Supporting autism therapy through Immersive Virtual Reality Game

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Abstract. *Children suffering from autism face many challenges. The logistics required to treat their disorders is costly and it can be difficult for families to access them. Whereas games and virtual reality systems have been widely used in therapy to propose affordable and effective treatments for different type of disorders, only few of them addressed the particularities of autistic disorders. In this work, we propose the design for a virtual reality game that aims to provide a relaxation experience for children with autism. After reviewing the current state of the art and understanding the challenges underlying the conception of such a system, we detail a conceptual architecture, highlighting the key components supporting autism therapy while promoting an engaging experience, how it was implemented and our plan for evaluating it.*

Keywords: Autism, Immersive Virtual Reality, Game, Relaxation Effects

1 Introduction

Modern virtual reality systems like HTC-VIVE or Oculus Rift lack research on its effects on children with autism spectrum disorders. Recent work like [7] studied the acceptance of the virtual reality equipment. However there is still much more explore like the relaxing effects of such a system.

Children diagnosed with autism spectrum disorders(ASD) manifests problems in areas of language and communication, social skills, play skills, praxis (i.e motor planning), cognitive abilities, attention, difficulties in the process of sensory input and stereotypic behaviour (i.e repetitive behaviours) [4]. Besides some of them present a deficit on their capability shared attention or on being able to relax or calm down.

For these reasons we built a game in virtual reality with relaxing elements to study how it can help these children. The game consists on a simple sequence of mini-games that reward the player on completion with relaxing events. The interaction tries to be as simple as possible only requiring the eye gaze. This way we expect to allow for a wider range of the autistic population to be able to play the game. Besides we aim to build this game as an auxiliary tool for therapists or others that work with individuals with ASD.

2 Autism Spectrum Disorder

Since the discovery of Autism in 1943 [11], the number of diagnosed children around the world has been constantly increasing [4]. Even if recent studies suggest that this increase could be influenced by a change in reporting methods [6], the medical community still estimates the number of people suffering from autism disorder at 1% of the world population [3].

ASD includes five different disorders of development according to [2]. These are Autistic Disorder, Asperger's Syndrome, Rett's Syndrome, Childhood Disintegrative Disorder and Pervasive Development Disorder-Not Otherwise Specified, [2]. Many of these children suffer from difficulties adapting to new environments or abrupt changes on current environments. They have a high sensibility to stimuli like sounds, smells and visuals. For these reason many aren't able to relax on some situations.

Finding treatments for autism is a challenging task as there are many different types of disorders. This led researchers to investigate how to address them individually and to propose adapted therapies for each one of them. For instance, throughout their work, Case-Smith and Miller, [4], highlighted the importance of occupational therapy approaches in improving a child's ability to regulate his sensory defensiveness in order to accept more easily new surroundings.

In [5], the authors evaluated the amount of different therapies used on children suffering with ASD and they reported that families can use an average of seven different interventions simultaneously on a child. They also report that a family tried in average eight different therapies and that parents of younger children or with mild/moderate ASD tend to use even more treatments [5]. The different therapies used by families and identified by the authors are the following: Applied Behaviour Analysis(ABA), Early Intervention Services, Floor Time, Music Therapy, Occupational Therapy, Picture Exchange System, Physical Therapy, Sensorial Integration and the Structured TEACCHing program.

ABA is used to explain how learning happens. For instance, positive reinforcement is used to reward good behaviours and reduce the occurrence of maladaptive behaviours. It aims to teach new skills while generalizing good behaviours to new environments. Furthermore another technique used is the use a special room called the Snoezelen Room. This room was first developed in the Netherlands and was designed to offer relaxing activities in a controlled therapeutic environment aimed to stimulate the senses with the use of lights, sounds, touches, smells and tastes [1]. These rooms are usually equipped with a variety of stimuli like for instance aromas, ball pools, bubble tubes, mirrors, optical fibers, projections or music. These stimuli can be used individually or altogether. Within such a room, the children are encouraged to freely explore and interact with the different stimuli. Whereas these rooms are very popular in autism treatments, they are very expensive and can cost more than 20 000 Euro. The price is such a barrier that some of them aren't even fully equipped.

