Supporting autism therapy through an 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 and how it was implemented and our plan for evaluating it.

Our game consists on a relaxing room where the player will gradually unlock different environments by interacting with different objects. All the interaction is made with eye gaze. First a mini-game with two tangrams is unlocked. By completing them the player is able to visualize an Ocean environment. Next the player can observe a sequence of the creation and death of a star and in the end it is possible to see the outer space with the planet Earth. With the game we pretend to study not only the child reaction to Virtual Reality (VR) but mostly what effects it may have relaxing them.

We conducted a study with three children with Autism Spectrum Disorders (ASD) to study the effects of the interaction. In order to analyze their evolution of their relaxing state we collected data, observations and questionnaires from the therapists and parents. The results are promising regarding temporary relaxation linked to the mini-games and some observations. However in a long term the effects are few or even none. Nonetheless we will discuss details on what can be improved and studied to offer a better
experience on future works.

Keywords

Autism; Immersive Virtual Reality; Game; Relaxation Effects;
Resumo

As crianças com autismo enfrentam imensos desafios. A logística necessária para tratar os seus problemas é cara e de difícil acesso às suas famílias. Enquanto que muitos jogos e sistemas virtuais têm sido vastamente utilizados em diferentes tipos de doenças, apenas alguns são dirigidos às particularidades do autismo. Neste trabalho, propomos a concepção de um jogo em realidade virtual que tem como objectivo fornecer uma experiência de relaxamento a crianças com autismo. Após revermos o actual estado da arte e entendermos os desafios subjacentes à concepção de tal sistema, detalhamos a arquitetura, destacando os principais componentes que apoiam as terapias para autismo promovendo uma experiência envolvente, como foi implementado e qual o nosso plano para avaliá-lo.

O jogo consiste numa sala de relaxamento onde, gradualmente, o jogador irá desbloquear ambientes diferentes interagindo com variados objectos. Todas as interacções são feitas com o olhar. Primeiro desbloqueia-se um mini-jogo com dois tangrans. Ao completá-los o jogador pode visualizar o ambiente do Oceano. Depois o jogador pode observar uma sequência da criação e morte de uma estrela e no fim é possível ver o espaço com o planeta Terra. Com o jogo pretendemos não só estudar a reacção da criança à realidade virtual mas principalmente que efeitos relaxantes poderão sentir.

Foi feito um estudo com três crianças com perturbações do espectro do autismo para estudar os efeitos da interacção. De forma a analisar a evolução do estado de relaxamento coleccionámos dados, observações e questionários dos terapeutas e pais. Os resultados são promissores no que toca a um relaxamento temporário durante os mini-jogos e algumas observações. Contudo a longo prazo os efeitos são poucos ou mesmo nenhuns. De qualquer forma iremos discutir detalhes no que poderá ser
melhorado e estudado para oferecer uma melhor experiência em futuros trabalhos.

**Palavras Chave**

Autismo; Realidade Virtual Imersiva; Jogo; Efeitos de Relaxamento;
# Contents

1 Introduction ................................................. 1  
   1.1 Motivations ............................................. 3  
   1.2 Contributions .......................................... 4  
   1.3 Document Organization ................................. 5  
2 Background ................................................. 7  
   2.1 Autism .................................................. 9  
   2.2 Virtual Reality ......................................... 12  
      2.2.1 Virtual Reality Problems .......................... 13  
         2.2.1.A Motion Sickness ............................... 14  
         2.2.1.B Locomotion .................................... 14  
         2.2.1.C Visual detail and scale ...................... 14  
         2.2.1.D Head-mounted display ....................... 15  
   2.3 Games and therapies .................................. 15  
   2.4 Virtual Reality games ................................. 19  
      2.4.1 Virtual Reality acceptance and skill learning generalization .......................... 19  
      2.4.2 Autcraft: social community for individuals with ASD ............................... 22  
      2.4.3 Discussion / Summary ............................. 23  
3 Architecture ................................................. 25  
   3.1 Choosing the Virtual Reality Hardware ............... 27  
      3.1.1 HTC Components .................................... 29  
   3.2 Game engine and library ................................ 31  
   3.3 System Architecture .................................... 32  
4 Implementation .............................................. 35  
   4.1 Pre-study ............................................... 37  
   4.2 First version .......................................... 39  
      4.2.1 Implementation .................................... 39  
      4.2.2 Testing ............................................ 42
# List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>A Snoezelen room.</td>
<td>11</td>
</tr>
<tr>
<td>2.2</td>
<td>Children interacting with the ECHOES system.</td>
<td>16</td>
</tr>
<tr>
<td>2.3</td>
<td>Virtual coffee shop.</td>
<td>18</td>
</tr>
<tr>
<td>3.1</td>
<td>Comparison of the VR-HMD.</td>
<td>27</td>
</tr>
<tr>
<td>3.2</td>
<td>HTC Vive controllers.</td>
<td>28</td>
</tr>
<tr>
<td>3.3</td>
<td>Oculus controllers.</td>
<td>29</td>
</tr>
<tr>
<td>3.4</td>
<td>HTC Vive HMD.</td>
<td>30</td>
</tr>
<tr>
<td>3.5</td>
<td>HTC Vive sensors.</td>
<td>30</td>
</tr>
<tr>
<td>3.6</td>
<td>Room setup.</td>
<td>31</td>
</tr>
<tr>
<td>3.7</td>
<td>Room grid.</td>
<td>32</td>
</tr>
<tr>
<td>3.8</td>
<td>Block diagram of our system architecture.</td>
<td>33</td>
</tr>
<tr>
<td>4.1</td>
<td>Example of a green light on the ceiling.</td>
<td>40</td>
</tr>
<tr>
<td>4.2</td>
<td>Interactive objects the child could use.</td>
<td>40</td>
</tr>
<tr>
<td>4.3</td>
<td>Bubble tubes, optical fibers and “stars”.</td>
<td>41</td>
</tr>
<tr>
<td>4.4</td>
<td>The second room.</td>
<td>42</td>
</tr>
<tr>
<td>4.5</td>
<td>Top down view of the whole virtual Snoezelen room.</td>
<td>43</td>
</tr>
<tr>
<td>4.6</td>
<td>The icosahedron room with the therapist interface.</td>
<td>45</td>
</tr>
<tr>
<td>4.7</td>
<td>Line drawing with the trail effect.</td>
<td>46</td>
</tr>
<tr>
<td>4.8</td>
<td>Interface when choosing the hand mode.</td>
<td>47</td>
</tr>
<tr>
<td>4.9</td>
<td>Icosahedron room, now with the green ball.</td>
<td>47</td>
</tr>
<tr>
<td>4.10</td>
<td>New therapist interface for the interaction room.</td>
<td>48</td>
</tr>
<tr>
<td>4.11</td>
<td>The feedback on the player headset when activating an object.</td>
<td>49</td>
</tr>
<tr>
<td>4.12</td>
<td>Cubes of the mini-game.</td>
<td>50</td>
</tr>
<tr>
<td>4.13</td>
<td>New therapist interface for the relaxation room.</td>
<td>50</td>
</tr>
<tr>
<td>4.14</td>
<td>All the cubes on the corners activated, after a while they would stop.</td>
<td>51</td>
</tr>
</tbody>
</table>
4.15 The interface feedback on the player headset. On this example the player is activating one of the tangram pieces. ................................................................. 53
4.16 The final room, the behind the red window is the space and the blue is the ocean. ... 54
4.17 Pieces appear through the room. ............................................................ 55
4.18 Completed fish tangram. ......................................................................... 55
4.19 Completed whale tangram. ....................................................................... 56
4.20 The blue sphere will allow the player to go near the window and observe the Ocean. 56
4.21 Ocean environment. ................................................................................ 57
4.22 White sphere will trigger the Space Relax Sequence. .................................. 57
4.23 Star explosion. ......................................................................................... 58
4.24 Star trail, moving through the room. ............................................................ 59
4.25 Star creation, moving through the room. ...................................................... 60
4.26 The red sphere will allow the player to go near the window and observe the Space. 60
4.27 The Space environment with planet Earth. ............................................... 61

5.1 Child M positional velocity change along the interaction. ......................... 68
5.2 Child M angular velocity change along the interaction. .............................. 68
5.3 Child G positional velocity change along the interaction. ............................ 70
5.4 Child G angular velocity change along the interaction. ............................... 70

B.1 Consent Form. ........................................................................................... 82
B.2 Child profile 1. ......................................................................................... 83
B.3 Child profile 2. ......................................................................................... 84
B.4 Conclusions 1. .......................................................................................... 85
B.5 Conclusions 2. .......................................................................................... 86
B.6 Conclusions 3. .......................................................................................... 87
### Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD</td>
<td>Autism Spectrum Disorders</td>
</tr>
<tr>
<td>VR</td>
<td>Virtual Reality</td>
</tr>
<tr>
<td>HMD</td>
<td>Head-Mounted Display</td>
</tr>
<tr>
<td>AD</td>
<td>Autistic Disorder</td>
</tr>
<tr>
<td>AS</td>
<td>Asperger's Syndrome</td>
</tr>
<tr>
<td>RS</td>
<td>Rett's Syndrome</td>
</tr>
<tr>
<td>CDD</td>
<td>Childhood Disintegrative Disorder</td>
</tr>
<tr>
<td>PDD-NOS</td>
<td>Pervasive Development Disorder-Not Otherwise Specified</td>
</tr>
<tr>
<td>ABA</td>
<td>Applied Behaviour Analysis</td>
</tr>
<tr>
<td>SI</td>
<td>Sensory Integration</td>
</tr>
<tr>
<td><strong>Structured TEACCHing</strong></td>
<td>Speech Therapy and Treatment and Education of Autistic and related Communication handicapped Children</td>
</tr>
<tr>
<td>ADL</td>
<td>Activities of Daily Living</td>
</tr>
<tr>
<td>VR-HMD</td>
<td>Virtual Reality Head-Mounted Display</td>
</tr>
<tr>
<td>VRT</td>
<td>Virtual Reality Therapy</td>
</tr>
<tr>
<td>MSE</td>
<td>Multi-Sensory Environments</td>
</tr>
</tbody>
</table>
Introduction

Contents

1.1 Motivations ................................................................. 3
1.2 Contributions ............................................................. 4
1.3 Document Organization .................................................. 5
Technology is constantly present in our lives. The fast growth and the impact it has in our quotidiant is remarkable. Most importantly it has allowed to help and change the lives of many people. One fundamental area of its applications are on individuals with ASD. Such individuals suffer from a variety of social, communication, behavioral and cognitional problems.

Some of the technology created to aid these individuals consists on educational games. However technology is constantly changing and evolving, offering unique opportunities to study different applications. A fundamental area is VR which allows to explore a multi-range of possibilities. A game created in VR can be completely unique from what has been made so far. Most importantly it has changed they way the user interacts in virtual worlds. For this reason VR may offer unique experiences to these individuals.

