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Immersive VR eHealth Strategies: VR games to treat schizophrenia negative symptoms

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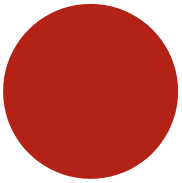

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Resumo

A esquizofrenia é um transtorno mental que recorre a tratamentos de reabilitação cognitiva para ajudar a reduzir os sintomas que não podem ser tratados com medicação. Em geral, os tratamentos farmacológicos não são eficazes no controlo dos sintomas negativos da doença. Os sintomas negativos incluem, entre outras dificuldades, a diminuição da motivação e do interesse em realizar atividades simples. As opções de tratamento disponíveis que utilizam tecnologias modernas ainda apresentam limitações devido à sua complexidade, falta de diretrizes de desenvolvimento e outros fatores relacionados, que impedem a obtenção de melhores resultados no controlo dos sintomas da doença e na melhoria da qualidade de vida da pessoa.

Neste contexto, o objetivo principal da presente investigação foi o estudo de estratégias de eHealth que possam ser utilizadas em tratamentos de saúde mental, em particular, estudar a aplicação de jogos sérios de Realidade Virtual (VR) no tratamento de sintomas negativos em pacientes com diagnóstico de esquizofrenia. Para isso foi utilizado um motor de jogo para desenvolver um protótipo de um jogo sério de VR que simula espaços e tarefas de atividades da vida diária, propondo a resolução de problemas. O protótipo permitirá a estimulação e treino de funções cognitivas, contribuindo para a avaliação das capacidades cognitivas do paciente, bem como ajudá-lo a superar os sintomas negativos. A visualização e interação com o jogo é efetuada através de um Head Mounted Display (HMD) de VR e controladores associados, através do qual o jogador recebe indicações do jogo e atua sobre os elementos aí representados.

Espera-se que a sua utilização de forma regular ajude a pessoa a tornar-se mais confiante, aumentando a sua motivação para fazer terapia, com uma mentalidade mais positiva e acelerando o processo de recuperação da sua vida normal.

O protótipo foi testado com 21 participantes e os resultados foram na sua maioria positivos. A partir do estudo realizado e dos resultados obtidos, foi possível identificar um conjunto de características importantes, bem como diretrizes, que podem auxiliar no desenvolvimento de jogos nesta área. No futuro, espera-se alargar os testes realizados a pacientes com diagnóstico de esquizofrenia, e envolvidos num processo de terapia cognitiva.

Palavras-chave: Realidade Virtual, Design de jogos, Jogos Sérios, Esquizofrenia, eHealth

Abstract

Schizophrenia is a mental disorder that uses cognitive rehabilitation treatments to help reduce symptoms that cannot be treated with medication. In general, pharmacological treatments are not effective in controlling the negative symptoms of the disease. Negative symptoms include, among other difficulties, decreased motivation and interest in performing simple activities. The available treatment options that use modern technologies still have limitations due to their complexity, lack of development guidelines and other related factors, which prevent better results in controlling the symptoms of the disease and improving the person's quality of life.

In this context, the main objective of the present investigation was the study of eHealth strategies that can be used in mental health treatments, in particular, to study the application of Virtual Reality (VR) serious games in the treatment of negative symptoms in patients diagnosed with schizophrenia. To achieve that a game engine was used to develop a prototype of a serious VR game that simulates spaces and tasks of daily life activities, proposing problem solving. The prototype allows the stimulation and training of cognitive functions, contributing to the assessment of the patient's cognitive abilities, as well as helping them to overcome negative symptoms. The visualization and interaction with the game is carried out through a VR Head Mounted Display and associated controllers, through which the player receives game indications and acts on the elements represented therein.

It is hoped that its use on a regular basis will help the person to become more confident, increasing their motivation to go to therapy, with a more positive mindset and speeding up the recovery process to get back to their normal life.

The prototype was tested with 21 participants and the results were mostly positive. From the study carried out and the results obtained, it was possible to identify a set of important characteristics, as well as guidelines, which can help in the development of games in this area. In the future, it is expected to extend the tests performed to patients diagnosed with schizophrenia, and involved in a process of cognitive therapy.

Keywords: Virtual Reality, Game Design, Serious Games, Schizophrenia, eHealth

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First of all, I would like to give a special thanks to my advisor Paula Rego for all the care, support and guidance she gave me throughout this past year and for writing my recommendation letter that helped me get in this master. Equally, I would also like to thank my co-advisor António Coelho for all his assistance with the dissertation. I would like to give a big thanks to the professors Pedro Moreira, Pedro Faria and Luís Romero for all their extra help that was very much needed. And also, I could not forget to thank all my professors from my Bachelor's and Master's for being a part of this long journey and for everything they taught me.

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Last but not least, I would like to thank my parents and siblings, the most important people I have in my life, for all the unconditional love. To my whole family I thank them for all their care and for believing in me.

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Beatriz Almeida Miranda

Contents

List of Figures

List of Tables

Acronyms

2D	Two-Dimensional
3D	Three-Dimensional
AR	Augmented Reality
CCTV	Closed Circuit Television
DBR	Design-Based Research
DGBL	Digital-Game Based Learning
ECGM	Multimedia and Computer Graphics Engineering
eHealth	Electronic Health
EI	Informatics Engineering
HMD	Head Mounted Display
IEEE	PubMed, Institute of Electrical and Electronics Engineers
IT	Information Technology
MASI-VR	Multimodal Adaptive Social Intervention in Virtual Reality
MC	Master in Cybersecurity
MEI	Master in Informatics Engineering
MR	Mixed Reality
OS	Operative System
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-analyses
SDK	System Development Kit
SST-VR	Social Skills Training VR
SUS	System Usability Scale
VCS	Version Control System
VR	Virtual Reality
VR-VRTP	VR Vocation Rehabilitation Training Program
VRVTS	VR Vocational Training System
VSST	Virtual Supermarket Shopping Task
UI	User Interface
UX	User Experience

1. Introduction

1.1 Context and Motivation

Schizophrenia is a complex chronic brain disorder (Torres, 2020) that affects less than 1% of the world population (Schizophrenia, 2022). When untreated it is characterized by symptoms like hallucinations, delusions, disorganized speech and lack of motivation (Correll & Schooler, 2020; Torres, 2020). However, when properly treated, symptoms can decrease and become less of a burden to affected individuals. In that sense, antipsychotic medication and interpersonal therapy has been enhanced over the years with the development of new and better treatment options. In regards to therapy, positive results like a decrease in symptoms and rehospitalization rates and an increase in treatment compliance, social cognition and quality of life have been shown in recent studies (Sotos, Caballero, & Jimenez, 2020). One of the most recent strategies used is the integration of VR serious games, games with the main focus of developing new/existing skills instead of just pure entertainment, to obtain longer lasting results and higher motivation rates.

Despite the promising results obtained, digital interventions using VR and eHealth technologies, health services delivered using the internet or related technologies, are not yet as established as a well-founded recommended treatment like those with medication and traditional forms of therapy (Sotos, Caballero, & Jimenez, 2020). Consequently, it is of great importance that we standardize this kind of therapy, make it easily accessible by anyone, decrease its development costs and increase its quality. Yet, first it is necessary to understand the current state of similar treatment options, their limitations, strong and weak points to develop a solution. One way of standardizing this type of intervention is to develop guidelines for therapists and developers to follow.

Additionally, part of this study was developed as a part of the GreenHealth project, where the author works as a research fellow. This project includes a multidisciplinary team of researchers and specialists, including professionals in the field of medicine and rehabilitation therapy who are responsible for clinical validation of the analyzed tasks and proposed layout of the spaces where the interactions take place. The study of existing solutions, the implementation of the virtual environment and the proposal and implementation of interaction mechanics, as

well as the studies with the users were developed by the author within the scope of the work here presented. Also, as a part of the project, the background and the state of the art presented at chapters 2 and 3 were submitted as a systematic literature review to an international journal (impact factor 3.160). The systematic review is currently waiting for a final response from the reviewers, but can be seen in Appendix A.

1.2 Problem Statement

If possible, having schizophrenia should not be a concern to anyone diagnosed with it and it should not affect their quality of life in any way. If there was a cure or an effective treatment, patients would not experience any kind of maniac behavior or struggle socially at any level. However, at the moment we have reached the conclusion that there is no cure for this disorder (Torres, 2020), so people who suffer from it need to rely on antipsychotic medication and one-on-one therapy to reduce their symptoms (Park, Kim, Lee, Na, & Jeon, 2019). And, although most people manage to live an ordinary life with minimal symptoms, for some people available treatment options are not enough.

In reality, medication is generally effective in managing the positive symptoms, but when it comes to negative symptoms, the available medication remains not so successful (Correll & Schooler, 2020). The symptoms of schizophrenia are usually classified into: positive symptoms, any change in behavior or thoughts, such as hallucinations or delusions, and negative symptoms, where people appear to withdraw from the world around them, take no interest in everyday social interactions and activities. Moreover, the necessary medication needed to be taken by individuals to reduce their positive symptoms often causes several side effects, one of them being the increase in negative symptoms. Consequently, there is a big necessity to develop high quality therapy interventions to help reduce this current gap.

Therefore, it is intended to study current negative symptoms treatment options, to understand what are their strengths and weaknesses, and then propose ways to develop more effective interventions that theoretically will help reduce in a long term those symptoms and increase the overall quality of life of people who suffer from this condition.

It is important to point out that, due to the concern that VR may cause the reappearance of positive symptoms, this study will only focus on the development of treatments to reduce negative symptoms in people who are on psychotic medication and with no active signs of any kind of positive symptoms.

1.3 Research Questions and Objectives

What eHealth strategies can be applied to positively affect mental health therapy for schizophrenia patients is the main research question of this study. Subsequently, this poses sub questions like:

- What are the current eHealth trends in the treatment of schizophrenia?
- What is the impact of immersive VR on schizophrenia negative symptoms?
- How can immersive VR positively affect mental health therapy?
- How can VR improve, on a long term, negative symptoms?
- How to develop more effective serious games for therapy using immersive VR?

Such questions are also considered in order to better define and lead the focus of this investigation. To answer these questions, this study aims to identify eHealth strategies that positively affect mental health therapy. Therefore, the research objectives are to explore the efficiency of eHealth and immersive VR techniques used in schizophrenia therapy, to develop an immersive VR serious game targeted at schizophrenia therapies, and then to propose recommendations to be used in mental health game therapies using VR in terms of increasing therapy results.

1.4 Methodology

In terms of research methodology, the approach for this research is a descriptive inductive process of gathering data to build concepts and hypothesis, based on the Design-Based Research (DBR) model proposed by Reeves (2006) and shown in **Erro! A origem da referência não foi encontrada.**. The model is based in a four-stage iterative process aimed at finding problems, designing solutions and then iterating on them, by the refinement of the solutions based on the results obtained. The first stage focuses on the analysis, by the researcher, of the research problems found. The second stage attempts to develop solutions for the practical problems based on the current design principles and available technology. The third stage implements those solutions and tests them to then make improvements. And finally, the fourth stage studies the outcomes to produce "Design Principles" and enhances the solutions outlining potential future work opportunities. On a more in depth view of the methodology used on this study and in relation to each chapter, the analysis of the problem is study of the state of art, the design stage is the system description, the implementation and testing is the implementation and testing of prototype and the outcome is the results and conclusions.

This way, to address the key research objectives, this study will use non-experimental qualitative methods. Primary sources of data should be, ideally, people with schizophrenia negative symptoms. As a researcher, my position in the data collecting trials will mostly be as an observer. As a result, the data collected will provide information about the game usability, on

missing main requirements, validity of the data collection during sessions, a more insight patient and therapist point of view and some other important considerations.

Correspondingly, secondary sources of data will be achieved by an extensive state of the art study, including reports and thesis on the related subjects. Other reputable sources like journals, newsletters, newspapers, books and websites may be included as well.

In terms of instruments, method analysis will be based on the qualitative content analysis that resulted from the secondary data collected. In addition, the opinion given by the participants in the validation tests, regarding a more therapy efficiency point of view, along with the participant observation and field notes, collected while testing, will be taken into consideration for the data analysis.

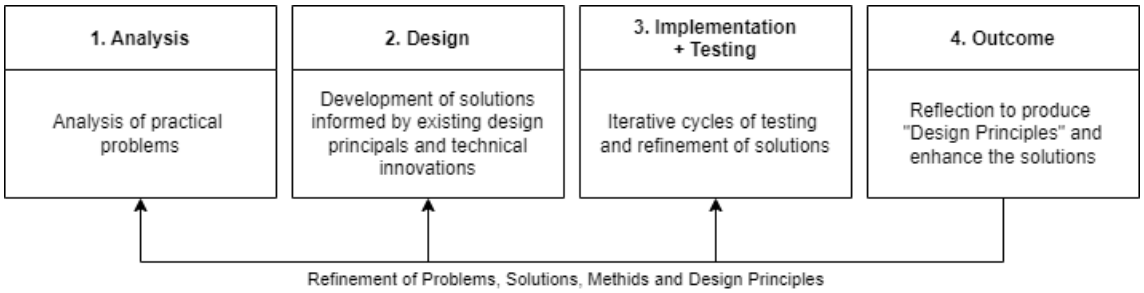

Figure 1 - The 4 stage DBR model (Reeves, 2006)

1.5 Summary of Contents

This section briefly describes the layout of the document, how many chapters it is divided and which aspects are discussed in each chapter.

1) **Introduction:** The current chapter has the purpose of introducing the reasons behind this study. By reading it, anyone needs to be able to understand the importance of the study of this subject, its main goal, as well as the strategy used to achieve the desired results.
2) **Background:** Most of the required previous knowledge, necessary for anyone to comprehend this study at a good level, is briefly explained in this chapter, right before the start of the study of the subject in depth. This includes concepts more related to technology, like VR, as well as concepts more related to health, like schizophrenia, and the concepts that connect these two.
3) **State of the Art:** Chapter 3 illustrates the current state of research in the field of study. It describes the main results obtained by different studies and to which conclusions they have reached, up to date, and how those relate to what this study aims to conclude.
4) **System Description**: Describes the study of the target audience used to design the prototype necessary for this study.

5) **Implementation:** This chapter explains the implementation of the functional prototype designed specifically to be used with the study, to both test the assumptions made and understand how the development of this type of system works.
6) **Results Analysis:** In here, is described the testing of the prototype and theories stage, including how tests were planned, how tests were performed and the discussion of the obtained results.
7) **Conclusion and Future Work:** Finally, the last chapter is meant to discuss all the work developed, draw conclusions accordingly and reflect on potential future work that either requires more time or resources to complete.

2. Background

2.1 Introduction

The industry of VR games has been growing exponentially over the years, and with its popularity, not only big companies are investing in this technology. Since VR has become so mainstream, it is now available for everyone to try and easily develop for it, at affordable prices. As a result, a wide variety of distinct types of content is also being released for this platform, including videos, virtual tours, social platforms and serious games. When it comes to serious games, they provide a fun way of learning something new or developing existing skills in a completely immersive environment. Besides their use for pure entertainment, they can also be used in fields such as education, art, tourism, health and so on.

