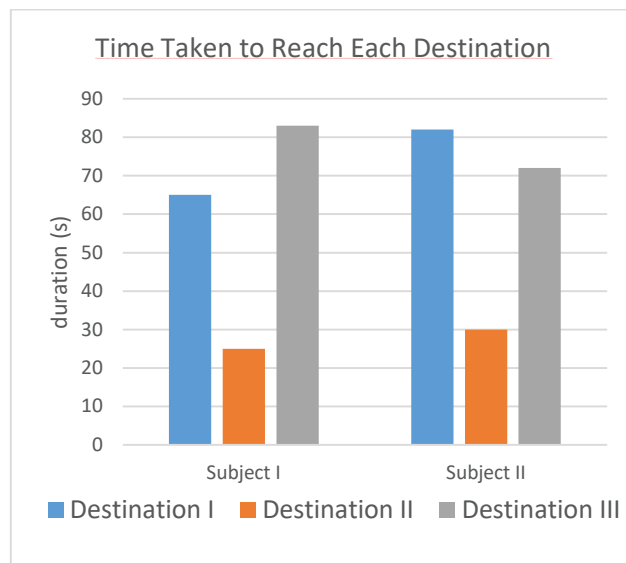


Figure 8. Rules and Signs Game Result

TABLE I. RESULT OF EYE GAZING GAME

		Gazing Direction	Answer
Subject	I	Right	True
		Left	True
		In front of virtual character	True
		Player	False
	II	Right	True
		Left	True
		In front of virtual character	True
		Player	False

C. Rules and Signs

Parameter that was measured from the subject when using this game was the time taken for the subject to arrive at each destination. Based on the result in Fig. 8, subject with motor impairment took longer time to reach Destination I and Destination II. But for Destination III, Subject II required a shorter time than Subject I.

Based on its location, Destination I and Destination II were easier to find. But for Destination III, it was located close to Destination II but the subject must go through a more circling route. Subject II, despite having a motor impairment, reached Destination III faster than Subject I. Subject I reached each destination faster than Subject II but when Subject I had to go through a circling route to find Destination III, the subject felt confused. Therefore, in designing game for children with autism, we should not make confusing route to reduce difficulties of using and to reduce stress for the subjects.

Overall, the time required for Subject I and Subject II to reach each destination decreased. The drop of time indicated that subjects were more proficient in using the game and they were better at interpreting the arrows given. To reach Destination I, Subject I took 82 seconds, 80 seconds, and 78 seconds respectively. While for Destination II, he took 30 seconds, 28 seconds, and 25 seconds respectively. For Destination III, Subject I took 72 seconds for the first training and second training session then 70 seconds for the third training session. Subject II reached Destination I for 65 seconds, 63 seconds, and 60 seconds respectively. The durations to reach Destination II were slightly increased from 25 seconds on the first and second training session then 26 seconds on the last training. In contrast, durations to reach Destination III for Subject II were decreased. On the first training session she took 83 seconds, then 80 seconds and 78 seconds.

D. Eye Gazing

During the experiment, there were several directions that were seen by the virtual character in the game that showed what the virtual character wanted. The directions were left, right, toward the top, and toward the player. With this game, children with autism could practice to interpret the eye gazing from their interlocutors. Therefore, they could learn to understand their partner of conversation as one of the social skills they should learned.

In Table I, Subject I and Subject II had the right number of answers and the same number of incorrect answers. Both

of them had answers that were interchanged between looking down (avocado bottles) and towards the player. The direction of looking at the player was intentionally made so the subject more concerned about where the virtual eyes of the character actually looked.

In this game, the Camera was the Player. The location between the avocado bottle and the camera was in line. So, the subject felt confused about where the virtual eyes were gazing. Therefore, the position and distance of our objects must be set correctly so the subjects could interpret the gazing directions clearer.

IV. CONCLUSION

We designed a multipurpose game for children with autism spectrum disorder. Participants in this study were engaged with the game environment. An interesting game environment attracted the attention of autistic children so they could practice through the game that has been developed. The use of Leap Motion as a means of rehabilitation required practice first before using to reduce difficulties of using for the participants.

For testing games that will be used for autistic children, it turned out that subjects who had difficulties to focus, were adapting to Leap Motion-based games quicker but had lower focus when compared to subjects who had motor impairments. Over the three training sessions, the accuracy of subjects increased by 11.16%.

Subjects who faced difficulties in focusing on objects, if they were situated in an attractive environment and full of distractions, they would lose their focus faster. But by using this game design, subjects could increase their accuracy by 16.6%.

Rules and Signs game design was able to educate subjects about arrows. Since they could reach each destination more accurately 2 seconds faster on each training session by following the arrows.

In the future, games can be developed using story line. Because, story line can be a way for the children to be more interested in participating in each process of the game.

We found in this study, the accuracy of both subjects were 75% and they were wrong for virtual character's gaze direction at Player. This was because the location of the object and player were positioned in line. For future development of Eye Gazing game, it can be made a proper distance between objects and it will be better if objects for Eye Gazing Game are positioned floating in a circle arrangement above virtual character's head, so the subjects will not be stressed to determine where the virtual character looks at.

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