1.1 Motivations

Nowadays individuals with ASD represent around 1% of the world population [1]. Part of those 1% are children diagnosed at a very early age. One particular challenge they are facing is the difficulty to adapt to new environments and contexts as they usually require new stimuli to be gradually introduced in order to avoid rejection.

Various methods and techniques have been investigated by health care specialists to address the different difficulties children with ASD encounter. However, these specialists still struggle to find common methods or techniques that can have a positive impact on such a wide group and they usually rely on specific treatments for specific conditions. This is mainly due to the fact that autism is a wide spectrum with different needs and problems. This tends to augment the cost of treatments for families as they need to have access to specialists with particular equipment to address the needs of their own child.

One solution that we investigated is to build the therapeutic environment needed to treat autism using a VR system. These systems are now becoming more affordable and they allow for customization and re-usability of the learning environment at a reduced cost. In other words, while offering a safe-environment (i.e in comparison with a real world environment where the amount of stimuli aren't controlled) that can simulate real-life situations, such a virtual world offers the possibility to be modified and adapted to each user’s needs. While desktop environments also offer this possibility, VR systems allow to build immersive environments that may improve the learning of new skills for children with ASD.

Additionally, these therapeutic activities could be created in a way that enhances their engaging effect. In the particular case of children suffering with ASD, their design needs to allow them to gradually become part of their daily life. Game research and Gamification techniques could be helpful to address these challenges as researchers in these fields have studied how games mechanics help create and shape highly engaging experiences, in particular in the context of learning [2]. The use of video games
for educational purposes has been studied for several years and researchers have highlighted their beneficial effects [3] and their potential to address autism [4].

Therefore, our work aims to develop a VR game that could be used as a complementary tool for therapy by simulating part of the treatment process. The game could be used by both therapists in sessions and by families at home. The system we propose does not aim at replacing the therapeutic session with the specialist but at offering a complementary activity in order to pursue (virtual) sessions at home between visits at the doctor’s facility. While we could study if such a virtual world has a positive impact on many different disorder treatments, we aim first to focus on relaxation and cognitional exercises. Consequently we will study the acceptance of the Head-Mounted Display (HMD). Although it has been extensively studied and proved that most individuals accept it, there are still contribution to be made. Most precisely contribution regarding modern VR systems. However, as these studies proved, every autistic individual is unique. This gives us a problem regarding generalizations and therefore to know what is best for these children.

Nonetheless in this work, we propose to study different approaches regarding the total or partial gamification of some therapeutic techniques. We took inspiration on a multi-sensory room called Snoezelen Room [5], opinions from medical personal and other games.

The VR game was based on techniques, methods and concepts used nowadays in therapeutic sessions for children with ASD combined with previous research about gamified learning and treatments. A review of the relevant state of the art was analyzed and discussed in order to establish the foundations of our system. However, since VR is such a new area, in particular for the general audience, very few studies have investigated the use of VR techniques on populations with ASD. We see this as an opportunity to bring new contributions to both the area of autism treatment and the emerging area of virtual reality at home. Another important and expected contribution of this work will be to study if the game-based VR therapy can have a positive effect on the children. Mainly we look forward to see if such a system like ours can relax the children.

1.2 Contributions

Regarding VR, and as we will discuss on sections ahead, still has much research to be made, specially on its effects on individuals with ASD. On this thesis our goal is to answer the question: How can a VR game relax children with ASD. To try to answer it we developed a VR game which promotes a relaxing environment to be interacted by children with ASD and We evaluated their state during the game interaction.

The game is really simple to be played using only the eye gaze interaction. Most of the game consists on visualizing relaxing events and solving simple puzzles. We aim to give another tool to therapists and
others who work with children with ASD and not to substitute any existing method used.

1.3 Document Organization

The document is organized as follows. In section 2, we first review the literature about autism and virtual reality in order to establish a framework for our work and to understand what are the requirements from a computational point of view. Most specifically, in subsection 2.4, we present related works and we explain how we build upon the previous research, by identifying the differences and similarities our approach has with the literature. In section 3, we detail the architecture of our proposed solution. In section 4, we present the different components of our application along with interaction and game designs that will support our objectives. In section 5 we also establish our evaluation and results conducted. Finally, in the section 6, we identify the challenges of this investigation, its outcomes and we discuss future work that can still be made.
This section introduces the concept of ASD, the symptoms associated with it, existing methodologies of treatment, what is VR, its problems and finally, discusses games and therapies related to our work.

2.1 Autism

Since the discovery of Autism in 1943 [6], the number of diagnosed children around the world has been constantly increasing [7]. Even if recent studies suggest that this increase could be influenced by a change in reporting methods [8], the medical community still estimates the number of people suffering from autism disorder at 1% of the world population [1].

ASD includes five different disorders of development according to [9]. These are Autistic Disorder (AD), Asperger’s Syndrome (AS), Rett’s Syndrome (RS), Childhood Disintegrative Disorder (CDD) and Pervasive Development Disorder-Not Otherwise Specified (PDD-NOS), [9]. Children diagnosed with 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 behavior (i.e repetitive behaviors) [7]. For instance, this includes disorders that can affect social gaze (i.e focus on the eyes and mouth of the person while interacting with them) or joint attention (also called shared attention) which is the ability of two individuals to share attention to the same object.

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, [7], 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 [10], 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 [10]. 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, Sensory Integration (SI) and Speech Therapy and Treatment and Education of Autistic and related Communication handicapped CHildren (Structured TEACCHing) program. On section 4.1 we will present a preliminary study justifying the most relevant therapies for this thesis.

In [11], the authors presented works applying some of these therapies and aiming at identifying how positive their outcomes are.

The ABA is used to explain how learning happens. For instance, positive reinforcement is used to reward good behaviors and reduce the occurrence of maladaptive behaviors. It aims to teach new skills
while generalizing good behaviors to new environments. The ABA methods are used to increase and maintain desirable adaptive behavior while reducing maladaptive behavior. It is a widely used method and it has been shown to have a positive impact on children with ASD from a early age [11]. The improvements include gains in IQ, language, academic performance, adaptive behavior and social behavior. Most importantly, the methods of ABA aim to improve the generalization of learned behaviors to its use in more natural environments.

The TEACCH program from the University of North Carolina gives emphasis to structure teaching. For that reason was created the Structured TEACCHing method. The topics addressed by this method include the organization of the child’s physical environment, the use of visual materials, how to develop schedules and work systems and having a predictable sequence of activities. Structured TEACCHing focuses on the individual needs, skills and interests of the person with ASD. Parents represent a key role on this method by supporting it.

The SI method, used by occupational therapists, doesn’t aim to improve the children social skills but focus instead on the child’s neurological process and sensory information treatment in order to allow them to adapt and interact more easily in new environments [11]. Nonetheless, improvements on the sensory system and the adaptation to new surroundings are expected to have a positive impact on the children social interactions. This method was created due to the dysfunctional sensory system of individuals with ASD. It focus on three basic senses, tactile, vestibular and proprioceptive.

The area of Social Stories is used to address social problems. It consists on creating a short story from the point of view of the children with ASD. It intends to teach the children on how to behave accordingly in a situation. Therefore, descriptive, perspective and directive sentences are used. Thus it is explicitly described where and when the activity will happen, what will occur, who is involved and why should the child behave in such situation. The authors of [12] describe different social stories and the positive impacts they had on disruptive behavior of children with ASD.

In Floortime therapy, therapists and parents engage children through activities they enjoy. It focus on the emotional development like emotional ideas and thinking. It also intend to promote self-regulation, interest in the world, intimacy in human relations, two-way communication and complex communication. The therapy takes place in a relaxed environment. The parents or therapists participate actively in the child’s games, being him the one who lead the game.

Regarding the Activities of Daily Living (ADL) technique, it has been developed to address the lack of autonomy some individuals with ASD may have regarding a variety of daily activities like dressing, eating or washing the hands for instance [13]. Different strategies can be used like visual stimuli (e.g. pictures, videos, text or line drawing) [14]. In [14], the authors compared the uses of pictures and videos and, although both systems were effective, video appeared to be slightly more effective and efficient. However, the authors mentioned that the addition of audio in the videos might have had an impact on the
effectiveness of the treatment. This could indicate that the use of multi-sensory inputs is more effective to stimulate and teach the children.

This is one of the strengths of the Snoezelen Room, a technique widely adopted by therapists (see fig.2.1). 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 [15]. 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.

![Figure 2.1: A Snoezelen room.](image)

The spectrum of autism is wide and so are the challenges that arises from it. The main factors we identified through the reviews of [10, 11] were that in order to maximize the positive outcome of a therapy, it has to be started at the earliest age possible and that it should try to encompass different types of stimuli. Researchers developed a great amount of techniques and therapies that may be applied to individuals with ASD and it might be challenging for families to integrate so many different and costly
techniques in their daily life. In this context, a virtual reality application could help to solve some of these difficulties. While a simulation of all the different techniques described before in VR would represent an immense amount of work to develop and is not entirely feasible given the current state of the technology, principles from these techniques and methods can still be used to inspire a VR system aimed to support children with ASD. The extensible nature of these software solutions and their reduced cost make them viable candidates to establish a new framework aimed at conducting autism therapies. For instance, positive reinforcement can be used in real life, to encourage the use of the VR head-mounted displays, but also to make rewards in the virtual game and encourage trained behaviors. Stimuli based on touch or taste could be difficult to implement but audio-visual and smell can be simulated, making it possible to partially simulate a VR Snoezelen room. Finally, ADL techniques can be simulated in a game, focusing on the objectives inherent to it. Those objectives can consist on simple goal-oriented tasks to teach the children basic daily activities.

In the following section, we present what is VR while highlighting its strengths for creating therapy simulations.

2.2 Virtual Reality

Many definitions of virtual reality can be found in the literature. In [16], the authors reported different technologies that can be classified as virtual reality. These technologies include Virtual Reality Head-Mounted Display (VR-HMD), virtual environments simulations, collaborative virtual environments, immersive virtual environments and virtual worlds.

As 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 [17]. 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 [17] 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 [17] 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.
A common terminology is usually found to describe VR system used in a therapeutic environment: Virtual Reality Therapy (VRT) [18, 19]. VRT, as in [18], is described as “...the deployment of immersive virtual realities used to aid trained mental health professionals in the therapy of client, most often by recreating a cognitive-behavioral exposure therapy approach within the virtual setting.”. Within this work, the authors highlight the potential of VRT on treating psychological disorders such as autism. The authors of [19] mention, based on previous research, on how VRT can ease physical and psychological pain. They also refer on the increase application of VR for treatment instead of entertainment. More precisely, VRT is used to help phobias like acrophobia and claustrophobia [20, 21].

In particular, other works highlighted the importance of generalizing the concepts build within the virtual world into the real word [16, 22]. This is not limited to the capability of transferring the skills learned on the virtual world to the real world but also includes the capability of the system to adapt to different types of users. This is particularly relevant in a virtual environment, where almost anything can be created and customized to satisfy the user’s needs. For instance such systems can allow people with disabilities to experience situations they couldn’t otherwise.