As it happens, serious games have been used in the health sector for years, both for education purposes and in the treatment of certain conditions. It can be used as a part of physical, occupational and speech therapies to promote faster results. One example of interventions making use of serious games is the psychosocial therapy administered in people with schizophrenia. The use of treatments like immersive VR serious games to treat schizophrenia patients is only one of the many ways that can be used to apply eHealth strategies to improve the well-being and quality of life of these individuals.

This way, in order to fully grasp all the knowledge involved in this study, chapter 2 presents an exploration of the main concepts, the difference between them, current advances and how they can be related with each other in fields like the one of this study. The two subjects most distinct from each other are VR and schizophrenia. The use of concepts in between, like Serious Games and eHealth can be used as a bridge to connect the two main subjects and study them.

2.2 Virtual Reality

2.2.1 Definition

The term VR is commonly used to describe a three-dimensional (3D) computer made environment that can be virtually navigated and interacted with (Lambe, et al., 2020). With the rise in popularity in the last few decades, this term has become strongly associated with the type of VR that uses headsets to give a fully immersive experience to users, but the term is wider than that. Actually, VR can be categorized into three distinct categories (Heizenrader, 2019):

- **Non-immersive VR:** The experience of virtual environments through a flat screen. Commonly used in game consoles and computers;
- **Semi-immersive VR:** The use of several screens together with other specific devices that mimic physical mechanisms. It is commonly seen in flying and driving simulators;
- **Fully-immersive VR:** The use of VR headsets to fully immerse users in the virtual world.

On that note, fully-immersive VR, also referred to as immersive VR or just VR, on the contrary to non-immersive and semi-immersive VR, does not make use of a flat screen to display the digital content, instead needs to use a VR headset, placed on the users' head, that has one screen for each eye (to create the illusion of vision depth like in the real world), blocks their vision from real world and tracks its head and body position (University of Toronto, 2021).

Most of this promising technology's popularity comes from the games industry, with companies increasing the release of VR versions of already popular games as well as producing completely new games specifically to be played in VR headsets. Nonetheless, its potential goes beyond just games for pure entertainment. Its application has been used for years in areas such as education, medicine, art, military, engineering and so on (Aniwaa, 2021). For instance, in education, this technology can be used to emerge classrooms and supplement teaching of subjects (University of Toronto, 2021) like history or science, enabling students to experience what it was like to live in a lost civilization or see what the human body looks like from the inside. In fields such as the military, VR has been used for years to train soldiers in combat, enabling them to gain the necessary skills without getting injured and at much lower costs.

2.2.2 The Difference between Virtual, Augmented and Mixed Reality

Although quite different from each other, for those not so familiar with these types of technologies, VR, Augmented Reality (AR) and Mixed Reality (MR) may seem to not have that much of a difference. Since this study will only focus on VR, it is important to clearly

comprehend what the term is referring to. Overall, the main difference stands on how each one views and interacts with physical reality. In this sense, having understood the definition of VR now follows the explanation of what the other two similar concepts mean:

- **Augmented Reality:** This technology displays virtual content into a direct or indirect view of the real world, through some sort of device, mostly seen in smartphone applications, but it can also be seen in AR glasses as well. Essentially, the virtual content does not interact with the real world, it just augments it, adding new objects or characters that can only be seen and interacted with through the device that is being used. When it comes to mobile phone usage, users hold their phones in front of them and the AR system uses the camera to view the area around the user, calculating in real-time the existence of points of interest, like floors, ceilings, walls or faces, and virtually add 3D animated objects in such a way that they look like they are actually there. Some well-known examples of applications that use AR technology are the IKEA Place (Figure 2), a mobile app to help visualize how furniture will look in a room, Pokémon GO, a game that allows users to hunt virtual Pokémon characters using real world coordinates, and Instagram, which allows users to add real-time video filters to their faces (North of 41, 2018).

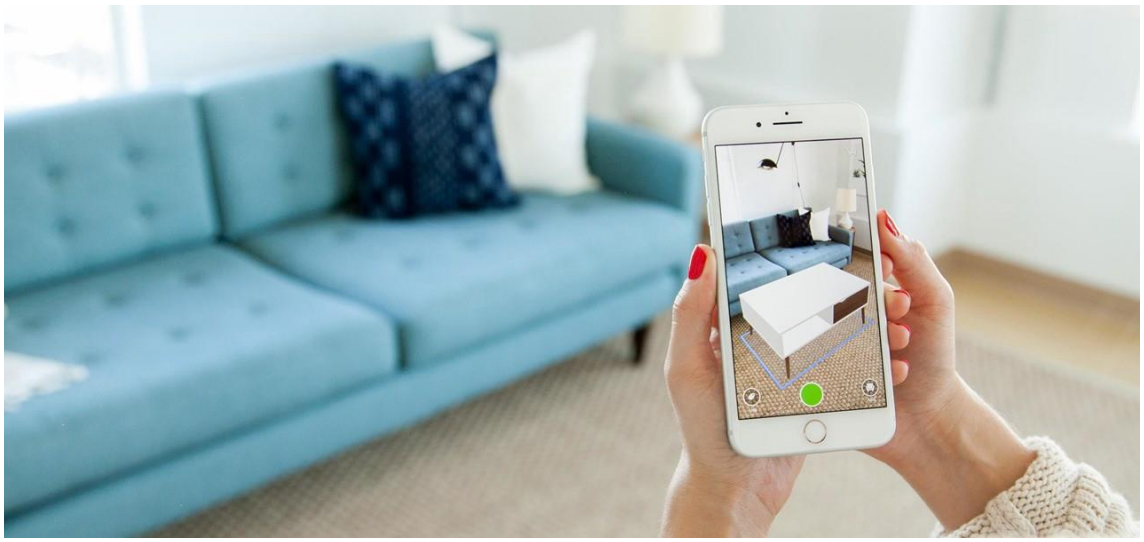

Figure 2 – Ikea Place (2018)

- **Mixed Reality:** It can be defined as a mixture of AR and VR, in the sense that it merges physical and virtual realities in a way that both real and digital objects can interact with each other. Like VR, MR uses a Head Mounted Display (HMD) and lets users interact with the mixed reality with their hands. But, unlike VR, users are not taken into a completely new world. Instead, they can still see everything around them as well as all the virtual features. Thus, these types of devices are hyper-aware of their real-world surroundings and take into consideration physics and

dimensions, which grant them enormous potential to replace mobile phones, computers and televisions in the future. Still, examples of MR system are not that common when compared with VR and AR. For instance, RoboRaid (Figure 3) is a game where the player needs to defend its home from a robot invasion and HoloAnatomy is an app that helps students study human anatomy (Girnyak, 2021).

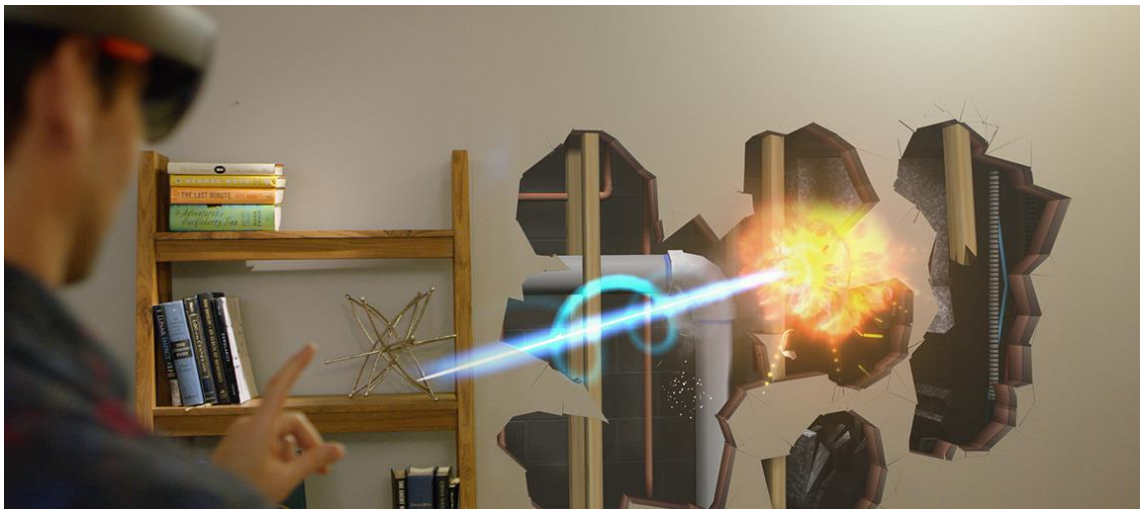

Figure 3 – RoboRaid (2016)

2.2.3 VR Technology Options

Whether to play a game or watch a video, these types of VR systems always require the use of some kind of VR HMD to allow users to be fully immersed in the experience. That said, all current available VR headsets fall into one of three categories:

- **Smartphone VR Headsets:** These are the most affordable and easy to use options in terms of VR headsets. It is essentially a combination of a head strap with a set of lenses and a place to slide a mobile phone. The user needs a correctly sized phone to use the headset. Likewise, the experience happens completely on the phone, so its performance is dependent on it. Additionally, some of these HMD have one basic controller to perform actions in a similar way to when using a mouse. Due to their lower computational capacity and less functional controllers, these types of devices are mostly used to watching immersive videos rather than playing games (Noble, 2021). An example of a headset that falls in this category is shown in Figure 4.

Figure 4 – Samsung Gear (2018)

- **Standalone Headsets:** Standalone headsets have their own system, processors, batteries, storage and display, so they do not require a connection to any external device to function. They are wireless and always ready to use, which probably makes them the funniest and most promising way of using VR. So much indeed that, they represent the future of VR devices and companies already seem to be focusing mostly on this VR category. However, they are less powerful than computers and still offer an overall lower quality when compared with the PC-powered HMD's (Aniwaa, 2021). An example of a headset that falls in this category is shown in Figure 5.

Figure 5 – Oculus Quest 2 (2020)

- **Tethered VR Headsets:** PC-powered headsets require a connection to a computer to function, most often via cables. Since they can use the connected device's capacity, which needs to be a powerful gaming computer, tethered headsets are currently the best option, offering higher quality experiences and a better sense of immersion. In terms of controllers, just like the standalone devices, these come with

two game-like controllers, but more advanced devices have hand recognition mode to allow the replacement of the controllers with hand gestures (Aniwaa, 2021). An example of a headset that falls in this category is shown in Figure 6.

Figure 6 – HTC VIVE Cosmos (2019)

2.3 Serious Games

2.3.1 Definition

There is no doubt that games are a powerful and useful tool in people's lives. Games provide us with moments of fun and relaxation and are often a way of building relationships. Indeed, games do not necessarily need to be all about having fun. They can also be seen as something more serious that aims at helping people learn useful skills, like learning math or a language. In that sense, people started developing serious games, which do not have a primary purpose of providing entertainment (Rego, Moreira, & Reis, 2010). Although, their definition is wide and differs from study to study, it has been agreed that serious games can be defined as: games with a specific purpose that allow players to develop specific skills to be used in real life and that use the entertainment factor as one of the ways to keep them motivated, and not just as the game's main goal (Machado, Moraes, & Nunes, 2009; Machado L. S., Moraes, Nunes, & Costa, 2010; Rego, Moreira, & Reis, 2010; Susi, Johannesson, & Backlund, 2007). It is then fundamental that they encourage cognitive function, motivation and the possibility to build knowledge (Machado L. S., Moraes, Nunes, & Costa, 2010). Machado, et al., (2010) divide Serious Games are divided into three categories: those that raise awareness over issues, those that build knowledge and those meant for training of individuals.

Evidently, different fields such as education, military and health, for instance, can benefit from their use for multiple reasons. For instance, in the military field, soldiers do not need to risk their life in real situations to train their combat skills. Also, in the treatment of phobias, people do not need to actually be exposed to their fears to treat them, for example, they do not need to be at the top of a building or touch real spiders, to treat these types of phobias. Its use is really beneficial since it involves risks, lower costs, requires less time to obtain results and can be specifically targeted for what it is intended to get (Machado, Moraes, & Nunes, 2009).

In the case of the health sector, serious games have been used for several years as a part of therapies, to promote health, to monitor health and to train professionals (Machado, Moraes, & Nunes, 2009). Current rehabilitation therapies are often boring and repetitive, but when associated with games, they help not only in keeping patients more motivated for therapy, but also in pain management (Rego, Moreira, & Reis, 2010). And since they assist in the treatment of specific areas, such as physical and behavioral therapy, games developed for this purpose require the validation of medical professionals (Machado L. S., Moraes, Nunes, & Costa, 2010).

2.3.2 Other Concepts Related to Serious Games

Many other concepts like edutainment and game-based learning, for instance, are also based on the principles of combining entertainment with education. Although different from each other they are often mistaken. Breuer & Bente (2010) explain the main differences between those concepts as:

- **Entertainment education:** Any effort to make the learning process more entertaining either in a digital or a non-digital format.
- **Game-Based Learning:** The use of any kind of game for educational or learning reasons.
- **Serious Games:** Games that also have applications in areas other than education and learning, such as therapy, advertising, art, etc.
- **Gamification** The use of games and game mechanics, like leader boards and score, in non-game environments. For example, as a form of advertising to encourage engagement with a product or service (Dimitra, Konstantinos, Christina, & Katerina, 2020).
- **E-learning:** Learning systems like podcasts or games that combine digital media with learning, but do not necessarily merge education and entertainment.
- **Digital-Game Based Learning (DGBL):** The subcategory of Serious Games that has education/learning as its primary or exclusive goal.
- **Classical Edutainment Games:** A subset of DGBL mainly target at young children and mostly focused in addressing elementary school subjects like basic math and vocabulary.

Erro! A origem da referência não foi encontrada. presents an update with the introduction of the concept of gamification on the diagram proposed by Breuer et al. (2010), which represents the relations between each concept.

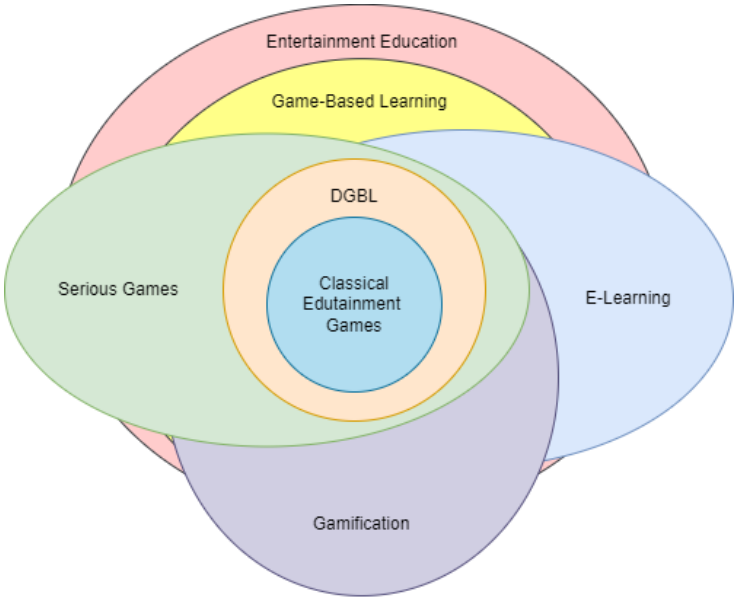

Figure 7 - Serious Games and other related concepts (Breuer & Bente, 2010)

2.4 eHealth

Health interventions are widely acknowledged to have a high potential for increasing patient engagement. Nowadays, those interventions are often based on eHealth technologies (Barello, et al., 2016). Even though eHealth has a wide range of definitions, it is understood as a way to incorporate technology into health done through the delivery of health services using the internet and other technologies. It is not just about using technology to promote good health and well-being. It is also an attitude, a way of thinking and a commitment to improve healthcare globally (Eysenbach, 2001; Shaw, et al., 2017). On that sense, Eyesenbach (2001) explains this attitude towards this concept as considering that the "e" in "eHealth" does not only stand for "electronic", but it can also refer other underlying ideals, such as: efficiency, in health care; enhancement, of quality of treatments; evidence based, since nothing should be just assumed; empowerment, of consumers and patients; encouragement, of good relationships between patients and healthcare providers; education, though online sources; enabling, information exchange between health care facilities; extending, the range of healthcare distribution; ethics, the concern for ethical issues; and equity, to make it available to everyone.