3 Virtual Reality

As virtual reality(VR) is a powerful medium to simulate an environment, the feeling provided by a VR system is usually described by two dimensions: immersion and presence. Immersion is the capability the computer display has to deliver an inclusive, extensive, vivid and surrounding illusion of reality [9]. In other words, it encompasses the ability to shut down reality (to some extent, with a varying range of sensory stimuli), and at the same time the ability to match the proprioceptive feedback about the body movements while generating a correspondent information on screen. Immersion is also increased when the application is able to give a feeling of having a virtual body, usually achieve by a virtual representation of the user in the VR.

This sense of having a virtual body is the initial requirement for describing the feeling of Presence. Presence is described in [9] as "... the state of consciousness, the (psychological) sense of being in the virtual environment.". More precisely, it corresponds for the users to believe that they share the same reality as the virtual environment. The importance of these aspects have been stressed by researchers [9] as they insist that the similarities between the real world and the virtual world are the main factors on which psycho-therapies, with the use of an immersive virtual environment, relies on.

VR also presents problems. The most notorious problems are motion sickness and locomotion.

1. **Motion Sickness**.
   The motion sickness problem comes from the vestibular system. Basically it includes three semicircular canals lined with the hair cells. These canals have a fluid that moves according to our movements. One canal is responsible for detecting the vertical movement while the other the horizontal movement. Therefore this system allows to detect up, down, side to side and the degree of tilt and acceleration. This system works parallel to the visual system. The motion sickness happens where there is a lack of correspondence between our movements and what we see on the Head-mounted display.
2. **Locomotion**.
   Most VR application rely on teleport to move around an environment. This movement is simply done with the controllers, or gaze, by pointing to a place. The controllers are fairly simple to use but can grow complex if there are an enormous of interactions the player can do. This is one of the reasons that led us to find alternatives to the use of controllers to interact with the environment.

4 Related Work

Regarding VR system like ours, only for the past two decades, few works have been done to study the effects of using an immersive virtual environment on children with ASD.

1. **Virtual Reality acceptance and skill learning generalization**
   One of the pioneer works was made by Dorothy Strickland in 1996 and 1997 [10]. Her study aimed to determine if children with ASD would tolerate VR equipment and respond to the computer-generated world in a meaningful way. Two children, a nine year old boy and a seven year old girl diagnosed as autistic were asked to fulfil two tasks: during the first they had to recognize and track a moving car in a street scene and during the second task, they were trained to find an object in the scene, walk towards it, and stop. Both children had difficulties in understanding and expressing fully normal sentences therefore short and simple instructions were used. Responses from the children were based on previously known words or by playing out the requested action, like turning their heads to find a car.
   The results were very positive. The girl accepted to wear the helmet and was able to immerse in the virtual environment immediately. The boy required three sessions to accept the headset and respond to this new environment. Both children were able to identify the cars, their respective colors, and track them in the scene with their eyes, head and by turning their body. Both children were capable of verbally labeling the objects, colors and moving cars. For the second phase a STOP sign was placed in different areas of the sidewalk. Both children were able to turn and find the STOP sign and move towards it. One child not only moved towards it but also stopped moving when reached it, which was the exercise objective.
   In a more recent study [7], the authors investigated the willingness, acceptance, sense of presence and immersion of individuals with ASD. The research was divided into two phases, with 29 participants from 17 to 53 years old on the first phase and 11 participants ranging from 19 to 43 years old in the second phase. All of them were diagnosed with ASD, more precisely Autism Disorder, Asperger Syndrome and Pervasive Development Disorder-Not Otherwise Specified. The hardware used consisted of *Oculus Rift*, headphones, Xbox 360 controllers and a laptop computer.
   In summary, participants were willing to use the headset and explore and immerse themselves in the virtual world. This result is similar to the one from Strickland [10] and would support the idea that Virtual Reality can be used to generalized concepts learned within the virtual world to the real world [10, 7].
2. ***Autcraft*: social community for individuals with ASD**
   Although not being about VR, the research made by the authors of [8] is very inspirational for our work. The authors studied a private community server of the game *Minecraft*, called *Autcraft*, designed for individuals with ASD.
   They first observed how the players were able to regulate themselves, i.e how they were able to react to the changes that the environment presents regularly. On *Autcraft*, the players found creative ways to do it. The players dig holes on the ground and put a pile of dirt (i.e a block) above their heads, in order for the screen to turn completely dark. As mentioned by the authors, one of the most interesting behaviours exhibited by the players here is that