As therapies that make use of VR or virtual environments rely immensely on these feeling of immersion and presence [17, 22, 23] it becomes important to use technological solutions that have been shown to provide these feelings. Recent products such as the HTC VIVE \(^1\) and Oculus Rift \(^2\) are good candidates for our goal [24, 25]. Although these systems can provide a sense of presence, relying only on these systems can be limited and idea could be to combine it with the use of motion detection [24]. Additionally, other components could complete the immersive experience like headphones and smell synthesizers [26]. The controllers could also be customized with different textures to allow for tactile immersion.

As treatments for autism disorders usually involve multi-sensory experiences, we saw in this section how VR could be used to recreate such experiences. VR has the potential to trick the user into thinking he shares the same reality as the virtual environment and this could allow us to design experiences with a real positive impact on children with autism. Using a virtual environment could help to design rewarding therapeutic experiences, thanks to its immersive nature. However, it could be interesting to take advantage of the virtual nature of the experience to integrate game design principles within it, leading to a much more engaging experience.

### 2.2.1 Virtual Reality Problems

Developing a VR game is completely different from developing a traditional screen game. Even more difficult is to adapt all the required hardware for such a delicate population.

\(^1\)https://www.vive.com/eu/
\(^2\)https://www.oculus.com/
2.2.1.A Motion Sickness

Firstly, and as stated before, motion sickness can be and is a problem in VR. 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. This is where the motion sickness happens. The lack of correspondence between our movements and what we see on the HMD. Even worse this problem is much notorious when the game is simulating a fast movement (e.g a roller-coaster) while we stand up or are sit. For this reason the VR development community has explored what feels best for the user. Such advices consist on creating a reference point that is still on the screen such as a virtual nose. Following the same theory other games have a type of virtual helmet where parts of it work as references. However the best course of action in this situation is simply to avoid forced harsh movement on the player. Therefore the movements will feel natural and the player won’t feel any kind of motion sickness associated with the experience. So motion sickness had to be undoubtedly avoided in our application due to the delicate nature of children with ASD. Such effect could cause negative effect on the child leaving them sad, angry, confused and even reject to use the system again. For this reason all the iterations explored never imposed any kind of movement on the player leaving him to freely explore a defined area according to his movements. Although motion sickness may happen of these cases it occurs less often.

2.2.1.B Locomotion

As stated before motion sickness prevents us from scripting a pre-defined path that the player will automatically move. For this reason most VR application rely on teleportation. This movement is simply done with the controllers, or gaze, by pointing to a place. As later will be described this movement was used on some iterations. The controllers are fairly simple to use but can grow complex if there are an enormous of interactions the player can do. For these reason on each iteration we tried to simplify the use of the controllers even to the point of not using them and leaving only the interaction to the HMD. However the controllers offered an important stimuli for the children which is the vibration.

2.2.1.C Visual detail and scale

While developing on the Unity editor everything seemed proportionally correct and visually acceptable. However the HMD has less resolution and therefore less detail. It is best to keep it visually simple not only for performance but for a better experience. The scale has to take in consideration the real world objects. This means that the object dimension has to be careful defined otherwise the player can
feel very small or very big in the world. One technique is to fill all the blank space with proper objects and with the correct scale. Not only the player will feel much more immersed but also better on the virtual world.

2.2.1. D Head-mounted display

Even though the weigh isn’t a problem the cables connected to the VR-HMD can be. After some movement they start to tangle the player breaking the immersion and therefore representing a problem. There isn’t much that can be done to avoid this and it did represent a problem with the children. Due to the lack of real world space notion some children ended pushing the cables to the limit or constantly tangled themselves requiring help from us, the parents or the medical personal. Nonetheless the industry is evolving and wireless HMD for HTC VIVE and Oculus have been announced already. This will certainly offer a much more immerse and natural experience not only for the children with ASD but also for every user.

In the next section, we present works that investigated the effect of video games in therapies in order to understand how their concepts could be applied to satisfy our objectives.

2.3 Games and therapies

Research have concluded that the use of technology can have significant and positive impact on individuals with ASD [27]. Serious games have been used to support the learning of social interactions, languages and affective skills [28]. Some of these studies relied on agent-based systems, using physical robots or virtual avatars. Expressive avatars have been used in education process and they showed a promising effect and to improve the social skills [29]. It has also been suggested that avatars with a more cartoonist aspect instead of photographs or real faces show greater improvements in children with ASD [29, 30]. This conclusion goes in line with the results from [27] who said that children with ASD have a strong interest in films, animations and comic books. The same results suggest that the learning experience should take the form of a game with fun being taken into account. In VR it is possible to take in consideration all of this aspects, with the advantage of being such a unique experience that may allow for enhancement or the learning of certain skills.

The use of video games or virtual environments for therapy treatments as been a growing area of research for the past decades. There are reported uses of VR-HMD to treat mental conditions like acrophobia [20] or claustrophobia [21] with great success. Their results are very promising and show the great potential an immersive virtual experience can have for psycho-therapies and therefore to help children with autism.

It is important to highlight that these virtual experiences can be combined with physical activities
as well and therefore, they can provide the necessary tools to reproduce the wide spectrum of autism therapies. For instance, in [31], the authors experiment virtual therapies using the *Nintendo Wii* console. In their work, they use the *Wii Sports* software, a sports game that requires the players to perform movements in the real world. The authors stress that using virtual rehabilitation allows the patients to do therapy in various and controllable environments. Furthermore the conciliation of fun and rehabilitation through this virtual environment was suggested to be an additional positive factor. The authors also report the potential of telerehabilitation, i.e providing therapy services from distance with the use of technologies. Therefore we can imagine using the VR-HMD in children’s homes for telerehabilitation with a fun and controlled game environment.

Different VR games aimed to rehabilitate patients who suffered from a stroke were studied in [32]. The different games were designed to train different physical movements and it was possible to customize the virtual environment to adapt the degree of difficulty according to the patients’ needs. Their conclusions are extremely promising as they showed how improvements could happen after six weeks of sessions and how immersive VR could have a meaningful impact on physical rehabilitation.

*ECHOES* a serious game built to help children with ASD to practice social communication skills, based on the principles of having a virtual avatar with a cartoonist aspect [33].

![Figure 2.2: Children interacting with the ECHOES system.](image)
This serious game used artificial intelligence to control the virtual avatar while focusing on two problematic areas of children with ASD, joint attention and symbol use. The interaction with the system was possible through a multi-touch display. The system used cooperative turn-taking activities with no end-goal and an environment with some story-based elements. However, it lacks goal-oriented activities, with well-defined and identifiable end-goals. ECHOES conclusions were positive. The users were able to initiate a conversation with the virtual avatar and the room facilitator. The number of interactions increased as more sessions were made. In a particular case, a child, whose parents, therapists, and professors thought he was non-communicative, was able to wave and say "Hi" to the avatar agent. However, being this study limited to a small heterogeneous population (19), generalizations couldn’t be made to other groups of ASD. Although this research presented remarkable conclusions, with the increase of social interaction on some of the children with ASD, there are some drawbacks. The authors argued that the level of credibility and believability of the agent has to be particularly high for systems aimed to children with ASD. The use of a VR environment would enhance the visual believability of the agent while allowing for the integration of adaptive mechanisms. Another limitation of this system is giving less prominence to goal-oriented training, focusing more on exploration and free play. Individuals with ASD tend to make things comprehensible by seeking patterns to structure it [34]. For this reason, goal-oriented training is important to do, giving a more structural design of the game, for children to interact with.

In [35], a study to measure the effects of a virtual environment replicating a coffee shop on six individuals with ASD was conducted, see fig. 2.3. The study aimed to improve the social behavior of the participants with the use of mouse and joystick on a desktop environment.

It used two types of intervention. The first intervention consisted on four virtual coffee shops environments. The four scenarios presented different conditions, where the level of noise and occupations was different. The system would allow to choose from a set of options usually having two correct and one incorrect. When taking the wrong action, the system would warn about it and advise to try a different behavior. At the same time, a facilitator would supervise the actions made by the individuals with ASD and would discuss with them the actions they took. The second intervention consisted on video measures of five different scenes. The first two scenes were coffee shops, one completely full and another with a free table to sit. The other three scenes were in a bus. Scene 1 and scene 2 were the same as the two coffee shops scenes. The third scene consisted of only the driver seat available. This scene intend to observe if the skills learned hadn’t generalize too much, presuming any free seat was correct to sit down. The individuals with ASD had to communicate verbally or just indicate what would be the most appropriate behavior on that situation. The goals were to identify a correct place to sit or on how to behave socially. These videos, of real-life environments, could be presented with or without the virtual environment intervention before. In the author’s conclusion the participants showed signs of improve-
ment according to the number of sessions completed. In the video measures used after the intervention of the virtual environment coffee shop, there were signs of improvement. This was a notable conclusion, since the capability of generalizing the learning from the virtual environment coffee shop to the real world environment on a short period was observed. So, this study serves as proof of the possibility of a virtual environment for the generalization of skills. Therefore, we can study on how a more immersive virtual environment, i.e with VR-HMD, can have a much bigger positive impact on generalizing learning. Finally the authors refer to the necessity of studying collaborative systems for individuals with ASD.

Collaborative systems are 3D worlds where users can interact in real time with each other and with virtual objects [36]. On [37], a collaborative system, the authors investigated the usefulness of a training session focused on social skills, cognition and functioning. The system was using the Second Life environment. This study, as well as [16, 22], praised the use of virtual environment. It describes it as a controllable and safe way to represent real-life experiences and social interactions without its drawbacks like stress, fear or rejection. The study was conducted with eight participants with high-functioning autism. They were able to represent themselves in the virtual world by customizing their avatars and were asked to interact in different scenarios such as an interview, meeting new persons, dealing with conflict, negotiating or making social decisions. These interaction were in real time with other avatars controlled by therapists. The results showed a positive effect, although not significant, on verbal, non-verbal recognition and conversational skills. However, one can wonder if the system would not be more efficient if it was like Autcraft [38]. In Autcraft, the user communities work to develop a self-controlled
Minecraft world aimed only for the autistic populations whereas the usability of Second Life may be a bit complex, comparing to other popular customizable games like Minecraft, specially for ASD individuals. Our work intend to develop a system adapted to the needs of autistic children so it can include a wider range of the population.

Additionally, games have been recently used as an effective exercise tool using fitness or dance techniques. Game consoles, like the Nintendo Wii, allow to play a variety of games with body movements with proved positive results [39, 40]. In [28], the authors report that individuals with ASD are less likely to participate in group sport activities, so children with ASD have a higher risk of developing obesity compared to general population. However, exercise games, have been shown to encourage individuals with ASD to exercise. They also report positive secondary effects such as the reduce of repetitive behaviors, the improvement of motor skills, and the improve of behavior on executive function tasks. Like modern immersive VR, these systems rely mostly on body movement tracking. A VR-HMD like the HTC VIVE, which track the player in a confined space would be a appropriate environment to develop VR games that integrate physical activities. The controllers are also tracked in the space allowing the users to perform complex actions. Therefore, we propose to take this into account while designing our system. Since some individuals with ASD may not be willing to move, some precautions will have to be made but this could lead to a more general and efficient system.