Certainly, the integration of medical informatics in public health management is improving the distribution of information to patients and consumers. This emphasizes the relevance of

Internet-related services in supporting, enabling, promoting, and improving health, as well as enhancing the efficacy and efficiency of the healthcare process (Barello, et al., 2016).

In reality, eHealth is now more than ever spread over everyone's life. For instance, it can be seen in smartwatches that monitor the user's heartbeat and daily steps, actively using technology to provide a basic form of health care (Shaw, et al., 2017). Another example of the application of these strategies can be found in the mobile applications to track COVID-19 cases and exposure to infected people, helping to keep people healthy and to fight the world pandemic. The tendency is that the frequency of examples like this will only keep growing, with the integration of more efficient technologies to assist people with all their needs and at one hundred percent of the time.

2.5 Schizophrenia

2.5.1 Definition

Schizophrenia is a serious mental disorder with no cure and is believed to be caused by a combination of genetics, environmental factors and psychosocial factors. Although it is not as common as other mental illnesses, like generalized anxiety or depression, it still affects one in every three hundred people around the globe (World Health Organization, 2022).

This condition affects how people think, speak, feel and behave and may affect their personal life, family relations, social integration and academic success. People also often experience discrimination and social exclusion as a consequence of their abnormal behavior and misconceptions about the disease, which can prevent them from getting access to health care services, education and employment (World Health Organization, 2022). Some of those misconceptions include thinking that schizophrenia is a multiple-personality disorder or that it causes aggressive behavior (Torres, 2020).

In fact, when the symptoms are active they commonly include: delusions, a fixed idea on something whether it makes sense or not; hallucinations, a perception of a nonexistent event or object; thought insertions, a feeling that one's thoughts, impulses or actions are placed in their mind and not generated by the individual itself; and disorganized thinking, speech and behavior (Torres, 2020; World Health Organization, 2022).

However, like with any other illness, the duration, severity and frequency of symptoms may vary, and when properly treated, the most impairing symptoms became almost nonexistent. Current available treatment options consist of the combination of antipsychotic medication, to decrease symptoms like hallucinations and delusions, with psychosocial therapy, to help develop social skills, deal with stress and identify early signs of relapse (Torres, 2020). The more traditional types of therapy include individual one-on-one therapy sessions with a therapist at a hospital or clinical setting, while the more advanced types of therapy may include the use of

immersive VR systems that guide the patient throughout the session, do not require the presence of a therapist and can be taken in the comfort of the patient's home. Some examples of this kind of studies are presented on chapter 3.3.

2.5.2 Schizophrenia symptomatology

Although schizophrenia is mostly known for its psychotic symptoms like delusions and hallucinations, in fact, those are just some of all the symptoms that individuals may experience. The two main domains in which the symptoms can be divided are denominated positive and negative symptoms. Those two domains can be briefly defined as follows (Correll & Schooler, 2020; Torres, 2020):

- **Positive symptomatology:** Abnormally present symptoms causing an excess or distortion of normal function, including symptoms like delusions, hallucinations and disorganized speech.
- **Negative symptomatology:** Abnormally absent symptoms leading to a diminution or absence of normal behaviors, including symptoms like a decrease in motivation and interest.

While people often get diagnosed with schizophrenia due to exhibition of positive symptoms, usually the first symptoms to appear are the negative, which are also the ones that persist for a longer period of life (Correll & Schooler, 2020). Because negative symptoms are so common in many mental issues and are easier to manage, many times patients may get misdiagnosed or only get diagnosed later in life.

In particular, the negative domain is composed of five main symptoms: the blunted effect, a diminution in facial expressions; the feeling of avolition, a reduction in goal-oriented activities; the feeling of alogia, a decrease in the number of words spoken; and the feeling of anhedonia, a decrease in the experience of pleasure (Correll & Schooler, 2020; Park, Kim, Lee, Na, & Jeon, 2019). These negative symptoms can be caused due to primary or secondary sources. Essentially, primary sources are the illness itself and the symptoms are a bit more difficult to manage with current available medication. Whereas, secondary sources may be the positive symptoms, medication side effects or other associated factors (Correll & Schooler, 2020).

3. State of the Art

3.1 Introduction

One of the most recent technological trends is eHealth (i.e., electronic health). From web-based applications to mobile applications, digital technologies hold tremendous potential to facilitate the delivery of healthcare for mental disorders, including schizophrenia. It can either be used to provide an assessment, (Lim & Penn, 2018) like real-time evaluation of emotions, thoughts, behaviors and physiological responses (Sotos, Caballero, & Jimenez, 2020), or used within an intervention, like prompting the individual to activate adaptive coping strategies (Lim & Penn, 2018). It is possible to provide challenges similar to the real ones, however, in a controlled way and compatible with the user's limitations (Rocha, 2015).

In schizophrenia, many of the basic mental and cognitive functions of individuals such as cognition, perception, and reality testing are all severely affected, often leading to social disengagement, apathy and lack of willpower (Patsi, Yfantidou, Antoniou, Gkoraki, & Lagiou, 2016). Causes of this anxious withdrawal include paranoia, menacing voices, social anxiety, poor self-image, panic attacks and lack of confidence (Lambe, et al., 2020). Mental health disorders are quite common and encompass great societal and personal costs, but far too few people receive the very much needed appropriate healthcare assistance. People who do receive treatment are more likely to be given psychotropic medication rather than psychological interventions (Freeman, et al., 2018).

Psychosocial interventions can be classified into in-person and computerized remediations. Standard interventions include exercises often considered repetitive and boring for patients (Rego, Moreira, & Reis, 2010) and treatment is delivered in the clinical setting, which lacks characteristics of real social situations (Calafell, Maldonado, & Sabaté, 2014). Among computerized interventions, the most recent interventions are based on VR, which seems to offer an interesting and motivating therapeutic option for patients suffering from schizophrenia (Calafell, Maldonado, & Sabaté, 2014; Park, et al., 2011; Sotos, Caballero, & Jimenez, 2020). VR is supposed to mimic the real world in an immersive environment (Amado, et al., 2016)

enabling the inclusion of diverse scenarios based on real-life situations (Sohn, et al., 2016), that otherwise would be too difficult and/or expensive to reproduce (Rocha, 2015).

The VR system can be one of the most important tools for therapists to train patients in the clinical setting due to the utilization of simulated social environments, interaction with diverse virtual persons, and the ability to provide rapid feedback to patients (Calafell, Maldonado, & Sabaté, 2014). Being a simulation, the level of exposure can be controlled, repeated training is simple and the situations are predictable (Sohn, et al., 2016) providing patients with the opportunity to actively tackle their daily functioning and, consequently reducing the negative symptomatology (Calafell, Maldonado, & Sabaté, 2014).

Although it presents tremendous benefits, digital interventions still need to overcome several limitations. Firstly, when digital technologies are not adequately designed or applied, it is possible that they will fail or take too long to detect patient risks (Lim & Penn, 2018). Secondly, there are technical issues such as dry eyes and motion sickness and user hurdles such as addiction (Park, Kim, Lee, Na, & Jeon, 2019). Thirdly, the reappearance of positive symptoms such as hallucinations and delusions need to be closely monitored (Tsang & Man, 2013). And lastly, current rehabilitation games lack motivational and entertaining aspects and regular games lack key components to allow an effective rehabilitation (Rego, Moreira, & Reis, 2010).

Additionally, these results hint that there is plenty of room to grow and several aspects to be improved. For instance, automated treatments delivered using VR could become an inexpensively way of providing effective interventions, without the need for a therapist to be present (Freeman, et al., 2018). For efficient learning it is also important to provide feedback on all the patient's correct and incorrect actions, allowing for adjustments in difficulty based on their performance (Adery, et al., 2019).

To conclude, there is yet a long way to go before developing solutions for VR game therapies. To the best of my knowledge, as regards the specific use of eHealth in the treatment of schizophrenia, it is a subject that has not been studied yet.

3.2 Study Selection Process

To perform the state of the art review on the available studies using VR game therapies in the treatment of schizophrenia it was used the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) methodology (Page, et al., 2021). To look for the research papers it was used the combinations of the words "Virtual Reality" or "VR" with "Schizophrenia" or "Negative symptomatology" on three databases: PubMed, Institute of Electrical and Electronics Engineers (IEEE) and Scopus. The inclusion criteria were being written in English and having at least one of the keywords mentioned above. A total of 74 results were found, from those it was applied the exclusion criteria, to select which ones would

be revised. The exclusion criteria were being systematic reviews, not being specifically targeted at schizophrenia, not being focused on negative symptoms, and not being about the development of a game therapy. This resulted in 19 papers to be screened, evaluated and excluded for particular reasons, which resulted in a total of 11 studies. Figure 8 illustrates this entire process.

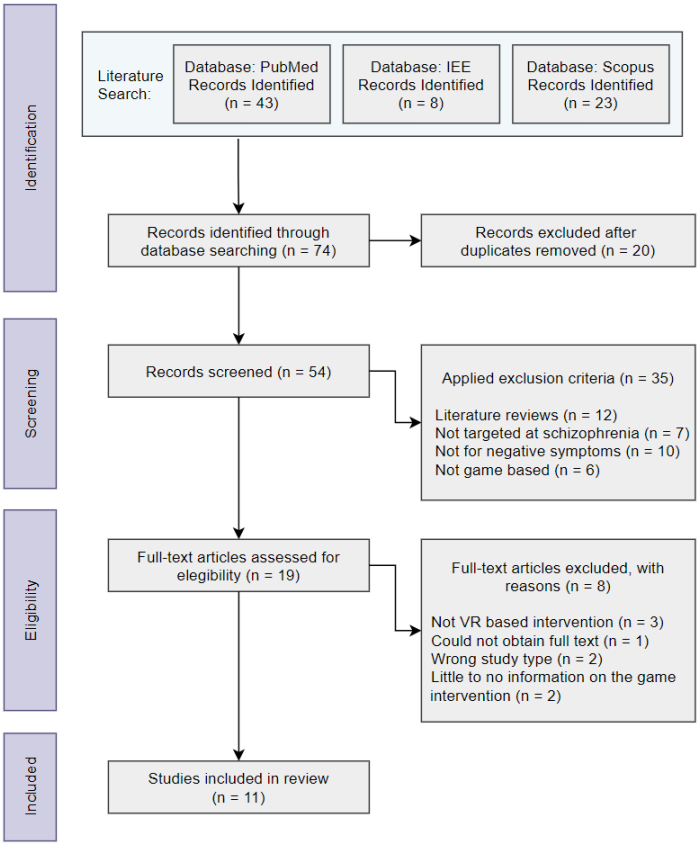

Figure 8 - Search process for study selection

This systematic review was submitted for publication in an international journal (impact factor 3.160) and is in the final phase of responding to reviewers. The submitted review can be seen in Appendix A.

3.3 Related studies

The resulting eleven studies, to be discussed, are similar to the current study, since they all also developed a VR system to be used in the treatment of schizophrenia. Following there is a more detailed explanation and analysis on the selected VR game therapies.

3.3.1 gameChange

Lambe et al. (2020) developed gameChange, an automated VR game therapy for patients with schizophrenia targeted at anxious avoidance of everyday social situations. Its main goal was to automate the delivery of psychosocial therapy, replacing the usual therapist with a virtual one and using commercially available VR equipment, reducing its costs and increasing its scalability.

The resulting product is an immersive VR game system based in six scenarios (**Figure 9**) of different difficulty. Nic, the virtual coach, is someone who guides players throughout the game, explaining how it works and introducing the goals of the treatment.

In the beginning and end of each session, patients are asked to rate their confidence levels in managing daily situations, to decide which scenario to move on to and measure the effects of the intervention. As patients progress though each scenario, the difficulty level increases by adding anxiety triggering elements, like Closed Circuit Television (CCTV) cameras, noise and more people, more challenging tasks, like ordering drinks or shouting across the room. It was expected that with these situations, patients would become more confident by facing fearful events.

Figure 9 - The 6 scenarios in gameChange (Lambe, et al., 2020)

3.3.2 Multimodal Adaptive Social Intervention in VR (MASI-VR)

Adery et al. (2019) developed a non-immersive VR social intervention, MASI-VR, for improving social functioning and clinical outcomes and examine the feasibility and acceptability of schizophrenia patients to this kind of intervention. It was intended to enhance social skills in a stress-free virtual environment.

To achieve that, they implemented three game scenarios, a bus stop, a grocery store and a cafeteria with a total of twelve social missions that varied in difficulty, i.e., four easy, four medium and four hard. Mission difficulty was determined by the number of social interactions required to complete it. Those social interactions included tasks like greeting people, starting conversations and requesting information. Midway through the game, realistic background

noise was added to also increase mission difficulty, for example, a quite bus stop allows for easier and less stressful situations than during a noisy peak hour.

Every session requires the player to select a mission, which begins by allowing the player to freely explore the scene and choose with who they should engage to start a conversation and complete the mission goal. In addition, if the player performs any wrong action, audio feedback was played explaining why they made a mistake, and then they were given an opportunity to try again. Thus, a game narrator would also guide players throughout the game providing auditory feedback.

Lastly, game performance was measured with the number of missions completed with success, number of errors and gameplay time. This way, with the feedback given and game performance players can have an idea of their social skills progression.

Figure **10** shows examples of MASI-VR game scenarios.

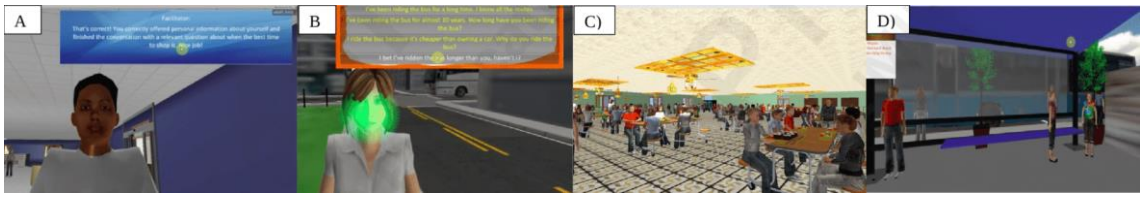

Figure 10 - MASI-VR gameplay examples (Adery, et al., 2019)

3.3.3 Virtual Supermarket Shopping Task (vSST)

Plechatá et al. (2017) developed a system specifically designed at the remediation of memory and executive functions of people with schizophrenia. The game vSST is a shopping simulator where players need to memorize a shopping list and then look for and collect the correct items to buy. Game difficulty can be adjusted by increasing the number of objects the player needs to find.