they opted to stay in the virtual world when they could have just turned off the monitor.
Another interesting finding was related with multi-sensory environments(MSE), like the Snoezelen Room. *Autcraft* server created designed spaces that mimic the MSE but limited to the visual and sound stimuli. It was observed, by reading the on-line forum of the *Autcraft* server, that the users enjoy this spaces and use them as ways to calm down from bad memories and they wish they could visit in real life. Players can teleport at any time to this rooms and regulate themselves almost instantly which is a tremendous advantage because these type of rooms aren't available physically at any time. Regarding mood regulation, there are also reported cases of players using mini games in the *Autcraft* server where they can attack monsters and posteriorly they would forget how sad or upset they were.
The findings of this work are very important for ours. Firstly, they showed how the players with ASD took a sensory break by digging a hole on the ground. It shows that virtual environment may not represent a problem to children with ASD. Furthermore, the adaptation in-game to solve a real problem, may also prove how immersive and helpful these environments can be. This can be easily implemented within the system and may be one helpful technique to deal with the acceptance of both the immersive VR world and the headset.
Secondly, it is very interesting to find that the community have built, with the tools available, a virtual MSE. Not only it has been shown to have positive effects but is also something that they desire to have in real life [8]. This motivates the implementation of a simulated Snoezelen room in our work.
Finally, players seem to regulate themselves, regarding mood regulation, with the use of mini games. This is also an aspect that can be explored within in our system.

5 Architecture

On this section we present the evolution of our game and the choices and changes we made along the past months. We also talk about the chooses VR headset for this thesis.

5.1 Virtual reality hardware

In order to choose what VR headset we could use, we defined the following requirements: the price, the comfort (i.e weight) and the features (i.e resolution, refresh rate, field of view, tracking area, display and the requirements).

The best options would be both Oculus Rift or HTC VIVE. Both offer enough characteristics to allow us to explore more vast and complex environments. This way we can have more liberty to study more detailed relaxing events. Both offer an immersive virtual experience as we intend to. Furthermore developing for

HTC Vive, in our case, is the same as developing for *Oculus Rift* and so the final solution may be used on both HMD. However we opted to choose the *HTC VIVE* mainly due to the possibility of having a better spatial movement than the *Oculus Rift*. For these reason we expect the *HTC VIVE* to deliver a more fidelity experience on our system. With this spatial movement we are able to define an area where the player can physically move around and explore the virtual world.

5.2 Game evolution

The first version of our game consisted on a simple room with various elements. Most of the elements of a real Snoezelen Room, e.g projection, fiber optics, bubble tubes, can be recreated on the virtual world and offer an experience close to reality with even more liberty and at no cost. The approach we took was to recreate the elements as they are in reality. However some elements were creatively created without reassembling anything that may exist. Nonetheless their purpose was the same as the others, to offer a relaxing effect.

Through meetings with medical personnel of clinic Passo a Passo and testings with two children, L and G we began to modify the various versions. Further details on these children will be given in later sections.

The second version took inspiration from a tablet game shown at the clinic. This game consisted on drawing a line with a posterior sparkle effect going through the line. Since the background of the game was a sky with stars we decided to recreate a space scenario. On this scenario the player couldn't teletransport as he could on the previous described version. He stood on the center of an icosahedron with a floor underneath. The icosahedron had a transparent material to observe the outer space, stars and the planet earth. The main interaction was to draw a line and see it sparkle as it transformed into a figure, just like the tablet version. It was possible to draw infinitely but only one line each time. The player had to wait and see the effect until the end. We created again a few spotlight with different colors and intensities. The spotlights moved slowly in every directions around the icosahedron.

For the third version we used the same environment but added a We added a simple bouncy ball that could be grabbed and thrown away. The line drawing was improved defining a maximum limit of the line size and the ability to have more then one line each time. On the room we also added a mini-game. The game consisted twelve cubes with different colors would appear all over the icosahedron. The objective was by order of color, to find and look at the cubes. This would allow to train cognitive movements with the head and concentration when making color associations.