In the next section we are presenting works that aimed at building Virtual Reality systems specifically to treat autism disorders.

2.4 Virtual Reality games

For the past two decades, few works have been done to study the effects of using an immersive virtual environment on children with ASD. One of the pioneer works was made by Dorothy Strickland in 1996 and 1997 [22].

2.4.1 Virtual Reality acceptance and skill learning generalization

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 fulfill 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 first challenge was to convince the children to use the VR-HMD due to its strangeness nature and also due to the unfamiliarity with the experience itself. The physical test area was designed to accommodate familiar schedules, work, and play activities (principles of the Structured TEACCHing concept). Parents and siblings served as co-therapists in the process and had a key role on helping with the familiarization of the VR-HMD. Before the tests, parents tried with the children different helmets like horse back riding helmet. The older siblings were asked to wear the VR-HMD and show a positive attitude towards the VR environment. The helmets were never forced on and to encourage participation, M&Ms candies were given to the children following the positive reward technique used in ABA.

Regarding the virtual scene, it consists on a very simple street scene with a sidewalk and some buildings. The only moving objects were the cars as there was no animal nor person. Due to the fact that the children only knew how to distinguish between red and blue colors, these were the colors used on the moving cars.

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 HMD 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.

Strickland details reasons why she thinks VR may be useful for children with ASD. First the virtual environments can be controlled and simplified to produce stimuli that are tolerable by the children. The virtual world is a safe place to learn new skills associated with activities of daily living without the possible harsh impact associated with the mistakes that may happen in the real world. Studies have concluded that individuals with autism are more likely to think and understand things with the use of visual imagery [41], making VR an appropriate tool due to its audio-visual nature. The fact that a virtual world can be freely shaped by its creator is a strength for individuals with ASD. It can allow the system to easily adapt to their constant change of behaviors but also because introducing gradually small differences on the same scene may lead to generalization of the effect. Moreover, social skills are one of the most problematic aspects of individuals suffering with ASD. As reported by Strickland, children with ASD can respond well to the structured, explicit and consistent expectations and challenges provided by the computers. Therefore, virtual world could allow children to learn the basis of social interactions in a gradually and acceptable manner. Lastly, this study praise the advantages of motion trackers (i.e head tracking, hand tracking) on vestibular responses, which may be monitored in the VR and adjusted.

This is one of the most important works to date regarding our objectives. The findings of Strickland,
regarding the acceptance and the learning of the skills with a VR-HMD, encourage the development of our system. Despite having some limitations, some of her conclusions highlighted the limitations of the technology she used in 1996. Firstly, the capacity to render a real and complex system nowadays have greatly improved. This means that more environments with different settings and adaptations can be built. Secondly, the VR-HMD used on 1996, Pro Vision 100, was very big and heavy. It weighted approximately 3.629 kilograms, when more recent HMD, like HTC VIVE with a weight of 0.555 kilograms, is more easy and comfortable to wear.

In a more recent study [42], 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.

The first phase was divided in three different scenes. On the first scene, virtual cinema, the individuals with ASD could choose a film to watch, the goal being to be introduced to the VR technology. The second scene was a virtual coffee shop where the participant had to keep eye contact with a virtual character, the goal being to immerse the participant in a recreated social scenario. The third and last scene of the first phase was a virtual safari. In this scene, the participants had to control a car with the use of a controller and also watch animals during the virtual safari trip. The goal was to engage the participant in a greatly stimulating experience while at the same time showing them the potentials of VR.

On this first phase all of the 29 participants were willing to wear the HMD and completed the first and second scenes. Only 25 of the 29 participants completed the third scene. The 4 participants who rejected the HMD after the second scene reported problems like dizziness, confusion and being upset with the HMD. From the 29 participants, 23 wanted to return for the second phase of the study.

The second phase was divided in two scenes. The first scene was an Apollo 11 mission, participants experienced entering the spacecraft, taking off and entering zero-gravity, the goal was to immerse the participant in an engaging and learning experience. The final scene was a Tuscan house where participants could freely explore the surroundings of the house and admire landscapes. From the 11 participants, all accepted to wear the HMD and completed all of the scenes. In general, the feedback was extremely positive, regarding the acceptance of the HMD but also regarding the scenes themselves. Overall, the participants felt immersed in the scene with only few negative side effects.

In summary, participants were willing to use the HMD and explore and immerse themselves in the virtual world. This result is similar to the one from Strickland [22] and would support the idea that Virtual Reality can be used to generalized concepts learned within the virtual world to the real world [22,42].

However, whereas they used a recent technology similar to the one we aim to use, the scenarios and
environments used are very exceptional and do not focus on the specific problems of ASD population. For this reason, no generalization regarding the adaptation of the virtual to the real world can be made. Within our work, we intend to recreate day-to-day scenarios where ASD children have to deal with a variety of problems.

2.4.2 *Autcraft*: social community for individuals with ASD

Although not being about VR, the research made by the authors of [38] is very inspirational for our work. The authors studied a private community server of the game *Minecraft*, called *Autcraft*, designed for individuals with ASD. This server receives a daily average of 50 players in peak hours and 1200 unique players each month. With previous consent, the authors were able to observe and study how the individuals with ASD behaved in-game. 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. As already mentioned, a main issue with individual with ASD is their high sensibility to the various stimuli of an environment. For this reason, this population usually requires to take breaks more frequently. 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 behaviors 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). As mentioned before, MSE like the Snoezelen Room, help people with ASD by supporting SI. *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. Besides sensory regulation, observations were also made for mood regulation. Most of this aspect is approached by the players expressing their feelings and experiences with the use of the in-game chat or the on-line forums. However, regarding mood regulation, there 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 HMD.
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 [38]. 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.

In the next section, we summarize what we learned from our review of the literature and the related work to establish how we can propose a system built upon these foundations aiming at improving the current state of the art.

2.4.3 Discussion / Summary

The ASD population have uncommon stimuli responses to their surrounding environment and they can suffer from social and cognitional problems. This increases the difficulty they have to adapt to new scenarios and environments. Moreover, as there is a wide range of different autistic disorders, it can be extremely costly and time consuming for families to give to the children the appropriate therapies.

The use of VR-HMD-based serious game for therapy offers great potential in the treatment of these conditions. A virtual environment can offer realistic experiences in a safe and controlled environment. Moreover, virtual reality equipment are becoming affordable nowadays and the applications using it can be easily extended and adapted, making it possible for just one system to reproduce any therapeutic activity at any time. Previous experiment supported the fact that autistic children can willingly wear VR-HMD although they were using outdated technology [22, 42]. Today, the VR-HMD devices that can be bought for home usage are even more comfortable and offer an even better experience. From the games and experiences presented in our review of the literature, all of them reported signs of improvement on various autistic disorders like social communication [33,37] or social behavior [35]. Other works highlighted the engaging effect of game activities on autistic children. In Autcraft [38], the players reported the enjoyment they had using the virtual MSE or the mini-games and in [29–31], the importance of fun and cartoonist aspect of the games was established.

Based on these works, their conclusions and our analysis, we propose to develop a system integrating a relaxing gamified experience aiming at engaging autistic children in enhanced therapeutic activities based on the techniques presented in section 2.1 and on the previous work presented in section 2.4. For instance, the positive reinforcement of ABA may be used to reward the children in game. Ultimately, the goal of our system will be to study the impact of virtual scenarios in relaxing/calming children with ASD. Further we aim at observing changes on concentration and calmness of the children through the whole interaction. As a consequence we will also study the children response to scenario changes.

Next we present the architecture of our system.
On this section we present our system architecture. We begin to justify the chosen hardware, game engine and libraries used, which there is an enormous variety to choose from. Each one has unique characteristics that helped decide on the best option.

### 3.1 Choosing the Virtual Reality Hardware

In order to choose what VR-HMD we could use, we defined the following specifications: the price, the comfort (i.e. weight) and the features (i.e. resolution, refresh rate, field of view, tracking area, display and the requirements). Some of these aspects are presented on table 3.1 and discussed below.

<table>
<thead>
<tr>
<th>Name</th>
<th>Positional Tracking</th>
<th>Display</th>
<th>Resolution (per eye)</th>
<th>Refresh rate</th>
<th>Field of View</th>
<th>Weight</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samsung Gear VR</td>
<td>No</td>
<td>Super AMOLED</td>
<td>1280x1440</td>
<td>-</td>
<td>101°</td>
<td>345g</td>
<td>99€</td>
</tr>
<tr>
<td>PlayStation VR</td>
<td>Yes</td>
<td>5.7” RGB OLED</td>
<td>960x1080</td>
<td>120 Hz</td>
<td>100°</td>
<td>610g</td>
<td>399€</td>
</tr>
<tr>
<td>Oculus Rift</td>
<td>Yes</td>
<td>OLED</td>
<td>1080x1200</td>
<td>90 Hz</td>
<td>110°</td>
<td>470g</td>
<td>499€</td>
</tr>
<tr>
<td>HTC Vive</td>
<td>Yes</td>
<td>OLED</td>
<td>1080x1200</td>
<td>90 Hz</td>
<td>110°</td>
<td>555g</td>
<td>599€</td>
</tr>
</tbody>
</table>

*Figure 3.1: Comparison of the VR-HMD.*

Firstly we take a look at the most simple, cheapest and less powerful VR-HMD the Samsung Gear VR\(^1\). This HMD requires a Samsung smart phone like Galaxy Note8, S8, S8+, S7, S7 edge, Note5, S6 edge+, S6 or S6 edge. Both the display and refresh rate are of the phone and not the HMD itself. Although it offers a simple and cheap solution it lacks CPU and GPU power, compared to a desktop, to process more complex scenarios. As we aim for a relaxation environment the use of particles and shaders requires more process power. Further it lacks positional tracking which allows to know the position of the player in all axis. For these reasons we would have some drawbacks on the quality and possibilities of scenarios we wanted to explore and so we excluded as an option.

Secondly we looked at the PlayStation VR\(^2\). Although fairly similar with Oculus Rift or HTC Vive the problem was the exclusivity of developing for a PlayStation system. Besides it has less field of view and resolution which are two of the most important aspects to take in consideration when choosing a

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\(^1\)https://www.samsung.com/global/galaxy/gear-vr/
\(^2\)https://www.playstation.com/explore/playstation-vr/
VR-HMD. As for the difference of price we think that the better quality and less weight compensates to choose Oculus or HTC.

So the choice had to be between Oculus or HTC. Both of the VR-HMD have included, in the price, the controllers and sensors. Reports on both controllers show that they have a great design and usability, although the feel of Oculus controllers is more natural. HTC VIVE was considered in CES 2016 by Thrillist the best new tech and gadget and Techradar gives it 5 stars out of 5. Oculus Rift was given by Techradar 4 stars out of 5.