Each session started with a small period of exploration, so that the participant could get used to the space and controls. Then, the level started. Levels are divided in two stages: the acquisition phase, where participants had 3 minutes to look at a list of groceries and memorize it, and the recall phase, where participants no longer had the list, but had to find the items there.

Game errors are measured in two types: the intrusion errors, which happen when the player picks up an object that was not on the list, and the omission errors, which happen when the player arrives at the cashier without all the required objects.

3.3.4 Serious Games to Improve Cognitive Functions in Schizophrenia

Amado et al. (2016) study aimed at the demonstration that the application of a serious game to therapy can benefit planning, executive functioning and social cognition. They designed a virtual town (Figure 11) where players need to use a map to find a specific location within the town. The game was played in groups of two patients, where one had to look at the 2D paper map of the city and the other had to use a joystick to control the game character. The one with the map had to instruct the other on how to travel to the desired location.

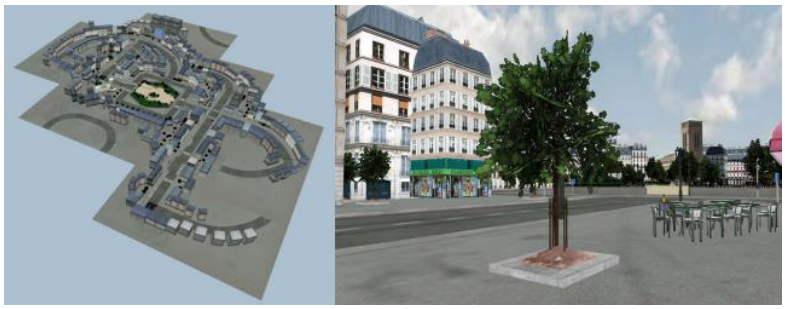

Figure 11 - Game Map and player point of view (Amado, et al., 2016)

3.3.5 VR Vocational Rehabilitation Training Program (VR-VRTP)

Sohn et al. (2016) developed a VR vocational rehabilitation game-based system, VR-VRTP, targeted at evaluating the feasibility of the treatment, in people with schizophrenia, as an alternative to common traditional alternatives.

The game therapy consists of two scenarios, a convenience store and a market, chosen because that is where people diagnosed with schizophrenia have better chances of being employed. Figure 12 shows examples of game tasks in these scenarios.

At the beginning of each session, and before entering the scenario, players were presented with a tutorial on how to perform basic game interactions necessary for their job positions. They are also given the opportunity to test their voice, by speaking into a microphone, to test it, since they then are required to use it during the game. Each scenario had a specific role the player had to perform and involved the necessity to complete tasks like greeting and other social interaction, to which they were given feedback on their performance.

At the end of each session, patients can view their performance status and final scores so they could be aware of their game skills progress and feel accomplished if their scores improved.

Figure 12 - Examples of game tasks in VR-VRTP **(Sohn, et al., 2016)**

3.3.6 Social VR Simulation

Hesse et al. (2016) developed an immersive VR game to test if rejection, even if it is simulated, leads to an increase on paranoid ideation, one of the symptoms of schizophrenia. The scenario is an office space and it consists of two main tasks. On the first one, players have to request their colleagues for help handling a program. And on the second one, players have to request money from their colleagues to pay for a present for their boss. In both tasks it is necessary to speak to every single character with their real voice. Also, both tasks had two modes, one in which all colleagues are nice and cooperative and one in which all colleagues do not cooperate, meaning that they do not help or give money. Besides the five colleagues, there is also a personal assistant to help the player throughout the game.

In addition, even though the game was immersive, it has no teleportation system. This means that the room where it was tested had to be the same size or bigger than the virtual office, so that participants could move freely on the game. The office can be seen in Figure 13.

Figure 13 - Gameplay example (Hesse, Schroeder, Scheeff, Klingberg, & Plewnia, 2016)

3.3.7 Virtual Morris water maze and carousel maze

Fajnerova et al. (2015) developed a system to demonstrate that schizophrenia patients suffer from a deficit in spatial cognition due to their negative symptoms. It has two levels, the stable arena and the rotating arena. The stable arena has a four goals navigation task to find and remember certain locations within the arena. And, the rotating arena is similar, but contains two

different frames, one in which both the arena and the player rotate and one in which there is a static room that only moves according to the player's position. Thus, both levels require players to navigate towards various locations throughout the arenas.

3.3.8 Soskitrain

Calafell, Maldono & Sabaté (2014), developed a VR program, which allows users to practice social interactions with virtual characters, encouraging continuous learning of social skills. The program aimed to improve social cognition and general functioning on patients' daily life.

They took great detail in the development of the characters facial expression and voice, so that they would look as realistic as possible, so that interactions would seem natural and so that patients could experience some level variety during gameplay.

Sessions were divided into two sections. The first part was meant to allow the therapist and patient to spend some time discussing the progression of the intervention and the second was meant to be spent playing the game.

The VR program's difficulty changes as the game increases the difficulty of tasks, ranging from the most basic social skills tasks, like facial emotion recognition, to more complex social skills, like maintaining a conversation. The program also registers the patient's number of errors, the number of correct actions and gameplay time.

Moreover, therapists have the option to stop the game whenever necessary to discuss aspects with the patients, as well as to modify and manipulate characters and environments to guide the session, as necessary. Figure 14 shows examples of Soskitrain scenarios.

Figure 14 – Examples of Soskitrain scenarios (Calafell, Maldonado, & Sabaté, 2014)

3.3.9 Virtual City

Zawadzki et al. (2013) developed a system to serve as a measure of cognition during clinical trial for schizophrenia cognitive treatments.

Virtual City is a non-immersive VR game of a complex 6 by 6 block city with different target buildings to serve as a reference for players while they explore the city. The goal of the game is to find the shortest route from point A to point B in the city.

There were eight distinct levels, each starting with a passive view of the pre-recorded path, followed by a single attempt by the patient to locate the target location. From those eight, the first four were aimed at the assessment of the participants' ability to find targets seen in the passive view stage. The other four were aimed at the assessment of the participants' ability to return to the starting point after viewing the path that took them away from the starting position.

In terms of hardware, patients played with a joystick in one computer and a second computer, connected via the local network, was used to control the task settings.

3.3.10 VR Vocational Training System (VRVTS)

Tsang & Man (2013) developed a program to investigate the effectiveness and efficiency of non-immersive VR interventions targeted at the enhancement of vocational outcomes in people with schizophrenia.

The chosen game scenario is a boutique where the player plays as a salesperson that needs to use their social skills to interact with customers and handle conflicts and functional skills to solve problems and manage the store.

Also, the game's difficulty could be totally controlled, allowing for better control of challenges and skills to train. Besides that, the system was divided into three modules, the pre-trainee, the trainee and the sales level. The player had to complete each level, which increased in difficulty, in order to progress in the game.

Lastly, patients can check their performance through the immediate feedback provided as they play. Figure 15 shows the setup and gameplay examples of VRVTS.

Figure 15 - VRVTS setup and gameplay examples (Tsang & Man, 2013)

3.3.11 Social Skills Training VR (SST-VR Role-play)

Park et al. (2011) developed a game therapy to enhance patients' motivation towards social skills therapy. The game enables patients to train three types of skills: conversational, assertiveness and emotion expression. Virtual characters were added for players to socially interact with, as well as to provide positive or corrective feedback to help them with the game.

Players must choose the wright answer from a list of answers and select it (Figure 16). On the conversational training, the different social interactions were about starting conversations, maintaining a conversation, finding common concerns, listening to them and ending conversation. On the assertiveness training, players must make and reject demands. And, on the emotional expression training, players have to express positive and negative emotions.

In terms of interface, the game is immersive and played with a HMD, a joystick and a position tracker to track the player's head motion. Besides the patient's interface in the HMD, it a projector was also used to project the game onto a wall and allow the personnel in the room to watch it in real time.

The sessions were organized according to the three types of skills training. Every session included three role plays with different scenarios and included a main therapist guiding the patient and co-therapists for assistance. At the end of each session there was an assessment on the patient's motion sickness due to use of the immersive headset.

Figure 16 - Different game scenarios and interactions (Park, et al., 2011)

3.4 Analysis of the Related Studies on Key Concepts

The related studies were evaluated in terms of the six selected key concepts usually present in serious games. Some of those components were proposed by Rego, Moreira e Reis (2010) taxonomy on serious games. Following there is a description of each of the concepts and a table with a summary of the results (Table 1).

3.4.1 Immersion

A system is considered immersive if instead of the typical flat screen, it requires a VR HMD to play the game. Immersion allows for a more realistic experience while keeping the same benefits as a non-immersive system. On the down side, gameplay time needs to be shorter since it can make players feel dizzy and dry eyes. Also, it covers half of the patient's face hindering their facial expression evaluation by the therapist.

3.4.2 Interaction Equipment

It refers to the devices needed to interact with the system and play the game. This includes VR headsets and the respective joysticks, in the case of immersive systems, and usually a mouse and keyboard or a joystick, in the case of non-immersive systems. It can also include other interaction modes like face, body and/or voice control.

3.4.3 Adaptation Mode

For games it is fundamental that they keep the player engaged so that they play for as much time as possible. They need to balance how challenging the game is and how many skills the player needs to progress in the game. This way, if the game is too easy, it will get the player bored, but if it is too difficult it will get the player to give up (Schell, 2008). Thus, the adaptation mode is the way that the game allows difficulty and other parameters to be adjusted to the player's level of experience. That said, it can either be based on configuration, adaptability or both (Rego, Moreira, & Reis, 2018). When it is based on configuration, it means it allows for the therapist or the patients to set values like gameplay time or difficulty mode before the game starts. Whereas, when it is based on adaptability, it means the game adapts its difficulty based on the player's performance during gameplay. Pre-gameplay configuration is more often seen in games, however, especially in the case of serious games, during-gameplay adaptability seems to offer a better option for game adaptation, since it is really important that the player gets the most out of the game.

3.4.4 Progress monitoring

Monitoring the progress of the player during the game is a widely used and beneficial feature in common games. When applied to serious games for therapy, this feature can be even more advantageous because it not only helps players to keep track of their score and put on effort to improve it, but it also helps the therapist understand if the patient is responding well to the treatment and showing progress on the development of the desired skills.

The most common types of data that games collect to save the player's progress are related to time spent completing a level, accuracy to perform the required task and level score.

3.4.5 Feedback Type

Feedback helps players understand if they are performing well in the game. In terms of display, feedback can be provided as: visual, like written messages or object highlights; auditory, like a voice giving instructions; haptic, like the vibration of a controller; or a mixture of these. As for feedback type, it can be categorized as: system interface, when it is provided as

a direct result of user's action; system controlled, when it recognizes user's performance and reacts accordingly; therapist controlled, when it is the therapist generating it; or a mixture of these (Rego, Moreira, & Reis, 2018).

3.4.6 Portability

A game therapy can be considered portable if it can be easily performed outside the typical hospital or health facility (Rego, Moreira, & Reis, 2010). For instance, if the game requires a high performance gaming computer or a VR headset it makes it harder for patients to have that equipment or for facilities to set them in their houses. On the contrary, if it can be administered in a laptop, therapists can easily travel to the patient's house and take the device with them. Also, if the system is automated and portable, patients play it in their homes without assistance from the therapist.

3.4.7 Automation

An automated game therapy does not need to rely on the presence of therapist to lead each therapy session, since it relies on a virtual therapist to do that. On that sense, automation can lower therapy delivery costs and increases the chances of patients to have access to therapy as well as how often they get it.

Table 1 - Synopsis of the analysis on related studies

Study	Immersive	Interaction equipment	Adaptation mode	Progress monitoring	Feedback type	Portability	Automation
gameChange (Lambe, et al., 2020)	Yes	HMD	Configuration	--	System controlled	Home	Yes
MASI-VR (Adery, et al., 2019)	No	Keyboard and mouse	Configuration	Yes	Mixed	Home Assisted	Yes
vSST (Plechatá, Fajnerová, Hejtmánek, & Sahula, 2017)	--	--	Configuration	Yes	--	--	--

Table 1 – Cont.

Serious Games to Improve Cognitive Functions in Schizophrenia (Amado, et al., 2016)	No	Joystick	--	--	--	--	--
VR-VRTP (Sohn, et al., 2016)	No	Keyboard, mouse and voice	--	Yes	System interface	Health facility	Yes
VR-VRTP (Sohn, et al., 2016)	No	Keyboard, mouse and voice	--	Yes	System interface	Health facility	Yes
Social VR Simulation (Hesse, Schroeder, Scheeff, Klingberg, & Plewnia, 2016)	Yes	HMD, voice and voice	--	--	System interface	--	Yes
Virtual Morris water maze and carousel maze (Fajnerova, et al., 2015)	No	Joystick	--	--	--	--	--
Soskitrain (Calafell, Maldonado, & Sabaté, 2014)	Yes	HMD, voice and facial recognition	--	Yes	Therapist controlled	Health facility	--
Virtual city (Zawadzki, et al., 2013)	No	Joystick	--	Yes	--	--	--
VRVTS (Tsang & Man, 2013)	No	Keyboard, mouse and joystick	--	--	Mixed	Health facility	--
SST-VR Role-play (Park, et al., 2011)	Yes	HMD, joystick, voice and motion tracker	--	--	Mixed	--	--

3.5 Discussion

In conclusion, although VR game therapies have advanced a lot over the years, they still lack key features, like immersivity, adaptation, progress monitoring, feedback, portability and automation, which would allow them to fully replace traditional forms of therapy. Nonetheless, studies were still able to obtain satisfactory results on the treatment of schizophrenia, proving that these technologies have an enormous potential, they just need to keep being improved. Evidently, the best choice is still to combine them with regular therapy to take full advantage of both.

Additionally, important limitations and opportunities to improve were found that could be explored in the future. Those include the fact that, when compared to real humans, all virtual characters still display not so realistic behaviors which decreases the patient's sense of immersion and capability to connect with them. Also, therapy systems often depend on a great quantity of expensive equipment, which increases delivery costs and reduces their scalability. And lastly, when it comes to fully immersive systems, VR headsets cause concerns in terms of facial expression evaluation, with motion sickness and with a higher chance of causing positive symptoms to reappear.

Finally, the definition of development guidelines could solve some of the assessed problems and maybe allow VR therapy systems to finally be able to completely replace regular therapy.

4. System Description

4.1 User Research

Systems are designed to be used by people, so they need to be designed with them in mind. User research is the study of the target audience to understand their needs and expectations to develop a solution for them, placing users in the center of the design process. Different strategies can be used in the user research process to gain knowledge on the target audience, such as interviews, surveys, diary studies, the creation of personas and the creation of imaginary scenarios. Overall, the application of the user center design aims at developing products that meet user expectations.

4.1.1 Target Users

According to the study performed by Barranha et al. (2021) people with schizophrenia are more likely to be unemployed for the most of their life. Reasons for unemployment are both due to a lower level of education and due to the adversities of the disability. Their results showed that only 5% of their sample was employed and 70% was receiving a disability pension, which was much lower than the minimum wage. The value received from the pension is often low due to the lower levels of education and hardly any career background, in part caused because of the early onset of the disease. The lack of autonomy and the lack of financial independence explain their living condition and the reason for them to often live dependent of their families. Furthermore, a constant difficulty in establishing intimate relationships is also the reason why a high percentage (69%) of their sample had no marital relationship.