This time we also added a second room. The main idea was to separate the relaxing experience from the challenge experience. The second room reassembled a real room with glass walls to see the outer space. On this room the form of interaction was through the eye gaze. We though that not having to worry about the controllers and only using the vision would make it a more relaxing experience. This mean that the player had to look, for a few seconds, to an object to trigger its interaction. After activating it the object would deactivate automatically after a period of time.

These objects consisted on different cubes with different colours on each of the corners of the room. The player stood on the middle of the room. Each cube would activate a particle system and a sound. The different relaxing sounds consisted on rain, river, birds and rainforest sounds. All the sounds played at the same time mixed really well and were aimed to give a relaxing experience.

With all the iterations and feedback we concluded that the best course of actions was to focus on simple interactions (e.g using eye gaze) and removing the use of the controllers. Further we found a special interest and calming effect during the mini-game with all the children who participated in the early testing.

5.3 Final game

The final version consisted again on an uniform white room with two opaque windows. There were no controllers and all the interaction was done through eye gaze. The room had different spheres to trigger simple tangram puzzle games. They consisted on pieces all over the room to be interacted with. All together would form a figure of the ocean like a fish or whale. After completing this mini-game the player was rewarded with the possibility to look outside of one of the room windows and see the ocean. It consisted on whales and fishes swimming and also of different plants. With this we were applying basic principles of ABA rewarding the player with the conclusion of the mini-game. Next the player was able to observe a sequence of the death and creation of a star. The room would turn black through the rest of the interaction. After ending the relaxing sequence the other window would unlock and allow to observe the outer space with stars and the planet earth.

5.4 Evaluation

To study the evolution of the state of the children with ASD we had three methodologies. By observation, questionnaires and data collection.

1. **Observation**
   We did eye observation and video record to evaluate not only the children reactions but also his comments during the testing. Further we wad the help of occupational therapist Patrícia Caeiro from clinic Passo a Passo. It was important not only her professional knowledge but also her knowledge of the children personality. For this reason she could tell if the children were indeed relaxing or not. Regarding the video record we made a formal consent for the parents of the children to sign.
2. **Questionnaires**
   We made two types of questionnaires. One for the parents to fill the children's profile. Our objective was not only to get a general child profile like the age and type of ASD but also a more specific profile regarding interests and knowledge related to the game environment.

The other questionnaire was made for the therapist. It aimed to conclusions from the game. We asked about the humor state (e.g anxiety, relaxed, curious, frighten, sad, happy) of the child before, during and after finishing the game. With this information we can study the evolution of the child state during all the process. Further we ask if the VR material (i.e headset, phones, sensors) affected negatively the child and if they had any difficulty during the game. Nest we ask in a general way about the relaxing state of the child during the whole interaction and in a more specific way (i.e during the introduction of the room, ocean part, space part). Finally we leave space for the therapist to fill with observations regarding the child reaction or comments they did.

3. **Data Collection**
   Our last measure was to collect information on the child movement velocity and his eye/head angular velocity. This information was saved and processed by the application during it's runtime. With this data we can establish a relation between the different phases of the application and how calm (i.e in terms of motion) the child was.

6 Results

We present now the results for all the three participants.

6.1 Child L

Child L is 10 years old and has moderate autism. The child didn't communicate.

He was very agitated at the beginning as he was on the early version presented before. He accepted to use the VR headset but wasn't very relaxed and kept moving around. We had to keep telling him what to do although. We told him to search for a sphere to start the interaction. Remarkably when he saw all the tangram pieces on the room he was able to understand what to do and stood calm and still while doing so. After finishing both tangrams we told him to look at the blue sphere near the Ocean view which he did. He also remained calm. Next we told him to go to the initial green sphere. He was able to do it and activated the space relaxing sequence. During all the sequence and the observation of the Earth at the end of the sequence he remained calm. However at the end when there was nothing else to do he was very agitated again as on the beginning.

6.2 Child M

Child M, with 11 years old, suffered from a severe autism. The child didn't communicate and had stereotypic behaviors.