![HTC Vive controllers](https://www.ces.tech/)

**Figure 3.2: HTC Vive controllers.**

The sensors allow to recognize a defined space. On this space, the user is able to move around, while receiving proper feedback in-game. This has been an integrated technology of the HTC VIVE since the beginning. Oculus Rift has the same technology nowadays but with a drawback. On one hand HTC VIVE offers standalone sensors to be mounted diagonally on two corners of the defined play area. This allows for 360° tracking. On the other hand Oculus sensors are connected to the PC and only offer approximately 180° tracking, forcing the player to stand in front of them. Nonetheless Oculus Rift can also do 360° tracking but requires a third sensor and the setup is still in experimental phase. However the Oculus VR-HMD is lighter a few grams and have headphones integrated. Regarding the PC requirements, the HTC VIVE requires 4GB of RAM while Oculus Rift requires 8GB. However Oculus Rift requires i3 CPU and 960 GTX while HTC VIVE requires i5 and 970 GTX.

So in conclusion, looking at all the features of both HMD, they are both well capable to satisfy our

3https://www.ces.tech/
4https://www.thrillist.com/tech/nation/ces-2016-best-new-tech-gadgets-this-year
5http://www.techradar.com/reviews/wearables/htc-vive-1286775/review
6http://www.techradar.com/reviews/gaming/gaming-accessories/oculus-rift-1123963/review
needs for this work. Both offer an immersive virtual experience as we intend to. Furthermore developing for \textit{HTC Vive}, in our case, is the same as developing for \textit{Oculus Rift} and so the final solution may be used on both HMD. However we opted to choose the \textit{HTC VIVE} mainly due to the possibility of having a better spatial movement than the \textit{Oculus Rift}. For these reason we expect the \textit{HTC VIVE} to deliver a more fidelity experience on our system.

3.1.1 HTC Components

\textit{HTC VIVE} is composed by a pair of controllers (see fig.3.2), the HMD (see fig. 3.4) and a pair of infra-red sensors (see fig.3.5). In total this means there are by default five components. The infra-red sensors are responsible for detecting both the player and the playable area. They should be placed above the player height and disposed front to front diagonally, see fig.3.6. For the best experience they must be positioned five meter a far from each other. This way it will allow to build a rectangular area where the player can move freely. When near the limits of this area the player will see on the virtual world a virtual grid, see fig.3.7, as a warning of being to close to a wall or other obstacle near the edge. These sensors are also responsible to detect the player position and movements in all the directions as the controllers positions. This allows to detect if the player is moving too much or not which will be important data to study on later sections. The HMD is responsible to show the virtual world and can also
Figure 3.4: HTC Vive HMD.

Figure 3.5: HTC Vive sensors.
be detected in space and its velocity (i.e the player head movement velocity). It includes an audio cable connection to allow audio stimuli also very important on children with ASD.

![Figure 3.6: Room setup.](image)

### 3.2 Game engine and library

Both Unity\(^7\) and Unreal\(^8\) are the most popular engines to develop games nowadays. Either one is capable of supporting the necessary plugins to develop VR experiences. However, due to our previous experience with it and its simplicity, we decided to develop using Unity along with the SteamVR Plugin\(^9\). This software suite will allow us to easily control all the components and to integrate them seamlessly in a game environment. Additionally to SteamVR Plugin it will be used the Virtual Reality Toolkit \(^10\). This library allows to quickly use the VR specific functionalities and to build the VR application easily.

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\(^7\)https://unity3d.com
\(^8\)https://www.unrealengine.com/what-is-unreal-engine-4
\(^9\)https://www.assetstore.unity3d.com/en/#!/content/32647
\(^10\)https://vrtoolkit.readme.io/
3.3 System Architecture

So in conclusion our architecture consists on the integrations of both the VR hardware components and the software tools discussed. We present a block diagram of our architecture on fig 3.8.
Figure 3.8: Block diagram of our system architecture.
## Implementation

### Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Pre-study</td>
<td>37</td>
</tr>
<tr>
<td>4.2 First version</td>
<td>39</td>
</tr>
<tr>
<td>4.3 Second version</td>
<td>44</td>
</tr>
<tr>
<td>4.4 Third initial version</td>
<td>46</td>
</tr>
</tbody>
</table>
First we present a pre-study that not only confirms our finding in section 2 but helped us know how to start the first implementation of the game.

After, we present our game evolution through the different versions and the initial testings before the final evaluation we conducted. Every version was done taking in consideration the main objective of this thesis, to offer a virtual relaxation experience for children with ASD.

4.1 Pre-study

In order to support and complement the information found during our review of the literature, we conducted interviews and sent questionnaires to health professionals specialized in autism. This process was aimed to narrow down the parameters of our system. In particular, we aimed to establish the age range of the children who could benefit from it, which autistic disorders we could address, what problems may arise from the use of a VR-HMD with autistic children and to receive opinions and suggestions on what to incorporate on the game.

Thanks to our contact with an occupational therapist named Sofia Pereira, we were able to send the questionnaire, see appendix A, to a sample of professionals who worked with people with mental disabilities. We collected the answers from thirteen professionals but two of them were excluded for not having previous experience with individuals with ASD. The remaining eleven participants were all females with different experiences on autism. Eight of them were occupational therapists, one was a special educational teacher, one was a speech therapist and one was a physiotherapist.

The answers informed us that the most appropriate spectrum of autism that could be treated by our approach would be the AS, the PDD-NOS and the AD. When asked what are the most used therapeutic techniques and methods with ASD populations nowadays, the specialists replied similarly by mentioning SI, Structured TEACCHing, ABA, Floortime and ADL. About the age of the children that could use our system, the answers delimited an age range between 5 and 20 years old. Regarding the problems that could arise from the use of a VR-HMD, they mentioned dizziness, rejection and aggression towards it. Some suggestions were also given regarding the game design. They recommended to follow a sequential and structured logic, with well defined goals, to promote daily living activities and social interaction. Additionally, the system needs to take in consideration the individual needs of the child and not only global objectives. Even though our aim isn’t social interaction we took in great consideration having a well defined system with clear objectives with a will structured logic.

In order to clarify the answers obtained from the questionnaire and to remove any doubts, we conducted additional interviews with three occupational therapists. The interviews consisted of one open interview and one semi-closed interview using pre-defined questions from the questionnaire. Throughout these sessions, we reduced the age range of the children to 5-12 years old. Their answers confirmed
that the most appropriate disorders that could be addressed are AS, PDD-NOS and AD. However, they mentioned that the degree of AD is important and that maybe only individuals with a lighter degree (a more high-functioning autism) should be enrolled. When asked about the advantages that VR can bring to ASD individuals, the professionals said that it could offer new experiences and settings to these individuals that they would not be able to experience otherwise. Regarding the therapeutic methods that could be reproduced within the system, they highlighted two candidates: ADL and SI. For ADL, they proposed that the system should allow the repetition of daily skills in different scenarios and contexts and for SI, they suggested it should control the stimuli input in various environments. Regarding the VR-HMD, they stressed out again the negative impacts it may have in particular on rejection of the method and disorientation and dizziness of the child. Nonetheless, they suggested some ideas to help with the acceptance of the VR-HMD. One of them is to use masks of famous characters on the VR-HMD like superheroes faces. On the use of the controllers they suggested that an interesting idea could be to add different materials on them allowing for tactile stimuli. Finally, we asked about the simulation of a Snoezelen room and the therapists mentioned that it would be a good idea as it would allow the children to experience, even partially, the sensory inputs without having to go to a real Snoezelen room. They added that it would be optimal to be able to customize the virtual room to accommodate each children needs.

Lastly, an additional open interview was done with Doctor Pedro Garcia, a Paediatrician specialized in ASD, who received us at his autism clinic Passo a Passo\(^1\) to discuss our findings. He agreed with the results from the previous questionnaires and interviews, including the population (age and disorder) and the techniques to be used. He showed a great enthusiasm for the possibility of simulating a Snoezelen room. He emphasized the importance of developing such a system as not only it would be beneficial for the children but also for the clinics. Doctor Pedro Garcia also agreed on our proposal of developing a social interaction experience and the training of daily living activities in the game. He also agreed on helping us with the study by providing access to the clinic and by identifying potential candidates from the children with ASD for future tests.

On the following sections we will describe our initial concepts and the studies we made to improve our final version. All of the studies took place at clinic Passo a Passo in Lisbon with the help of some of the clinic therapists. They were able to help us through meetings by giving us feedback about our system. Before making the final version we had the opportunity to test the early versions with a small population. As a result we were able to understand what did work and did not. Also to note that the following sections will be more detailed to justify our final version. The final testing was evaluated with metrics and questionnaires to the therapists and parents, which later will be presented on section 5.

\(^1\)http://www.passoapasso.pt/
4.2 First version

4.2.1 Implementation

As already explained in previous sections, a real Snoezelen room can consist of many elements such as lights, bubble tubes, optic fibbers, light projections on walls and even music.

The first version of our game application was important to learn how to develop in VR and what constraints, described on 2.2.1, we were going to face. Further we tried to implement much of the VR core features to rapidly understand what could or could not work in the final version. These features consisted on moving, interacting and grabbing on a VR scenario. The main inspiration for this version was through the understanding of the concept of the Snoezelen Room. As described before these room is built to offer a relaxing experience. Therefore, being it our thesis objective, we decided to use it as our first inspiration to make the game.

In the virtual world it consisted of a simple room with various elements. The room had a height of 2 meters. Most of the elements of a real Snoezelen Room 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.

Unfortunately the room can consist of much more like tactile stimuli of different textures and food which is difficult to recreate in a virtual scenario.

So after analyzing what we could simulate we decided that to resemble a real Snoezelen Room the room had to be mostly dark and only illuminated by a few spotlights (i.e like flashlight) that projected light, in a circular shape, on the wall. These lights moved around and had different colors, see fig 4.1. This lights would fade in to blue, green or yellow colors and then fade out. This process of fading in and out would take 3 seconds and repeated as long as the interaction was running.

Next we created objects for the player to grab and visualize or just throw them out. In VR the feeling of throwing an object according to our hand movement and force is close to reality. This way we could offer a more immersive experience to the children. One particular object was a ball with a 1 meter diameter that would lightly bounce. The other objects mostly consisted on particle systems that changed light, color or shape along the time, see fig. 4.2. The colors interpolated along a rainbow spectrum of colors and had a duration as long as the game was running.

Bubble tubes were also implemented with different bubble speeds and colors and also with 3D surrounding sound. One of the bubble tubes had colors variating between red and blue with a random velocity between 0.1 m/s and 1 m/s. The other tube had colors of green and yellow with a random velocity between 0.25 m/s and 0.5 m/s. Only near the bubbles the player would be able to hear the sound of
the bubbles. Optical fibbers which changed color, according to a rainbow spectrum, over time were also implemented. Finally it was created a dark sky with floating particles reassembling stars. The player could lay down and just look at the "stars". Finally we added a mirror to the room as can be found on real Snoezelen rooms. Image of these elements can be seen in fig 4.3.
Those were the elements created to try to offer a relaxing experience. The way the player could move was simply by teleport. The player would point to a location with the controllers and received feedback with a line and the endpoint where he would teleport. The first issue was to teleport to a position near a wall. When doing so the player was able to see through the walls and see an empty space. To fix this we made a trigger detection to see if the virtual head was inside a wall and while so turn the screen black. This way the player had to take a step back and turn around to see again.