Having understood the target users it was developed the persona Benedita Ramos (Figure 17). Benedita is a fictional character, created based on the research performed, that represents an ideal user of system in development. She is a way into understanding the target user's real behavior patterns, skills, goals and motivations, when using such systems. Essentially, Benedita is a 34 years old woman diagnosed with schizophrenia. She has been has struggling with her

condition for several years and expects that with the appropriate medication and therapy she will recover and be able to maintain an independent ordinary life.

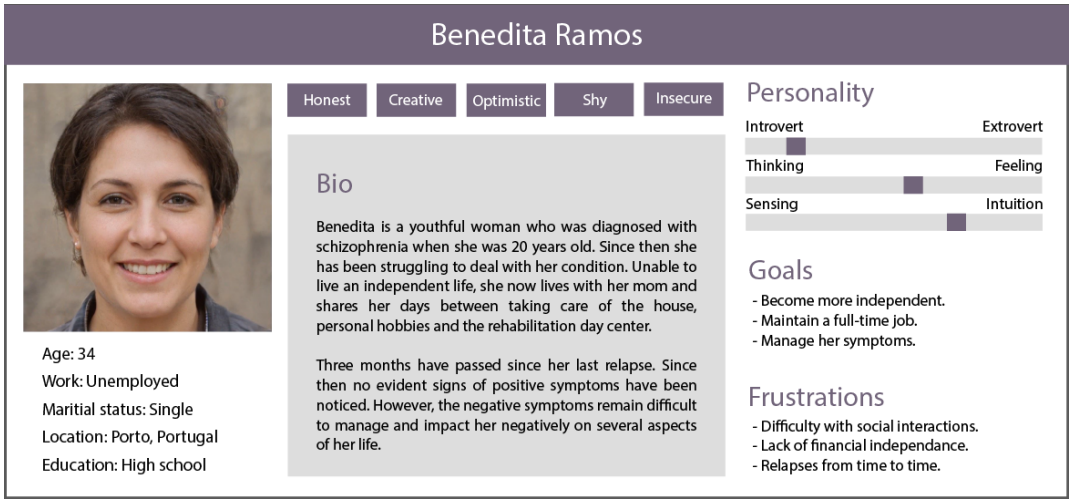

Figure 17 - Persona: Benedita Ramos

4.1.2 User Interaction Scenarios

User interaction scenarios are tools used by designers to understand how users might view and interact with a system. They also help to visualize the system's main functionalities, in which environment it will be used and which challenges users might face. Thus, these scenarios are imaginary short stories focused on the view of the user towards the product, in which situations they might use it and what they will do with it.

In particular, for the game therapy in development the user scenario follows the persona Benedita Ramos (developed in section 4.1.1) on a schizophrenia therapy session with her therapist in which they will be experimenting with the game. In this scenario the game has been fully developed, tested and approved to be used in the therapy.

Scenario:

Benedita is attending a therapy session at the psychiatric daycare center. Sessions usually consist of a roleplay between Benedita and her therapist, but today she will have the chance to experiment a new immersive VR game therapy instead. As usual she arrives at the office, greets her therapist, Dr. Maria, and proceeds to sit on the couch besides her. Dr. Maria starts the pre-session evaluation on Benedita's positive and negative symptoms. Her results show that it's safe to proceed with the session. Thus, she proceeds to explain the game they will be playing today. Benedita is excited to try the game, but also a bit concerned on how well she will adapt to the system, as she does not play video games very often. The therapist sets up the headset and then connects it to her computer, so that she can watch the gameplay, evaluate her performance and assist whenever necessary. Then, she requests Benedita to move to the center of the room,

where there is the empty space necessary to play in an immersive environment, and explains the game controls. She then helps Benedita put on the HMD and the joysticks. Benedita starts playing the game tutorial to learn the basics of the game. She struggles a bit to understand how the teleport works, so she is instructed to practice for a while until she gets used to it. Upon completion of the tutorial, she moves on to the first level. The level is about completing basic daily house chores, so the environment feels familiar to her. The game instructs her on what she needs to do, so she follows the instructions. When she makes mistakes the game displays visual and auditory feedback to warn her. Midway through the level Benedita gets confused. She keeps on making the same mistake as she does not seem to be able to understand what she is doing incorrectly. Dr. Maria interrupts her to explain what the problem is and how to fix it, then takes notes on incident. Benedita understands the error and the rest of the gameplay moves on without more mistakes. She completes the level successfully, so the therapist helps her remove the headset and put down the joysticks. They return to the couches to complete the post-session evaluation on her symptoms and chat about the overall experience with the game. Benedita says she really enjoyed the game and looks forward for more game sessions. She also shows no signs of positive symptoms and confirms she does not feel any kind of motion sickness. Lastly, the session is over, so Benedita says goodbye to Dr. Maria and leaves the office.

4.2 Functionalities

After the analysis of the existing similar applications, the problem statement and the target audience, it was decided which functionalities were going to be implemented in the game. It is important to notice that the time and resources are limited so ideally the game would have a much wider list of functionalities. Thus, only the ones that were considered to be essential were chosen for the game. Still, it is expected that these will be enough to test the game and obtain the desired results. The chosen functionalities were the following ones:

- **Tutorial:** Teaching the player the basics of the game is always important, so that they do not feel lost without knowing how the game works. With the help of a basic tutorial, players can understand what the game mechanics, controls and goals are.
- **Simulation of daily life activities:** Since it is expected that by playing this game patients will develop skills required on a daily basis, everything will follow this same logic. In other words, the virtual world is represented by a kitchen and it allows for the execution of everyday tasks like cooking and cleaning.
- **Realistic movement and interactions:** Different from non-immersive games, where users control their character through a mouse and a keyboard or a single remote, the immersive component allows players to interact with the game in somewhat realistic way by using their body to move and one controller in each

hand to interact with the scene. Although it allows for a more natural interaction with a faster learning curve and more freedom of movement, VR still requires some not so natural interactions. For example, the play area is limited to a predefined size with 2 by 2.5 meters, so players will require the use of teleportation to move around the scene.

- **Task execution in an orderly manner:** To help improve the attention deficits and the disorganized behavior displayed in people with schizophrenia, it will be required that players perform the game tasks trough a specific order.
- **Game feedback:** To let users know what they are doing, every action needs to result in some form of feedback. So, the game will provide visual feedback, whenever the user presses or picks up something, and auditory feedback, whenever the user performs a correct/incorrect action.
- **Performance monitoring:** It is important that patients can keep track of their performance so that they can have an idea on whether or not they are evolving their skills as expected. Therefore, the game will be monitoring the time spent completing the tasks and the number of mistakes made. And, then display the results at the end for users to see.

4.3 System Architecture

The system will function as described in Figure 18. It will be played by a patient with schizophrenia assisted by a therapist. To play the game, patients will use Oculus Quest 2, a VR headset, and its pair of controllers (one for the right and one for the left hand). In terms of User Interface (UI), the patients will be seeing the game in 3D through the headset, while the therapist watches it live on a different device, like a laptop or a tablet. And, as for the game mechanics behind the game, they will all be developed in the game engine Unity and programmed in the programming language C#.

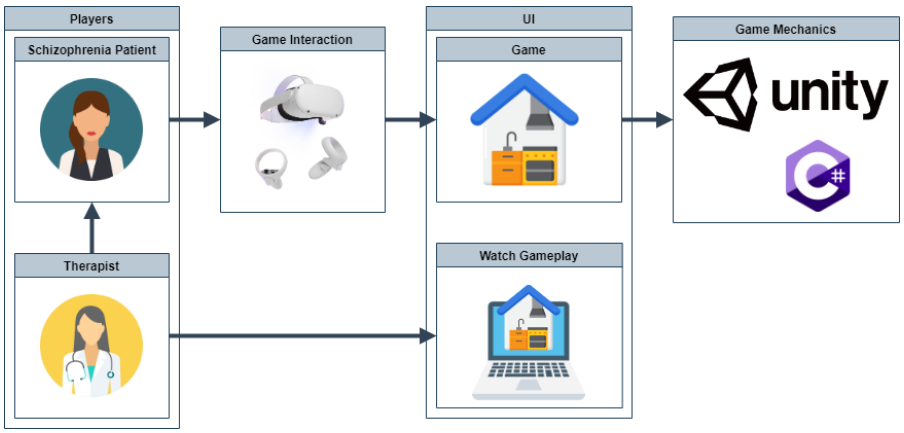

Figure 18 - System Architecture

4.3.1 Game Flow

The game will be developed entirely in Unity, meaning everything will run there with no connections to any database or any other system. Therefore, the game flow is quite simple and basically consists of the transition between game scenes. The game will start with the Tutorial scene where after learning the basics, players can move to the main menu. There they can choose between playing the breakfast or lunch level and exit the game. Both in the breakfast and in the lunch level, players need to successfully complete all the mandatory tasks for the game to display their score and move them back to the menu automatically. Players can also give up the level and return to the menu at any moment during the gameplay. Figure 19 presents the architecture of the system to be developed.

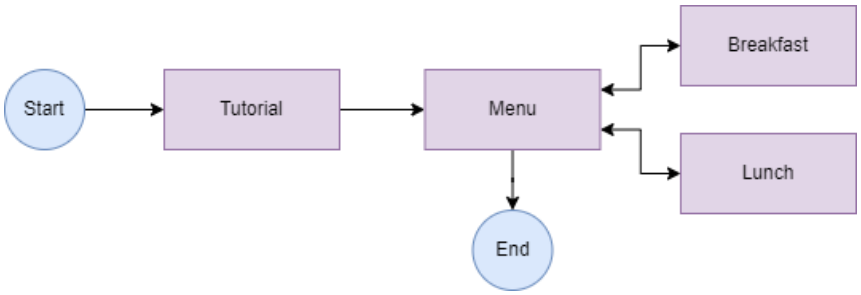

Figure 19 – Game flowchart

4.4 Game Design

Jesse Schell (2008) believes that the act of choosing what a game should be is the definition of game design. Surely, some of the principles addressed in his book were considered on the development of the game design.

4.4.1 Art style

Giving the target audience the game intends to be directed to, it is crucial that the art style takes their characteristics and necessities into consideration. Hence, the art style will be a combination of modernism, realism and minimalism. This means that it will follow a clean style similar to low poly, not too geometric, and that feels somewhat real. Also, the colors will be neutral, like the ones seen in Figure 20, and the music will be relaxing, so that they do not possibly trigger positive symptoms.

Figure 20 - Color palette

4.4.2 Game World

A game is an interpretation of reality, so it can be an approximation of real life or much closer to something fictional. Either way it will never be as realistic or as immense as the actual reality. This way, some part due to the device limitations to handle large quantities of data and some part due to other development limitations, game worlds will always be limited and divided in maps. Meaning that, the game world is the virtual place where everything happens, and game maps are portions of that. They can be as big as the aggregation of several maps that represent huge cities or as small as a single map of a room.

Therefore, this game world is a house and the maps are the kitchen and the entrance. The kitchen plays an important role in the game. There, players will spend most of the gameplay trying to complete the available levels. It was designed to look as seen below in Figure 21.

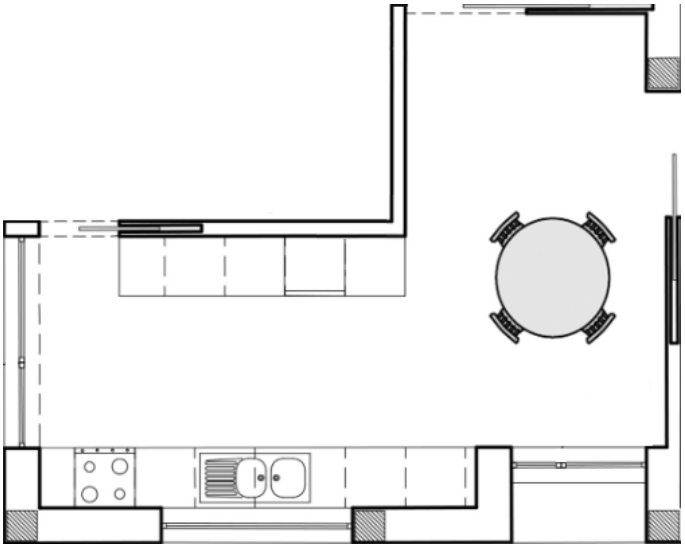

Figure 21 - Kitchen layout plan

The kitchen will have the dimensions of a real kitchen and the usual furniture and appliances found there. It will look somewhat realistic, despite the art style chosen for the game. Some of the points of interest are the table, a fridge, a cooker, a coffee machine and several cabinets.

This plan, containing the definition of the layout of the kitchen space, was defined by the multidisciplinary team of the GreenHealth Project to carry out activities related to the kitchen.

4.4.3 Level Design

The game loop essentially explains how the game flows. This means that each level will start, repeat a number of actions and then end. Both levels will follow the same logic, where players need to complete a predefined number of tasks that require them to find a certain object and then do something with it. As it can be seen in Figure 22, the level starts and players need to

understand what active tasks require them to do. If they need to find a kitchen utensil, they need to look for it and then place it at the specified place. If they need to find an item of food the same happens. And, if they need to cook something they must do it according to the appliance they are using to cook and then also place it in the specified position.

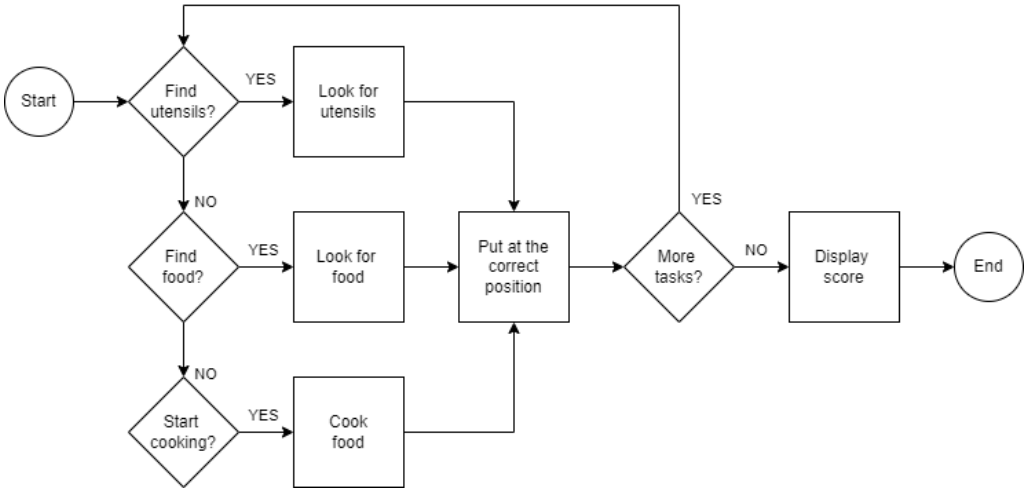

Figure 22 – Level game loop

There will be two game levels the first level is the Breakfast and the second level is the Lunch. Their goal will consist of both the preparation of a meal, breakfast and lunch, respectively. The tasks are divided into two categories: setting the table and cooking, and are organized according to the following list:

A. Breakfast

- Set the table:
  - Look for utensils (mug, plate, knife, pan placemat and napkin);
  - Look for food (butter and bread).
- Prepare food:
  - Look for food (coffee);
  - Heat up coffee.