The first challenge was to put the headset on the child. The child was the whole time sitting on a chair. With his parent help he accepted but tried several times to remove it. The headphones were also a problem to use but we managed to mount everything. Nonetheless he clearly was disturbed with all the setup and tried constantly to remove the headset and headphones. His father had to hold his hand during the whole process. Unfortunately the child kept bouncing his head up and down and wasn't interacting with the game. We decided to force, through the game programming engine (Unity), the occurrence of events. We made the fish puzzle appear with all the pieces on the room but the child couldn't keep his focus. Next we forced for the pieces to go to the correct position. Curiously he started following the pieces movements but only for a brief moment. After the completion of the puzzle we had to stop the interaction because the child couldn't relax and was trying to remove the headset.

6.3 Child G

Child G with 10 years old suffers from Asperger's Syndrome. He was able to give us verbal feedback.

The child was always eager to try the VR headset and without any hesitation we started the interaction with everything setup. Even though he hadn't issues with the VR headset, sometimes the headphones fell down. Nonetheless the child didn't had difficulties during the interaction. The child offered a lot of feedback. He made comments like "...look its a tangram!", "The music is relaxing...". So for this reason he was able to understand the game and was capable of figuring out what the different teleportation spheres were for. He found the scenarios relaxing most specially during the space scene. He also liked the visual aspect commenting it was pretty. However and as confirmed on the conclusions questionnaire by the therapist he was only more relaxed during the tangram construction. When he as to focus on something he can remain calm and quiet. When he doesn't have anything new to explore or do he starts to question a lot and isn't so relaxed. Further he pointed out he was confused for not having virtual hands. As we removed the controllers we also removed the virtual hands representation. Without it he has no body reference to organize himself and may loose his focus or relaxing effect due to it.

Nonetheless he showed signs of being relaxed although momentarily. Being a curious child he needs a lot of stimuli to interact and try different things otherwise he will loose his focus and starts questioning about the possibilities. In the end he was curious to see the Unity engine and learn how to make room which we taught him and he quickly learned how to use the program and create a simple cube.

7 Conclusions

Unfortunately we only had a small population to study the effects. As we stated before in this type of population, the individuals are unique which leads to a difficulty in the generalization of a game for them. Nonetheless we conducted two studies on the effects of our game.

Child M had a really negative impact mostly due to the lack of tolerance to the VR headset. The study had to be interrupted which leaves us with few data to analyse.

Child L was an interesting case that proved that the interaction has relaxing effects. He was able to calm down specially during the mini-game as he did on the early version. He accepted the VR equipment and didn't had difficulties besides understanding what to do in the game. As child G he was able to relax momentarily.

Child G which participated in all the studies we did before the final one, reacted positively. He accepted all the VR equipment as he did before and didn't had difficulties in understanding or accepting the game. He could relax during the puzzle interactions or the space sequence. However when the interaction was in the end he wasn't calm, on the contrary we was very curious and wanted to know more about the VR possibilities. So we can conclude that partially it impacted positively the child but not in a long term.

Due to the heterogeneity of ASD population it is difficult for a game/interaction to be adequate to everyone. So it's important to take in consideration the individual needs of each participant and develop accordingly. Nonetheless we can conclude that there is indeed indications of a VR game relaxing children with ASD however limited to the occurrence of the interaction and without showing posteriori effects. We believe that the novelty factor may have influenced their pre-interactions and pos-interaction behavior. With a more frequent and continuous study there it may be possible to observe relaxing effects after the interaction and not only during it.

In conclusion the whole interaction as to be more dynamic. This mean that it should accept every type of interaction (i.e with or without controllers or by eye gaze). This way we can approach a wider population. The game should also have multiple environments and separate the mini-games from this environments. A room should only be made to relax or to interact not both. We propose to develop an unlock system as a reward for completing the mini-games. Further the mini-games should promote the development of skills that the child needs. For example it may promote eye gaze, social skills or other cognitives needs.

Additionally the use of VR on a study may be complex due to the necessity of having a capable computer and everything that needs to be mounted for it to work. So we propose to use standalone version of VR to be released soon or simpler ones like the Samsung. However simpler versions will delimit what can be done in terms of complexity.

On a final note we also propose for future studies to have a wider population and test for longer period of times. The tests should be done on a daily basis with different iterations taking in consideration the needs of the population.

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