After this first iteration and testing ourselves on the VR-HMD we concluded that there were some problems. One of the issues was with the darkness of the room. We simply increased the ambient light to fix it. Secondly there were many elements on the room functioning at the same time. We decided to implement switches near each interactive element. These switches would be green when turned on and red when off. This way the children could turn off something that was bothering him or turn on something he liked. The scene didn’t felt overwhelmed as before, offering a much more calm experience.

However the biggest issue was the feeling of claustrophobia. The room wasn’t properly scaled which made the ceiling much lower then it should be. Finding a proper value was initially difficult. However the metric system in Unity is in meters. With this reference we started to scale everything with real life measures which made it work perfectly. Lastly we noticed some elements were disposed in a higher position. While it wasn’t a problem for adults it was for children. Since HTC Vive detects the spatial position of the HMD it also takes into account how high we are. For this reason everything had to be disposed at an acceptable range for a children to grab or see. We used an height of 0.5 meters to dispose interactive objects.

Finally we added a second room. To go to it the child had to teleport near the door and open...
it. Inside there was another particle system for relaxing purposes. This system had particles floating around alternating from blue to white colors. See figures 4.4 and 4.5.

![Image](image.png)

**Figure 4.4:** The second room.

### 4.2.2 Testing

For this early phase we had two different children to test the prototypes. The tests happened in two different days. Just one of the children participated on the first and second day. The other was only available on one of the two days. For privacy and respectful reasons we will call them child G and child L. A more detailed description about them and further children described on this thesis, will be given in section 5.

The session took place at clinic Passo a Passo in 26 of April and took about 20 minutes to complete. We used one of the rooms at the clinic to setup all the hardware. We tested with one child, the child G. The whole session occurred with the presence of the child’s aunt and the occupational therapist from the clinic, Patrícia Caeiro. We tested the first and second versions. The second version will be described on the next section.

Child G was very curious about everything and wanted to know how the game worked, how it was programmed and what engine was used. He was extremely anxious to try the VR-HMD. Remarkably he was very obsessed with technology and at a very early age wanted to learn how to program. Without any hesitation he mounted the HMD on his head and allowed us to touch his hand to adjust the controller.
cord to his wrist. He kept asking us questions about how the VR worked and what was he going to see. Nonetheless he clearly had difficulty on eye contact when talking with us and had difficulty on remaining calm. He was eager to try the application and for that reason he was agitated.

Next we tested the first version with the Snoezelen Room. The first challenge was to explain the virtual grid and its meaning. He kept bumping into real world objects. The problem is the lack of understanding that individuals with ASD have to understand abstract concepts. Even so, through the session, child A was able to the control his movements. The second challenge was for the children to follow our instructions. His curious nature didn’t help allied to the lack of concentration many individuals with ASD suffer. The problem relies on the varied amount of objects that the children can look and interact with. The most negative aspect was due with the teleportation mechanism. Even though he understood the visual feedback he kept teleporting too close to a wall. As a result the screen would go black as we implemented. However the child couldn’t understand he was inside a wall and had to give a step back. He found extremely hard to go to the door open it and explore the second room. Nonetheless he did after some attempts. Nonetheless the child found really interesting exploring and interacting with all the elements available on the room. Interestingly he found the bubbles and other particle systems relaxing. Unfortunately the child wasn’t relaxed after the experience.

The first reason may be related to the fact of being the first time the child was experience VR.
The second reason we thought was the amount of interaction the child had the liberty to make. From teleporting, turning on and off some of the stimuli and grabbing and throwing objects all the experience was overwhelming. Even though the child reacted positively he wasn’t able to show signs of relaxation. Further he pointed out the fact he had difficulty on teleporting with the controllers.

After it we tested the second version with the same child which will be described on the next section.

### 4.3 Second version

#### 4.3.1 Implementation

As mentioned before, the first version was made many months before testing. Before, in 13 of April, we had a meeting with some of the medical personnel from clinic Passo a Passo. The topics of discussion was to discuss what we already had developed and what could we do. The therapist Patrícia found the idea of the Snoezelen room interesting. She showed us a tablet game they use with some of the autistic children. On this game the player draws a line. When the players stops the line starts to sparkle from the beginning until the end and when it reaches it explodes with a figure like a star. Since the background was a sky with stars we decided to recreate a space scenario. Further the therapists found interesting the idea of controlling the stimuli of the scenario and so they proposed to have a simple user interface. This way if the child felt overwhelmed with the stimuli the therapist could turn off instead of being the child doing it.

On this scenario the player couldn’t teleport as he could on the previous described version. He stood on the center of an icosahedron with a floor underneath, see fig 4.6. The icosahedron had a transparent material to observe the outer space, stars and the planet earth. Next to the player we decided to just put a simple cube. The reason is simply to give the player a reference point and avoid any possible dizziness.

The main interaction was to draw a line and see it sparkle as it transformed into a figure, just like the tablet version. However this time the player could draw in all directions. It was possible to draw infinitely but only one line each time. The player had to wait and see the effect until the end. The line was drawn by triggering the controller. As long as it was pressed it would draw. The line was yellow and when the player releases the triggers it sparkles from the beginning of the line until the end. The colors of the sparkling effects ranged on the rainbow spectrum randomly. The figure could be a circle of a square and was of the yellow color.

We created again a few spotlight with different colors and intensities. The spotlights moved slowly in every directions around the icosahedron. After, we made a special camera to render the scenario from a far perspective and see everything that was happening. On the left side we provided a panel where the therapist could turn on/off the lights, change their color and intensity, see fig 4.6. The objective was
not only to study the interest of the therapist in such a feature but also to see how the children would react to runtime changes.

### 4.3.2 Testing

The setting was the same as previously described. The child took 10 minutes to complete the testings.

Child G found the room very appealing because he could see the outer space. He enjoyed having the ability to draw lines. However due to the limitation of one line he kept saying that more lines should be drawn which we did on the second iteration of the icosahedron room. He also pointed the fact that the lines were too close to his vision. Next we gave voice instructions for him to look at the lights on the icosahedron changing color and size. The child reacted enthusiastically and kept saying what colors the light were and their position. However he felt that the interaction lacked more interactions. Although he enjoyed he wanted to see asteroids and other planets and explore.

We think that his curious nature may have influenced his feedback. Nonetheless the problems he pointed regarding the lines were accepted and corrected for the next version. Further we expanded this version adding another room and more interactions as will be described next. The therapist also pointed out the lines being too close and thought that there should have been an interactive object, like the green ball of the first version, on this one. Additionally she proposed to have some sort of feedback while the children grabs the green ball. Finally she also pointed that not having the ability to see the child’s vision, during the user interface panel, wasn’t the best course of action.
4.4 Third initial version

4.4.1 Implementation

After the child G and the medical personnel feedback described before, we decided to improve the second version. We added a simple bouncy ball that could be grabbed and thrown away. Further we added the requested feedback when grabbing it. The controllers simply vibrated when touching the ball.

The line drawing was improved defining a maximum limit of the line size and the ability to have more than one line each time. The idea was to allow the children to draw something they liked or even write their name, see fig 4.7. The child was able to change between two modes with the touch on the controller. Draw mode, for the lines, or grab mode to grab and throw the ball. This way the child wouldn’t by mistake start drawing when throwing the ball and vice versa. See fig 4.8.

The lights projections were kept in the room and the medical personnel was still able to change its definition in run-time. However this time the camera was the same as the view of the children.

The interface suffered small changes. We added three buttons to the interface, fig 4.10. One would start a new main feature, a mini-game fig 4.12. The mini-game was played through the child eye gaze. We decided to have this type of interaction to remove the necessity of the controllers and see how the child would react. We implemented a simple user interface feedback for the user of the VR-HMD know the remaining time until the object was active, see fig 4.11. To activate any interactive object it required 1 second of eye gaze. After activating the game twelve cubes with different colors would appear all over

Figure 4.7: Line drawing with the trail effect.
Figure 4.8: Interface when choosing the hand mode.

Figure 4.9: Icosahedron room, now with the green ball.
the icosahedron. The objective was by order of color (indicated in the therapist interface), to find and look at the cubes. This would allow to train cognitive movements with the head and concentration when making color associations.

However the game didn't had any reward besides completing it. This was a problem since ABA encourages this type of feature on therapeutic sessions to improve the children. This remained as an issue to take in consideration for the final implementation.

The other two buttons would allow to change between the room already described and a new 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 1 second, to an object to trigger its interaction. After activating it the object would deactivate automatically after a 30 seconds.

These objects consisted on different cubes with different colors 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, see fig 4.14. We decided to also add a second interactive interface for the medical personal to use. This way they could activate or deactivate any of the particle systems, the sound and control its volume. 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.
4.4.1.A Testing

The session took place at clinic Passo a Passo on 1 of June. Again one of the rooms at the clinic was used to setup all the hardware. This time we had the possibility to test with two children. Child G, the same as the previous study and child L. Child G had the presence of his father and child L of his mother. The whole session occurred without the presence of the occupational therapist from the clinic, Patrícia Caeiro. We tested the third version which took 10 minutes for each child to complete.

First we tested with child L. He was more difficult to deal with. He didn’t communicate but wanted to try the HMD without hesitation. He was very agitated and kept running everywhere. We tried to use voice instructions for him to draw the lines or look at the light projections. Unfortunately he didn’t follow our instructions and kept running around the virtual world and as a consequence bumping into real world
objects. We noticed that he wasn’t using the controllers and was even more agitated when he tried to. However when we activated the mini-game he stopped and follow our voice instructions for the color order he had to choose. Even more remarkably he knew the order without us saying anything. After
completion he seemed more calm. On the relaxing room he was able to activate the relaxing points of sounds and particle systems. However he started running around and again not showing any relaxation effect.

Child G was very enthusiastic to experience everything. He even remembered almost every detail from the past versions and didn’t had any difficulty to equip the HMD. For this version we started with the relaxing environment. At first the child was very active and kept observing and commenting on the differences and what he was seeing. After he relaxed we asked him to observe the cubes on each corner to trigger the sounds and particle effects. He was very happy to listen to it but couldn’t keep the focus too much time. After it we moved to the interaction room for him to play the mini game. While playing it he was focused and followed our voice instructions. After ending the game with success he lost his focus and wanted to move around a lot and jump. He also pointed out that he should have been rewarded for ending the game with success. On a final note the child commented for the first time on the sounds of the relaxing points. He enjoyed them very much and seemed calm to listen to them.

We conclude that there is a potential for mini games to allow for a momentousness concentration/calm effect on the children. Curiously child L could only remain calm during cognitional activities like the color cubes but not during the relaxation elements. Both child have in common relaxing during the mini-game but only child G can remain calm during the relaxation room. In the end, the therapist Patrícia could join to discuss what we observed. She pointed the fact that child L as more difficulties in concentration then child G. She though that this version had too many elements mixed, a room with projections...
(relaxation) and a mini-game (interaction). She thought that the experience should be more fluid and without the need of her having to use the interface to define the next steps. She proposed to go back to the first version of a room with interactions followed of relaxing rewards.