B. Lunch

- Set the table:
  - Look for utensils (plate, cup, knife, fork and napkin);
  - Look for food (water).
- Prepare food:
  - Look for food (bread, burger, ham, lettuce, cheese, olive);
  - Grill burger;
  - Assemble hamburger.

4.4.4 The experience

The game experience is how players perceive the game and not the game itself, yet it is essential for its success. To develop a pleasant experience, it is important to find ways to capture the essence of what the game is trying to simulate and those ways might not be a precise representation of reality (Schell, 2008). Thus, the experience is composed of different elements that work together to captivate the player. One such element is goals, in which players need to feel like they are playing to achieve something and not just wasting their time. The goals will then be:

- To make patients feel like they are learning something;
- To increase therapy motivation by providing moments of joy;
- To provide a peaceful environment in which patients can improve basic skills;
- And, to make players feel immersed in the virtual world.

Then, there is the realism and simplicity. As it was mentioned before, the game is an interpretation of reality, so some components will be made logical and similar to their real equivalent, but simpler, and others would not make any sense in the real world, but are still necessary in the game. And also, there is the feeling of freedom, since players need to feel like they are in control of their own actions. This implies that players need to follow the tasks in the correct order, but does not imply that they are not free to explore the kitchen and take their time to complete the tasks. They can play at their own pace in their own way.

5. Implementation

5.1 Technologies and Tools

This section aims to provide a basic insight on main technologies and tools used in the implementation of the prototype. The software was chosen based on its popularity and previous knowledge.

5.1.1 Unity

Unity is a powerful two-dimensional (2D) and 3D game engine launched in 2005. One of the advantages of a game engine is it provides built-in features to speed up game development and focus on other aspects of the development. Some of these features include integrated physics, the basics of gravity and collisions; lighting, the integration of different light sources; project management, the management of the different folders files; scene building, basically the setup of game level; and animation, the creation of cycles of movement in objects.

Most of its popularity comes from being cross-platform, which means developers create a game for any platform on the engine and then export it effortlessly to a variety of Operative Systems (OS) like Windows, Mac, Linux, Android, iOS and more (https://unity.com/).

Unity's open access library with millions of free and paid contents available for everyone to download is called Unity Asset Store (https://assetstore.unity.com/). There Unity and their users can upload and download all kinds of useful content to be used in projects. Some of the available content in the store includes textures, 3D models, 2D sprites, audio, add-ons, tutorials and much more. The store is really useful to easily integrate third party content into Unity and use it in games.

On that note, to save time in development, some 3D object packages were downloaded from the Asset Store. Those include:

a) Kitchen Appliance – Low Poly from Alstra Infinite;
b) Kitchen Cabinets – Low Poly from Alstra Infinite;
c) Dining Set from Luna Lea;
d) Old Pans from Pixel Cloud.

Hence, the development was entirely done on Unity 2020.3.33f1 using its native programming language, C#, and was then exported to android. And, like with physics, there is no need to develop existing code. So, because the development for VR requires specific code to

interact with the headset and controls, the official Oculus Integration Software Development Kit (SDK) package for Unity, currently at version 40, was used to speed up the development.

5.1.2 Blender

Initially released in 1998, Blender is a free open-source software mostly used to develop 3D projects. It is powerful software with a wide range of tools available. For instance, modeling, the creation of 3D models through meshes; animation, manipulation of objects to appear moving; rigging and skinning, the application of a skeleton to a model to allow its animation; rendering, generation of a 2D image from a 3D mesh; and much more (https://www.blender.org/).

Therefore, blender 2.93.1 was used to develop some of the 3D models necessary for the game. Those include the kitchen (as in the walls, windows and doors), the furniture, the food and objects for decoration or to interact with. Also, some of the models downloaded from the Unity Asset Store were modified in Blender to better fit the game needs. For instance, there were no available upper cabinets or sink that matched the chosen cabinets, thus they had to be created from the already existing furniture.

5.1.3 Version Control with Git and GitHub

Launched in 2005, Git is essentially a free open-source Version Control System (VCS). A VCS is like a file manager that tracks changes in files and stores them. The development of a project is not linear, there is a lot of trial and errors until it reaches its desired stage. Also, it is quite common that systems keep receiving updates after being launched. This way, with a VCS, developers can, at any time, revert to a previous version of the project and restore files as needed. Compared to other systems, Git sets itself apart because of its branching model. Branching allows cooperative development with the division of the project into branches that can easily be merged to automatically and effortlessly join modifications done by different people (https://git-scm.com/).

Despite this Git works locally, which means it only stores the projects on the device where it is being developed. To access it at any device, Git needs to be connected to a cloud-hosting service like GitHub.

Therefore, with the help of GitHub it became really simple to keep track of all the alterations in the code throughout the development, while not having to worry too much about losing it or damaging it. The Git version used in the development was 2.32.0.2.

5.2 Functional Prototype

Next there is the description of the main components of the prototype developed.

5.2.1 3D Assets

The house was not developed in its entirety, instead only the parts that would be seen in the game were created. Because the game happens inside the house, with the exception of the tutorial, this means that the house is the world's game, so loading only the required parts of the house is a better option in terms of performance. Hence, the kitchen and the backyard are separated from the entrance (Figure 23). The architecture chosen is modern and minimalistic. Also, the windows and doors do not open and are only there for decoration purposes.

Figure 23 - House 3D model - Kitchen (A); Backyard (B); Entrance (C)

Evidently, the house cannot remain empty, it needs furniture. As mentioned before some of the assets used were imported from the Unity Asset Store, namely: cabinets, a table, chairs, a cooker, a fridge and a coffee machine. All these assets had to go through some form of alteration to adapt it to the game requirements, yet these alterations were mostly quite simple. For example, the coffee machine did not have a button to turn it on, so it was necessary to add a pink button (in a bold color to make it stand out) to it. Also, the cooker knobs had no indication on how to operate them, so to each knob, a light indicating when a burner is on was added together with the words "ON" and "OFF". Still on the cooker, the burners were set to change color, also indicating it was on. The cooker and bottom cabinet can be seen in Figure 24.

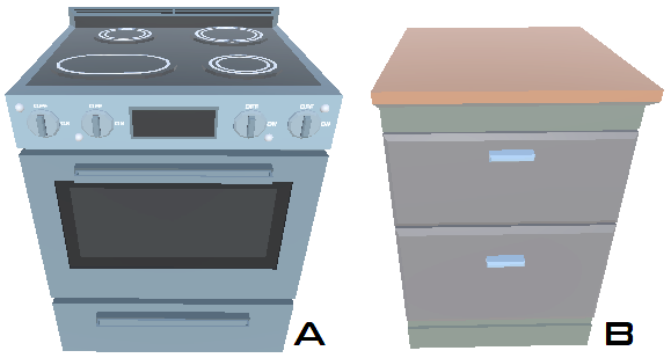

Figure 24 - Some of the models from Alstra Infinite - Cooker (A); Cabinet (B)

However, the packages imported did not have all the required cabinets to complete a regular kitchen. To fix this, the cabinet model was adapted into a sink and a top cabinet, seen in Figure 25. Both were used only for decoration and storage.

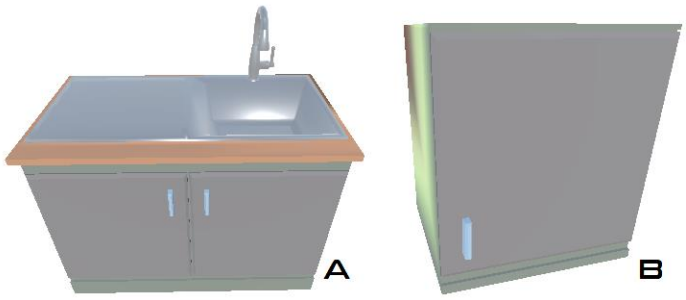

Figure 25 - Some of the Alstra Infinite redesigned models – Sink (A); Top cabinet (B)

Similarly, the cabinets had to be filled with something and the player needed to have objects to interact with. Thus, different 3D objects including decoration, containers and food were modeled and textured. Also, some of the intractable objects (the ones that can be grabbed), like the soap bottle under the sink and the juice bottle, do not have any purpose, so were only placed in the kitchen to help fill it and make it harder for players to find the actual objects they require. Figure 26 shows an example of three of the developed game objects.

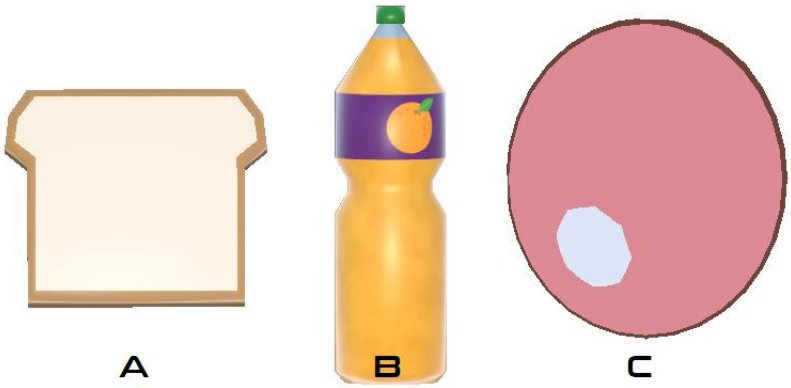

Figure 26 - 3D models developed – Loaf of bread (A); Juice (B); Ham (C)

5.2.2 Scenes

The game consists of three scenes, the tutorial (Figure 27), the menu (Figure 28) and the kitchen scene (Figure 29). Basically, a scene is to a game what a webpage is to a website. It can represent a level, a map or a menu. The first scene the game starts with is the tutorial. In here the player is supposed to learn the basics of the game, like moving by walk or by teleportation, grabbing objects, place objects on their correct positions, open doors and drawers, complete tasks and press buttons to move between scenes. Its main components are a table with objects, a door and a drawer to interact, a task list board and an exit button.

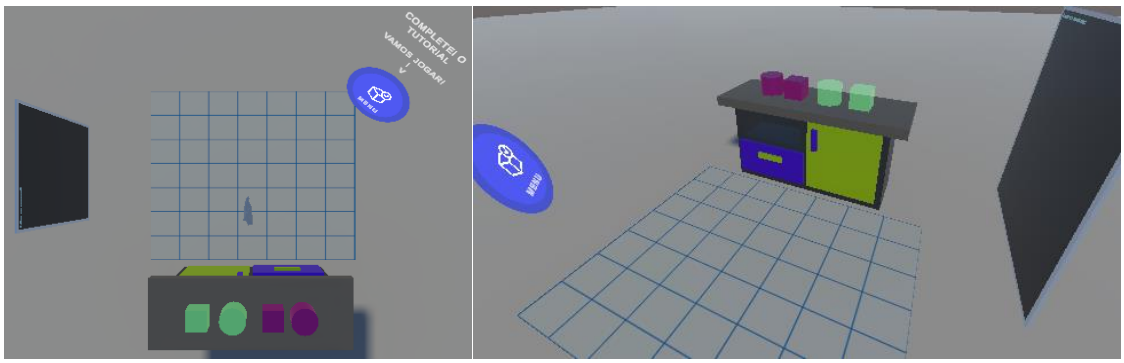

Figure 27 - Tutorial scene

After completing the tutorial, the players will be redirected to the main menu. There they can play the Breakfast and Lunch levels and exit the game. Upon selection of one of the levels the user will be redirected to the kitchen scene. The menu can be navigated through the navy round buttons that can be seen in Figure 28.

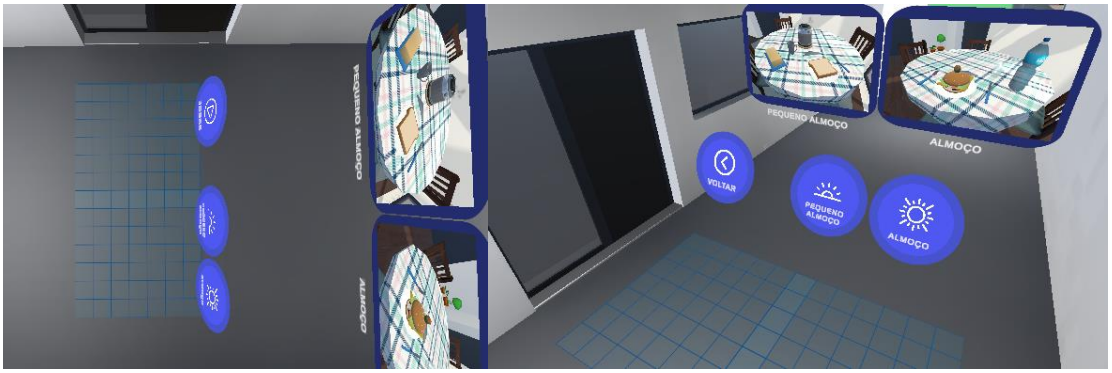

Figure 28 - Menu scene

Finally, there is the kitchen where most of the gameplay will happen. The scene is the same for the Breakfast and Lunch, the only things that change are the tasks in the task list. Its main components are the task list, the table, the fridge, the coffee maker, the stove, the tablet, some cabinets and the exit button.

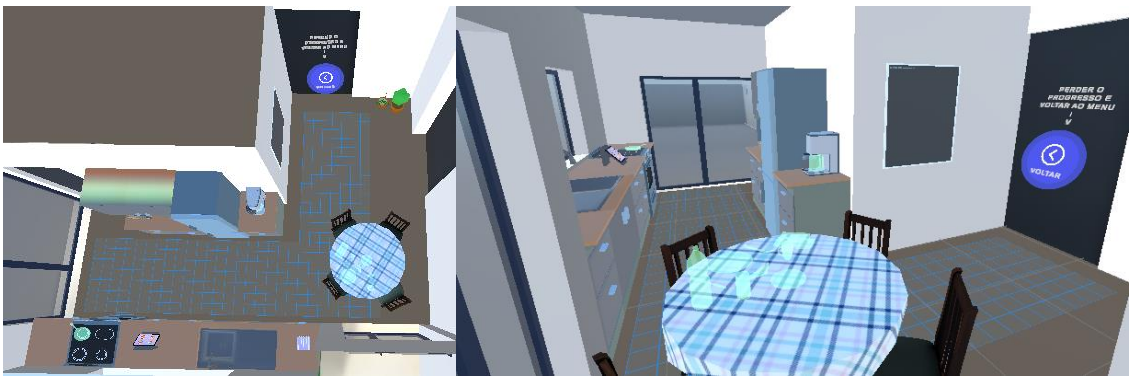

Figure 29 - Kitchen scene

5.2.3 Controls, Hands and Teleportation

Oculus Quest 2 uses the headset position and its controllers or player hands as input hardware. Since hand recognition is still not working quite well in object interaction, the prototype was developed to only allow for it to be played using the controllers. Thus, the player only needs to learn to use two buttons, the Grip Button and the Thumb Stick, specified in Figure 30. The Grip button is used to grab objects, so players should place their hands inside an object and then press the button to grab it. By releasing the button, it also releases the object. The Thumb Stick is used to teleport to a specific place in the map, and it requires players to press it after pointing at desired place to teleport.

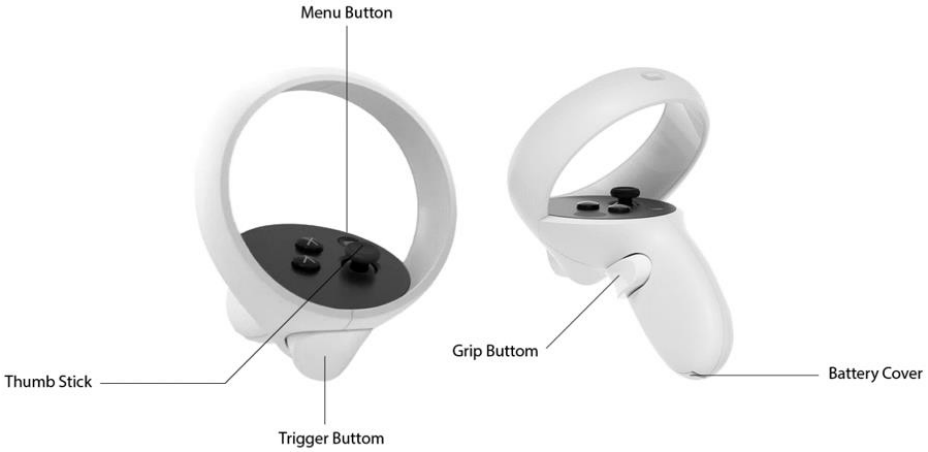

Figure 30 - Oculus Quest 2 controllers and button description

Through the controller buttons the player can achieve three hand gestures: Open hand, pointing finger and fist, as shown in Figure 31. The pointing finger is useful to press buttons or interact with the tablet. The other two hand gestures themselves are not necessary for any other action, but they intend to mimic the player's real hands. The open hand is displayed when no button is being pressed in the controller, the pointing hand is displayed when the Grip Button is being pressed and the fist is displayed when the Trigger button is being pressed. Also, these gestures are also used to grab objects, as usually objects are not picked up with an open hand and not all objects are picked up the same.

Figure 31 - Available hand gestures

In terms of game movement, players can do it in two ways: by walking in the real world inside the Oculus area or by virtually teleporting to a specific place. The blue grid on the floor indicates where teleportation is valid (Figure 32). To teleport somewhere they need to point one of the controllers to the place they intend to move to, and place their finger on top of that controller Thumb Stick. A line will appear that starts in the hand and ends in the position the controller is pointed at. If the place is valid, the line turns white and a reticle will appear on that place. So, the player just needs to press the Thumb Stick to appear on the chosen position. If the place is not valid the line will turn red and no reticle will appear.

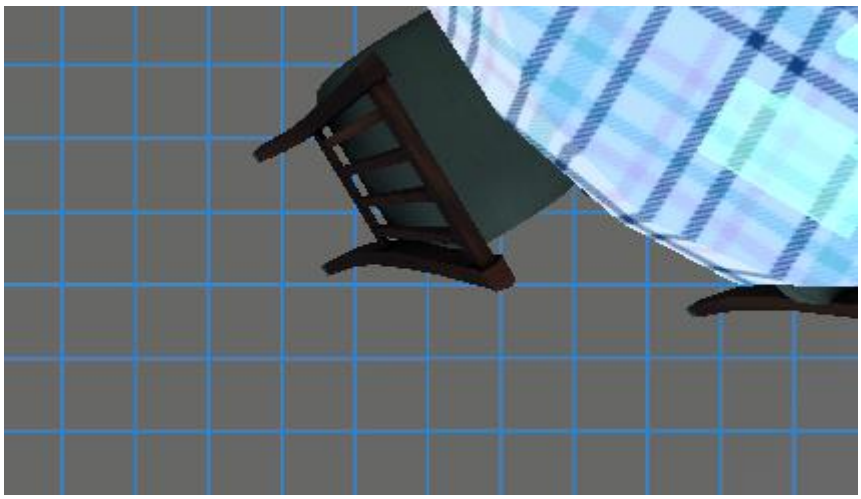

Figure 32 - Teleportation grid

5.2.4 Game Logic

5.2.4.1 Levels Breakfast and Lunch

The game is composed of two levels with different goals and levels of difficulty. They can be played in any order and no matter how many times the player intends to, but it is recommended that the player starts with breakfast due to its lower level of complexity. The breakfast level goal, as the name says, is to prepare the breakfast. It consists of nine low difficulty tasks, mostly meant for the player to find and place an object somewhere, and can be completed in about two minutes. Similarly, the Lunch level goal is to prepare a lunch meal. It consists of seventeen medium difficulty tasks, including finding objects, cooking and preparing food, and can be completed in about four minutes. Final results consisted of a basic breakfast of a toast and coffee and a hamburger with water for lunch. Those results can be seen in Figure 33.

Figure 33 - Breakfast and lunch with all tasks completed

A level is considered over when there are no more tasks to complete. When that happens, the game displays a message saying “Level concluded!” together with the number of errors committed and the time spent in the level (Figure 34). The message shows up for 10 seconds in front of the player’s sight and follows it around, and then the game is redirected automatically to the main menu.

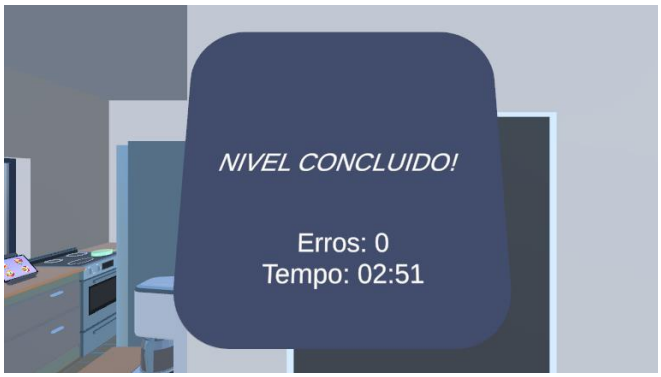

Figure 34 - Level complete message and score

5.2.4.2 Task List

The task list is like a board hanging on a wall, where players can check which tasks they need to complete. On the board (Figure 35) it can be read “Lista de tarefas:” (Task list in Portuguese), then strikethrough letters in grey indicating the completed tasks and then at the bottom, in orange and in capital letters, the next task that needs to be completed. At first, the list only has only one task to complete in orange, then as the player progresses in the game new tasks will appear and the old ones will be left in grey. Tasks need to be completed exactly in the same order they are shown, or else the task system (the script that manages tasks during gameplay) will not consider them complete. For instance, if task 1 is to place a mug at the table and task 2 is to place a plate at the table, the player needs to place the mug first and then the plate. So, when a task is successfully completed an affirmative sound is played and the next task is shown.

Tasks have three types: selection, placement and cooking. A selection task requires players to open the required recipe on the tablet, like opening the lunch recipe for instance. The placement requires them to place a specified object at the place indicated, like placing a mug at its correct place on the table. And, the cooking requires them to turn on a cooking appliance and wait for the required amount of time for the food to cook, like cooking a burger for 20 seconds on the stove.

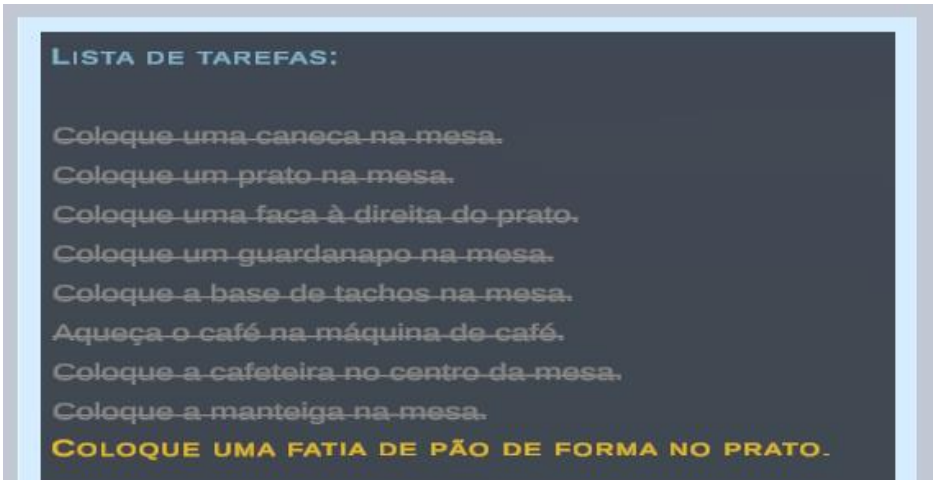

Figure 35 - Breakfast task list

5.2.4.3 Position Indicators

Throughout the kitchen there are several position indicators meant to show the player what object should be placed in there in order to complete a task. Position indicators are shaped like the object it is supposed to be placed there and have a green transparent material that distinguishes them from other objects. They are static, which means they are not objects that can be interacted with. Most of them are always visible, but some only appear after specific objects are positioned in certain indicators. For instance, at the table the indicator of the plate, fork and knife are always visible, but the bread only appears when a plate is placed on the plate indicator. This example can be seen in Figure 36. The green material in the indicators disappears when an object is placed there and reappears when that object is removed. Each indicator only allows the positioning of one object at a time.

When completing tasks, players will need to look at the task list to know which object they need to grab next and to different indicators in the kitchen to know where that object must be placed. If the object is correctly placed an affirmative sound is played making the task list display the next task, and if it is not a sound is played indicating it is wrong and the error counter is increased in one.

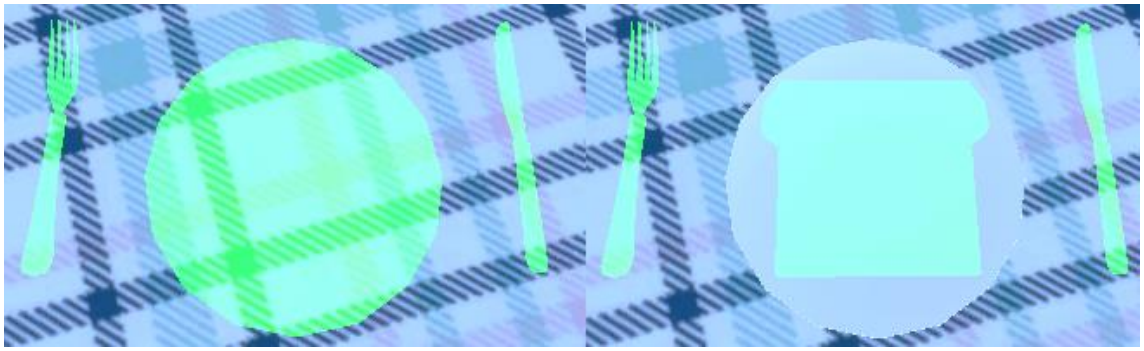

Figure 36 - Position indicators for the plate before and after placing a plate there

5.2.4.4 Tablet

The tablet was developed as a visual aid to the recipe preparation available at lunch. This means that players do not need to follow the recipe through the tablet, as they can still follow all the steps through the task list, but they can use the tablet if they prefer to follow the recipe as they normally would do in real life. It has three types of menus: the main menu, with links to four recipes (Breakfast, Lunch, Snack and dinner), the ingredient list, with the name of the chosen recipe and all the required ingredients, and the recipe steps one by one, with the written and visual instruction.

Its functioning is simple, just like a mobile application would function in a real tablet or phone. Basically, the user presses one of the four recipes on the main menu and the application opens the chosen recipe displaying first its name and ingredients. Then the user can navigate through the recipe by pressing the arrow buttons at the bottom left and right, to move one page back or forward, respectively, as shown in Figure 37.

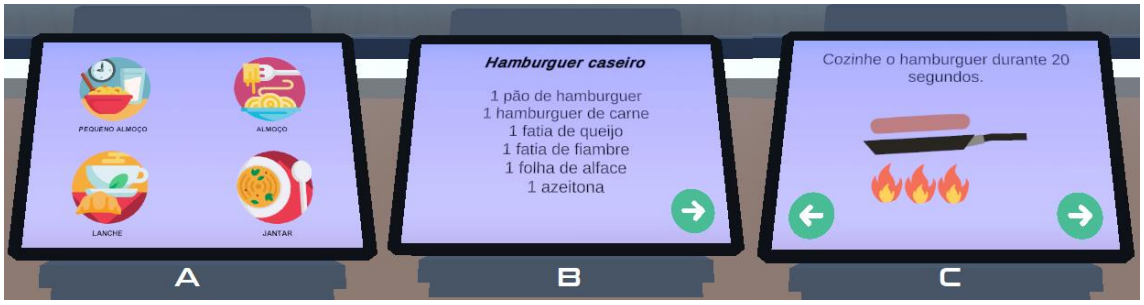

Figure 37 - Recipe Tablet – Main menu (A); Ingredients (B); Recipe step by step (C)

5.2.4.5 Coffee Machine and Stove

Cooking appliances, such as the coffee machine and the stove, let the player prepare some basic food, like hot coffee and grilled burgers. Their functioning is simple and similar. To make hot coffee, the player needs to add the coffee pot to its correct position in the coffee maker, press the pink button to turn it on and then wait for 10 seconds while the coffee heats up. As for

the grilled burger, the player needs to add a pan to its correct position in the stove and then a raw meat burger inside the pan, then turns on the knob by rotating its correspondent button until the light turns red and waits for 20 seconds while the burger grills. In both cases a purple pop up, like the one in Figure 38 appears above the food to indicate the time remaining for it to be ready. Also, if the pot or the pan are removed while cooking, the food will not be set as ready, so it will need to be cooked again. To let the player know the food is ready, the coffee pot will have hot smoke coming out of it and the burger will change color to a darker shade.

Figure 38 - Coffee maker and stove

6. Tests and Results

6.1 Testing of the prototype

The testing of the prototype developed is intended to evaluate its implementation, look for flaws and collect users' perspectives on the game. It is also intended to test theories speculated during the research and development process of this study. Thus, the tests will serve as a way to test the following four hypotheses:

- The game is capable of helping people follow a stream of tasks;
- Task A is easier to complete than task B;
- Realistic graphics don't affect the immersive feel of the game;
- The game is safe to be used in therapy.

Ideally, to test all these hypotheses the tests should be performed with people diagnosed with schizophrenia, the target users, but due to limitations in terms of time and ethics, tests will be made with regular users plus users related to the healthcare field.

6.1.1 Testing Methodology and General Procedures

Before the tests begin the room and the devices need to be prepared. Firstly, the laptop needs to have an Excel spreadsheet open, to take notes on the participant's performance, and a web browser with the oculus website open, so that the test administrator can watch the participants playing in VR. Then, the Oculus Quest 2 needs to be turned on and the boundary of the play area needs to be virtually drawn on the floor, it should have about 2 by 2.5 meters of area and an extra 0.5 meters around it to prevent users from hitting against the wall while playing. The game needs to be opened on the headset and the casting activated. Also, there should be available several clean copies of the informed consent for each participant to sign and a pen in case the participants do not have any.

Upon preparation of the equipment, the testing sessions may start. Each test session must not last more than an hour and should follow the defined schedule:

- Introduction to the session (about 5 minutes);
- VR Tutorial (maximum of 5 minutes);
- Tasks (maximum of 40 minutes for both);
- Questionnaire (about 5 minutes);
- Interview (about 5 minutes).