### 4.4.2 Final conclusions

In sum we had most of the observations we needed to try to make our final system. We now justify some of the core elements we tried on the previous described studies and their implementation, or not, on the final version.

#### 4.4.2.A Teleportation

This mechanic showed a lot of problems for child G. As stated before the lack of understanding of abstract concepts make it difficult to use. Further the need of the controllers to use it make it more difficult in cognitional terms. Nonetheless we kept the mechanic for the final version but with a different and simple way of using it as will be described.

#### 4.4.2.B Controllers

In all the versions we noticed that the controllers weren’t helping to relax. Even on the contrary they made the children more agitated. For this reason we decided not to use the controllers and only use the child eye gaze. This way the child can keep the focus while interacting and seeing the relaxation events implemented for the final version. In consequence, scratching the use of the controllers made us not to implement the line drawing or grabbing objects.

#### 4.4.2.C Sounds

The sounds were used in all the versions and always seemed to have a positive effect but most notorious on the version 3 with child G feedback. For that reason we kept for the final version.

#### 4.4.2.D Object/interactions

Objects and interactions are an important part as observed. Specially during mini-games. For this reason we intend to implement a mini-game on the final version. However we think limiting the amount of interactions will help on a more relaxed environment. For the final version we will try to keep it as simple as possible.
4.4.3 Final version

Now we present, in detail, our final system. On section 5 we will detail the results of the final test we did. In sum this version had a simple uniform room. The player had to use the eye gaze to activate events. Simply by looking at any interactive object (e.g. spheres, tangram pieces) and maintaining his vision will trigger the object correspondent interaction. This is the same mechanic as the one introduced on the third version described before. However this time we reduced the time of gazing from 1 second to 0.25 seconds. This way the probability of looking away before the objective was interacted was much less. Further the flow of the game would be faster which may help with any possible frustration that may occur on the children. See fig 4.15.

![Image of the interface feedback on the player headset. On this example the player is activating one of the tangram pieces.](image)

Figure 4.15: The interface feedback on the player headset. On this example the player is activating one of the tangram pieces.

At first the player starts in the middle of the room. Then he has to turn around and will find a green sphere. Looking at the sphere the player will teleport to its position and activates the first mini-game. Completing the mini-game would reward the player with a relaxing environment (ocean) on right side of the room. To observe it the player could teleport using a blue sphere near a window. Going back to the green sphere would trigger the second part of the interaction with a relaxing sequence of events and the unlock of a space observation. To observe the space, the player would use a red sphere. Finally there is a relaxing music that plays through the whole interaction. All of this elements will be detailed in the next sections.
4.4.3.A Implementation - Room

After the justifications described before and the feedback we had from the therapist after the third version, we decided to make a simple room. Completely white with two opaque windows on opposite sides and a front wall fully black. The black wall would serve for visual contrast to the mini-games and relaxing elements that will be described next. The windows allow the player to observe two environments space and ocean. On the room there is always a default sphere of green color. As on previous versions, the player uses his eye gaze to trigger the sphere interactions. All of the spheres when activated teleport the player to its position. In particular the green sphere will at first unlock the Ocean Mini-Game and second the Space Relax Sequence. A full view of the room, windows, walls and green sphere can be seen in fig 4.16.

Figure 4.16: The final room, the behind the red window is the space and the blue is the ocean.

4.4.3.B Implementation - Ocean Mini-Game

This mini-game consists on a simplified version of a tangram. It has two parts. The first part is to complete the tangram of a fish, fig 4.18, and the second the tangram of a whale, fig 4.19. When the green sphere is triggered the player goes to its position and the first pieces appear on the room, fig 4.17. The player only has to look, by order, to the pieces. The order is defined by the current moving piece. With the eye gaze looking for 0.25 seconds the piece will go automatically to its correct place. So it only requires for the player to look at the piece and doesn’t have to place it. Our choice is due to study a relaxing interaction. Having incorrect possibilities could lead to frustration. Additionally a correct sound can be heard. When all the pieces are in place the fish or whale will swim across the wall and disappear.
on the right side. Additionally a diving sound can be heard. This way we are establishing a relation between the ocean elements through the game and the following reward.

![Figure 4.17: Pieces appear through the room.](image1)

![Figure 4.18: Completed fish tangram.](image2)

After completing both parts of the Ocean Mini-Game, the blue windows start to vanish and a blue sphere shows up, fig 4.20. The sphere allows the child to go near the window and observe the Ocean.
Figure 4.19: Completed whale tangram.

On it we can see a flock of clown-fishes moving with the artificial intelligence flock system called BOIDs and a whale following a pre-defined path. Additionally we can observe corals and bubbles, fig 4.21.

Figure 4.20: The blue sphere will allow the player to go near the window and observe the Ocean.
4.4.3.C Implementation - Space Relax Sequence

After observing the Ocean the player can go back to the green sphere, triggering the appearance of a white sphere in the middle of the room, fig 4.22.

On triggering it all the wall will become black and small stars will appear everywhere on the room. On the middle appears a particle system that evolves from a star explosion, fig 4.23, to a star trail fig 4.24 and finally to the creation of a star fig 4.25.
The star takes 2 seconds to explode and then it transforms on the star trail. This trail travels on the room for 20 seconds passing near the player position and finishes on the middle, creating the new star. The new star will travel around the room for 10 seconds and vanish through the red window on the left side. When it happens the window vanishes and a red sphere appears, fig 4.26. Looking at the red sphere, teleports the player to the window and allows him to observe the Space and planet Earth, fig 4.27.

On this phase we decided not to have an interactive Mini-Game as before but to see the effect of all the relaxing sequence on the child. This way we can see the differences between having an interactive relaxing sequence versus just observing a relaxing sequence. Next we will detail how we did our evaluation and its results.
Figure 4.24: Star trail, moving through the room.
Figure 4.25: Star creation, moving through the room.

Figure 4.26: The red sphere will allow the player to go near the window and observe the Space.
Figure 4.27: The Space environment with planet Earth.
5 Evaluation and results

Contents

5.1 Evaluation methodology ............................................ 65
5.2 Evaluation procedure .............................................. 66
5.3 Results ............................................................... 66
This chapter describes our final evaluation methodology and the results obtained. This thesis aimed to study the relaxation effects a game in VR could have on children with ASD.

Next we will present our evaluation methodology and objectives. Further we will discuss each test individually. In the end we will discuss all the results and their meaning.

5.1 Evaluation methodology

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

5.1.1 Observation

The observations consisted of eye observation and video recording to evaluate not only the children reactions but also his comments during the testing. Further we had 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, see appendix B fig B.1.

5.1.2 Questionnaires

We made two types of questionnaires. One for the parents to fill the children’s profile as seen in appendix B fig B.2 and fig B.3. 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. Knowing the interest on themes like Ocean, Space and animals was a key point to make a correlation between getting the child attention and interest during the game and their knowledge on those themes. Additionally we wanted to know what resources the child uses to relax. As we will later see some of the child used resources in common to the ones we used in-game. Finally we had interest in knowing the child reaction to abrupt changes on an environment and to see new environments. With this information we studied also if the changes that happen in-game could have a negative or positive impact on the children.

The other questionnaire was made for the therapist as seen in appendix B fig B.4, fig B.5 and fig B.6. The objective was the get conclusions from the game interaction of the child relaxation state, reactions and VR-HMD acceptance. 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. After we asked about
the relaxing state, in general, 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.

5.1.3 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.

5.2 Evaluation procedure

The final evaluation took place, in 30 of September, in clinic Passo a Passo on the same room as
used in previous testings. This time we tested with three children, their profiles will be described in detail
in the following sections. Once again we had child G and child L. The new child was child M. All of
the testing were done with the presence of the parents of the child and occupational therapist Patrícia
Caeiro. Before starting we delivered the form consent and child profile questionnaire to the parents. The
conclusions questionnaire was delivered to therapist Patrícia. The whole sessions were recorded with
video. Each session took about 15 minutes.

For all the testings and when needed we gave speech instructions to help the child orient on what to
do next. Next we present the details of the sessions and results of each child individually.

5.3 Results

On the following sections we will provide a complete profile of the children and will also detail the
therapists conclusions regarding the questionnaires of appendix B figures B.4, B.5 and B.6.

5.3.1 Child L

Child L is 10 years old and has moderate autism. He was accompanied by his mother who filled our
questionnaire. He has weak attention, concentration, relaxing capacity and tolerance to frustration. He
has interest in video games, virtual reality, ocean, Universe and animals but few knowledge. He uses
cartoons and draws to relax. He reacts negatively to new environments and abrupt changes to current
environments. Besides he doesn’t speak which left us with no verbal feedback from him.
He was very agitated at the beginning as he was on the testing of the third version presented before. He accepted to use the VR-HMD 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.

The therapist conclusions goes in line with what we described before. She says the child was anxious, agitated and curious before the interaction, curious and more calm during the interaction but agitated again after the interaction. He had few difficulties with the VR-HMD although having some difficulties with the game during the interaction (the need of our orders for him to understand what to do). Although the child wasn’t very relaxed in general, he was during the mini-games and observation of the environments. So only for a brief moment of the interaction he was able to regulate and calm down but wasn’t able to keep his relaxing state after everything ended. To note that he his an extremely active child and has told by his mother on the questionnaire he has weak attention, concentration, relaxing capacity and tolerance to frustration. The therapists mentions on the observations that the fact that there isn’t a physical barrier make the child not have spatial notion.

Due to technical problems we weren’t able to get data information to discuss.

5.3.2 Child M

Child M, with 11 years old, suffered from a severe autism. The child didn’t communicate and had stereotypic behaviors (i.e repetitive behaviors). His parent was always present and helped during the process. His parent filled our questionnaire to get the child profile. He has very weak attention, concentration, relaxing capacity and tolerance to frustration. We has low interest and knowledge in video games, virtual reality, ocean, animal or the Universe. He uses music, visual stimuli and toys to relax. Finally he reacts negatively with abrupt changes to the environment and to new environments.

The first challenge was to put the HMD 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 HMD 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 Unity engine, the occurrence of events. We made the Fish Tangram 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 tangram we had to stop the interaction because the child couldn’t relax and was trying to remove the headset.

In the conclusions questionnaire the therapist says the child was relaxed before the interaction, disturbed during the interaction due to the headset and relief after he removed it. He was clearly disturbed during the whole time and the study had to stop due to his weak tolerance on the HMD.

Regarding the data collection his positional velocity, fig 5.1, was close to zero most of the time because he was sitting on a chair. Some of the spikes on the graphic may be related with: headset falling, parent near the child and making the sensors loose track of the child and adjustments on the headset during the interaction. Regarding the angular velocity, fig 5.2, we can clearly see by the end of the interaction more constant and abrupt changes on the velocity meaning the child was getting more intolerant as the time went by. For this reason we had to stop the interaction and end the study.

![Figure 5.1: Child M positional velocity change along the interaction.](image1)

![Figure 5.2: Child M angular velocity change along the interaction.](image2)
Even with negative results the conclusions are in line with what we established before in section 4.1. As told by other therapists severe cases of autism weren’t the most appropriate population to try this study. As predicted they could be intolerant to the VR-HMD which we can clearly see on these conclusions.

5.3.3 Child G

Once again we had child G to test our final version. Most importantly this child tried all the versions and now we can establish an evolution of his feedback and reactions.

Child G with 10 years old suffers from Asperger’s Syndrome. His profile indicates he has a strong interest in video games, virtual reality ocean, space and animals. However he has difficulties in relaxing. The whole interaction had his father present.

The child was always eager to try again and without any hesitation we started the interaction with everything setup. Even though he hadn’t issues with the VR-HMD, 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.

On the therapists conclusions the child was anxious, lively and curious before the interaction, lively and curious during the interaction and curious and enthusiastic with the Unity engine and how it worked. During the interaction the child had some difficulties regarding the virtual equipment but none difficulties regarding the interaction. In general the child wasn’t very relaxed except during the tangrams. During the observation of space and relaxation sequence according to the therapist we wasn’t relaxed at all. Nonetheless she pointed some observations he made like understanding the activity (“...look its a tangram!”), “...this illusion is bit odd.”, “...the music is relaxing...”, lack of a body reference for self-organization (“...I don’t have a hand...”) and she pointed that he stays relaxed while he does the activity, after exploring all the options he can’t fixate in any activity, he doesn’t use it as relaxation effect.

Note again that some data spikes may be related with: the headset falling, headset adjustments and teleporting in-game. The data collector though that the abrupt change in the virtual positional velocity was a real world positional change.

With the data we can see less spikes of velocity, fig 5.3 and fig 5.4 until the end of the interaction. It means that while the child had something to do (i.e interact with the tangram, observe the space sequence), he was more calm. After all ended he was curious to explore more of the room and kept asking questions about what could he do more and giving opinions on what to implement. He suggested to have an option to choose between the different rooms he tried on the other versions.
Nonetheless this was the version he showed more sign 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. Most notorious was the constantly asking for virtual hands. This is an individual need that may be shared with other ASD individuals, which leads us to conclude that the best course of action is to have the possibility of presenting virtual hands if desired.

![Child G Positional Velocity in m/s](image3)

Figure 5.3: Child G positional velocity change along the interaction.

![Child G Angular Velocity in m/s](image4)

Figure 5.4: Child G angular velocity change along the interaction.

Unfortunately our study population was less then was expected to be. Due to it our conclusions are limited but nonetheless we have positive and negative aspects do discuss on our conclusions on the next section.
6 Conclusion

Contents

6.1 Future Work ............................................... 74

71
On this thesis we proposed to study how VR can calm and relax children with ASD. We now summarize what we study from the beginning and what we can conclude with our results.

We first defined what is ASD and their problems defining a part of this population to use on our study. Some of their problems consist on cognitive abilities, attention, difficulties in the process of sensory input and stereotypic behavior (i.e repetitive behaviors). We concluded that the most appropriate spectrum of autism that could be treated by our approach would be the Asperger Syndrome, the Pervasive Development Disorder-Not Otherwise Specified and the Autism Disorder. We then studies different techniques used on children with ASD like Sensorial Integration, Applied Behavior Analysis and the use of the Snoezelen Room. We decided to inspire on the Snoezelen Room to study the relaxing effects such VR scenario could have.

Then, we analyzed some of the most important work related to ours. Dorothy Strickland, [22], studied many years before the acceptance of the VR-HMD. Communities like Autcraft, [38], are built for the special needs this populations have and use mini-games or special rooms reassembling the Snoezelen Room to relax his users.

Therefore we created a virtual reality game that had relaxing elements to study how it affects children with ASD. Additionally we studied the acceptance of the VR-HMD.

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-HMD. The study had to be interrupted which leaves us with few data to analyze.

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 tangram 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 it may be possible to observe relaxing effects after the interaction and not only during it.

Further we can also conclude of the three cases success in accepting the VR-HMD which goes in line with work discussed in 2.

### 6.1 Future Work

We now make propositions on what could be improved regarding the game. First of all the game 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. As we already mentioned the possibility of having virtual hands (with controllers) is something to be explored. 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 ADL, 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.

Further we propose to have a customizable game for therapists to change and adapt to the child needs. Some of the customizations could be, sounds, musics, skybox scenarios (e.g space, forest, water) and specific stimuli (e.g lights, particle systems) customization. This way it may be possible to offer another therapy tool to be used on sessions with children with ASD.

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.
Bibliography


Appendix A

1. Gender?

2. Age?

3. Profession?

4. For how long have you been working / worked with individuals with ASD?

5. Which types of ASD have you been working / work with?

6. Which techniques/methods/concepts have you used with individual with ASD?

7. Have you ever used any game or application as an intervention for individuals with ASD?

8. What is your interest in a VR game to help individuals with ASD adapt to different contexts and scenarios? (Likert scale)

9. Do you think the game may be useful both for you and for the individuals with ASD?

10. What age range would be the most adequate for the use of the VR game?
11. What types of ASD would be more adequate for the use of the VR game?

12. What problems may arise from the use of the VR HMD?

13. Suggestion or opinions you would like to give?
Appendix B
Autorização para participação em estudo

Caro(s) pai(s)/encarregado(s) de educação,

Venho por este meio pedir o seu(vosso) consentimento para a participação do(a) seu(sua) filho(a) na realização de um estudo no âmbito da minha tese de Mestrado em Engenharia Informática e de Computadores (pelo Instituto Superior Técnico da Universidade Técnica de Lisboa) sob a orientação do Prof. Rui Prada.

A minha tese tem como objectivo investigar a potencial utilização de novas tecnologias em terapias com crianças com Perturbações do Espectro do Autismo (PEA). Para tal, será realizado um estudo onde as crianças terão a possibilidade de interagir num mundo virtual através de um jogo com o uso de um sistema em realidade virtual (HTC-Vive www.vive.com). Este estudo pretende analisar a aceitação dos óculos de realidade virtual e o potencial efeito de relaxamento/concentração que o jogo poderá ter.

O estudo irá decorrer nas instalações da Clínica Passo a Passo no dia 30 de Setembro de 2017. Será realizada uma sessão com uma duração de 15-20 minutos. A terapeuta estará presente durante o decorrer da sessão. De forma a podermos avaliar as interações, os testes serão gravados em vídeo. Outras medidas métricas como a quantidade de movimentos da criança e rapidez dos mesmos serão gravados pelo jogo e posteriormente analisados. Toda a informação recolhida será anónima, totalmente confidencial e utilizada unicamente para fins de investigação. A participação será voluntária; a criança pode desistir da interacção a qualquer altura se assim desejar.

A sua participação é importante para que possamos descobrir novas e melhores maneiras de ajudar crianças com PEAs. Estarei disponível para o esclarecimento de qualquer dúvida.

Atenciosamente,
Miguel Filipe Morais Pólvora
Tel: 967 522 040
Email: miguelfmpt@gmail.com

Eu, ____________________________________________
autorizo a participação do(a) meu(minha) filho(a)/encarregado de educação
__________________________________________, acompanhado(a)
por ____________________________________________, no estudo em questão.

_________________________________________________________________

Figure B.1: Consent Form.
Perfil da Criança

Nome: ____________________________________________________________

Idade: ______

Espectro de Autismo: ____________________________________________

A. Qual o nível da criança nas seguintes competências:

<table>
<thead>
<tr>
<th>Não sabe</th>
<th>1 (Muito fraco)</th>
<th>2 (Fraco)</th>
<th>3 (Moderado)</th>
<th>4 (Bom)</th>
<th>5 (Muito Bom)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atenção/ Concentração</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacidade de relaxar</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tolerância à frustração</td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

B. Qual o interesse da criança nos seguintes temas:

<table>
<thead>
<tr>
<th>Não sabe</th>
<th>Criança não tem</th>
<th>1 (Nada interessado)</th>
<th>2 (Pouco interessado)</th>
<th>3 (Interessado)</th>
<th>4 (Muito interessado)</th>
<th>5 (Extremamente interessado)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jogos de computador</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Realidade virtual</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Oceano</td>
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<tr>
<td>Universo</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Animais</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
C. Qual a experiência/conhecimento da criança nos seguintes temas:

<table>
<thead>
<tr>
<th>Não sabe</th>
<th>Criança não tem</th>
<th>1 (Muito fraco)</th>
<th>2 (Fraco)</th>
<th>3 (Moderado)</th>
<th>4 (Bom)</th>
<th>5 (Muito Bom)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jogos de computador</td>
<td></td>
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<td></td>
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<tr>
<td>Realidade virtual</td>
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<tr>
<td>Oceano</td>
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<td>Universo</td>
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<tr>
<td>Animais</td>
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</tbody>
</table>

D. Quais os recursos que a criança utiliza para relaxar? (Ex: Jogos, música, filmes, estímulos visuais, objectos)

E. Geralmente qual a reacção da criança a mudanças bruscas do ambiente envolvente?

F. Geralmente qual a reacção da criança a novos ambientes?
Conclusões da interacção

A. Qual/quais o(s) estado(s) de humor da criança antes de começar a interacção:

☐ Ansioso
☐ Relaxado
☐ Animado
☐ Curioso
☐ Assustado
☐ Triste
☐ Zangado
☐ Outra(s)? Qual/quais:

B. Qual/quais o(s) estado(s) de humor da criança durante a interacção:

☐ Ansioso
☐ Relaxado
☐ Animado
☐ Curioso
☐ Assustado
☐ Triste
☐ Zangado
☐ Outra(s)? Qual/quais:

Figure B.4: Conclusions 1.
C. Qual/quais o(s) estado(s) de humor da criança depois de terminar a interacção:

- Ansioso
- Relaxado
- Animado
- Curioso
- Assustado
- Triste
- Zangado
- Outra(s)? Qual/quais:

D. O material de realidade virtual (óculos, fones, fios, sensores) perturbou a criança durante a interacção?

- Nunca
- Poucas vezes
- Algumas vezes
- Muitas vezes
- Sempre

E. A criança sentiu dificuldades durante a interacção?

- Nunca
- Poucas vezes
- Algumas vezes
- Muitas vezes
- Sempre
F. De modo geral, qual o nível de relaxamento da criança durante toda a interacção?

![Scale for relaxation levels]

<table>
<thead>
<tr>
<th>Introdução da sala</th>
<th>Pouco relaxado</th>
<th>Relaxado</th>
<th>Muito relaxado</th>
<th>Extremamente relaxado</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tangram do peixe</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tangram da baleia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observação do oceano</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observação das estrelas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observação do espaço e planeta Terra</td>
<td></td>
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</tbody>
</table>

Observações (comentários da criança, acções inesperadas, opiniões sobre a interacção, outras):

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

Figure B.6: Conclusions 3.