Therefore, every session starts with an introduction, where the test administrator should build a connection with the participant, help them feel comfortable and explain the test goals and schedule. Then if the participant decides to continue, they need to sign the informed consent (available in Appendix B). Then, the administrator positions the participant in the center of room, explains the game controls and sets up the headset on the participant. They start playing on the tutorial where the administrator needs to guide them and explain the basics of the game. Once they feel like they understood how everything worked, they could move on to the menu and then the breakfast level. The administrator observes as the participant completes the tasks and takes notes on their mistakes and performance. If they ask for game assistance it should be given to them and noted as well. Once they complete the level the administrator takes note on the time and errors and waits for the game scene to change back to the menu. The completion of the lunch level works the same way. Upon completion of the two tasks, it is given them a QR code with link to the questionnaire for them to fill. The administrator waits for the participant to fill the form and explains any doubt they might have.

Finally, if the participant works in the healthcare sector they should be interviewed where they will be asked for their medical opinion on the prototype. If the participant does not work in the healthcare sector or when the interview ends the testing session is finally complete.

6.1.1.1 Test Facility

Tests had to be performed in person since participants had to use the VR headset to test the prototype. Therefore, tests took place in a reserved room at a library, which was mostly silent with the exception of some occasional noise coming from the hallway. The room had a table and two chairs, where the test administrator and the participant could sit to chat, and an empty area of 2.5 by 3 meters reserved so that the participant could move around while playing. Also, because of its large windows, all the light coming from them was affecting the performance of the Oculus Quest 2 by interfering with its controller/hand recognition, thus one of the windows had to be covered with a black curtain to block the light. The layout can be seen in Figure 39.

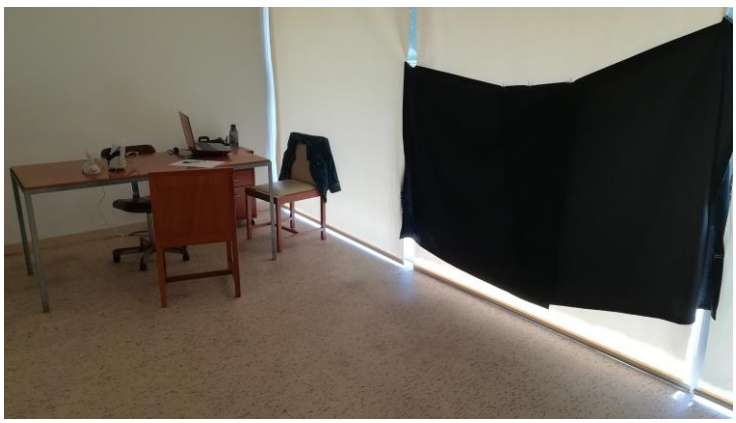

Figure 39 - Room where tests took place

6.1.1.2 Test Administrator Script

The role of the test administrator is to conduct the tests in order to achieve the predefined objectives. It is up to the administrator to help the participants feel comfortable, make sure they understand all the steps they will part in and be available to clear out any doubt they might have.

This trial stage will not be performed with any participant from the target audience. Hence, it will not be necessary to have the presence of a medical professional, so the administrator can perform the tests alone.

The following steps serve as a guide to what the administrator should do and say to the participant in each session. Since the script is generic it is expected from the administrator to use their words to explain everything in a natural way that fits the session the best.

1) Introduce yourself;
2) Introduce the thesis subject and its goal;
3) Introduce all the steps of the session;
4) Explain to the participant the game they will be testing;
5) Explain to the participant the two tasks they have to complete and what is their purpose;
6) Inform the participant about the questionnaire they will have to fill afterwards;
7) Inform that the participant has to sign the informed consent document to proceed;
8) Check if the participant has any doubts;
9) Explain how the headset and controls work;
10) Explain the game tutorial;
11) Watch the participant complete the tasks and assist when necessary;
12) Give the questionnaire to the participant and clarify any doubts that may occur;
13) Allow space for additional comments and questions from the participant;
14) (For healthcare participants) Interview the participant on their medical perspective.

6.1.1.3 Test Administrator Tools

In terms of hardware, to perform these set of tests the administrator will require a laptop with Wi-Fi connection and the Oculus Quest 2 headset with the left and right controllers, also with Wi-Fi connection. The administrator will not be using the Oculus, but needs to set it up.

In terms of software, on the laptop the administrator needs to have an Excel spreadsheet open to be able to take notes during the session, to have the oculus casting website open (https://www.Oculus.com/casting), to watch in real time as the participants play the game, and to have the QR code or the link for the Google Forms open, so that participants could fill it on their phone or the administrator laptop. On the Oculus it just needs to have the prototype installed.

6.1.1.4 Tasks

The prototype was developed around the execution of daily tasks and always with the purpose of testing its functionality. Therefore, the game has two levels that coincide with the two main tasks, A and B, which participants will have to complete during the tests. The first level objective is to prepare a virtual breakfast through the completion of a list with nine tasks. Mostly the tasks are simple and just require the participant to find objects and place them at the table on the correct positions.

Task A: Prepare the breakfast

- **A.01:** Place a mug at the table;
- **A.02:** Place a plate at the table;
- **A.03:** Place a knife to the right of the plate;
- **A.04:** Place a napkin at the table;
- **A.05:** Place the pan placemat at the center of the table;
- **A.06:** Heat up the coffee at coffee machine;
- **A.07:** Place the coffee pot at the placemat;
- **A.08:** Place the butter at the table;
- **A.09:** Place a slice of loaf bread at the plate.

The second level is similar, but a bit more complex. Its objective is to prepare a virtual lunch with seventeen tasks to complete. The logic is the same, and mostly requires the user to move around to find objects, with the addition of other more complicated chores. It is expected that Task B difficulty is higher than of Task A, because it has the double number of tasks to complete and the tasks themselves are more complex.

Task B: Prepare the lunch

- **B.01:** Place a plate at the table;
- **B.02:** Place a knife to the right of the plate;
- **B.03:** Place a fork to the left of the plate;
- **B.04:** Place cup at the table;
- **B.05:** Place a water bottle at the table;
- **B.06:** Place a napkin at the table;
- **B.07:** Open the lunch recipe on the tablet;
- **B.08:** Place the bottom half of the burger bread on the plate;
- **B.09:** Place a pan at the stove;
- **B.10:** Place a meat burger on the pan;
- **B.11:** Cook the burger;
- **B.12:** Place the burger on the burger bread;
- **B.13:** Cover the burger with a slice of cheese;
- **B.14:** Cover the cheese with a slice of ham;

B.15: Cover the ham with a leaf of lettuce;

B.16: Cover everything with the top half of the burger bread;

B.17: Stick an olive on top of the bread.

6.1.1.5 Questionnaire

Upon completion of the two tasks, participants had to answer a questionnaire meant to collect some personal information and their opinion on the game's User Experience (UX) and their satisfaction towards it. The questionnaire had a total of 27 questions and had at the end an opportunity to leave some suggestions for future improvement. It was organized into five sections: Agreement, Personal information, UX, Satisfaction, and Suggestions. The original questionnaire in Portuguese can be seen as the Appendix C. Following there is an exposition of each section:

I. Agreement

To complete the questionnaire, it was once again asked the permission of the participants to use their data anonymously in the study of the prototype's usability. There was only one answer authorizing the previous statement and participants had to choose it to proceed with the questionnaire.

II. Personal information

The personal information was collected to help understand their demographic and how much they might differ from the target users. Data was collected on the participant's gender, age, level of education, academic/professional occupation, experience with computers and VR and special needs. All questions had predefined answers to which they needed to choose only one, with the exception of the occupation that was an open answer due to the amount of possible different answers.

III. User experience

To evaluate the participant's opinion on the prototype's UX, this section had ten statements to which participants had to evaluate on a Likert scale from 1 to 5 (being 1 completely disagree and 5 completely agree) how much they agreed with each one of them. The selected statements were related to how the participants experienced the different components of the game.

IV. Satisfaction

This section had also ten statements for participants to vote. The statements were collected from the System Usability Scale (SUS) (Bangor, Kortum, & Miller, 2009), used to measure the participant's satisfaction with the system. Since the questionnaire was written in Portuguese, the statements used were the ones suggested form the translation done by Martins et al., (2015).

As with the UX section, to answer the statements participants had also to vote on a Likert scale on how much they agreed with it.

V. Suggestions

At the end of the questionnaire there was a space where participants were encouraged to leave suggestions of improvement of the prototype.

6.1.2 Testing Results

The testing stage took two weeks to complete and due to how long each session was expected to last it had a goal of 20 to 25 participants, which was achieved with a total of 21 participants. They all had to complete the test tasks and then answer a questionnaire with their opinion on the prototype tested. The raw results obtained were stored and described in a Test Report available in Appendix D. The study of those results will be exposed on the following sections.

6.1.2.1 Participants

The target audience is people diagnosed with schizophrenia, but finding and performing tests with that audience is difficult, time consuming and requires the supervision of medical professional. To bypass is preferable to test the prototype with people who understand about their needs and how their condition works, as well as people who understand about game development or have a basic knowledge in games. Therefore, tests were not performed with the target audience. Instead, they were performed with 21 regular users, which include 2 medical professionals, 17 people who are studying or have studied in the field of computer informatics and 2 people who work at a library. All the participants were volunteers who were interested in the games, VR, schizophrenia or just the project in general. Also, they were all considered healthy and did not declare any special needs.

As it can be seen in Figure 40, the test demographic was composed of about 29% female and 71% male participants, from the ages 18 (no minors took part on the tests) to 60 years old. As for academic background about half (52%) were either taking a bachelor's or did not enroll in university, the other half (43%) were either taking a master's or had completed their academic studies and one participant (5%) did not complete high school. Further, the majority of the participants (76%) were students from the field of Information Technology (IT).The remaining participants worked in the heath sector (9.5%), in the library sector (9.5%) and education (5%). In particular, students were composed by 9.5% enrolled in the Master in Cybersecurity (MC), 33.55% enrolled in the Bachelor in Multimedia and Computer Graphics Engineering (ECGM), 14% enrolled in the Bachelor in Informatics Engineering (EI) and 19% enrolled in the Master in Informatics Engineering (MEI).

In comparison with the target audience, while the gender and age fit the expected demographic, which means there is no preference for gender and the target age is comprehended between 20 and 50 years old, the education level and professional occupation are bit different from what is expected, which means that the target audience has lower levels of education and does not work in healthcare or IT sector. Nonetheless, it is relevant to test the prototype's usability with game developers and computer scientists and to collect medical opinions on the prototype's usefulness and safety.

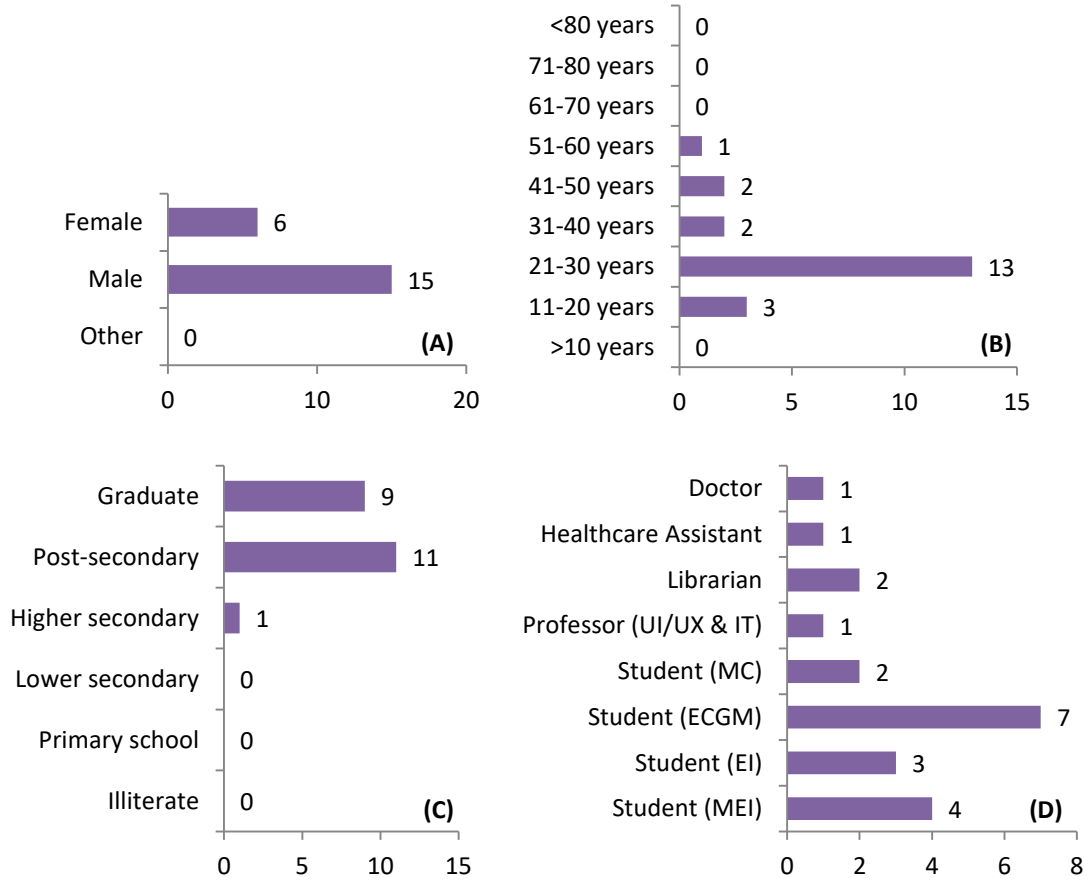

Figure 40 - Graphs on the participant's demographic – Gender (A); Age (B); Education (C); Occupation (D)

In terms of computer experience, participants had to grade their capabilities as: Low (if they never used or rarely use a computer), Medium (if they only use it for basic tasks) or High (if they use it regularly for advanced tasks). Since most of the participants were from an IT related field, it makes sense that the majority of them (86%) says they use a computer daily to execute advanced tasks, meaning they have a high level of computer experience. The percentage of computer experience for all participants can be seen in Figure 41. A person's experience with computers may affect their capabilities with the prototype, since people who use computers a lot, tend to also play more video games, allowing them to better understand how game interfaces and mechanics work.

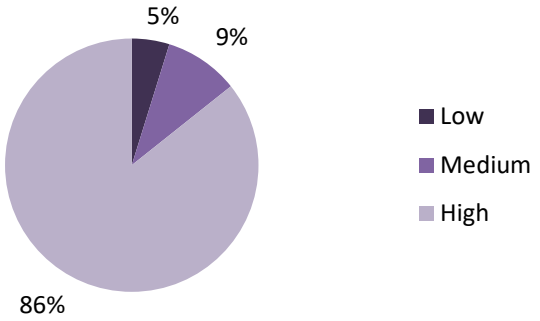

Figure 41 - Graph with participants computer experience

In terms of VR experience, participants graded their experience as Low (if they have never tried it before), Medium (if they have tried it less than 5 times) or High (if they have tried it multiple times). As for the results, seen in Figure 42, the sample was varied and balanced, meaning that about half (48%) of the participants had no prior experience with VR and the other half (52%) had experienced it before in some way. Having participants with fewer skills in VR is beneficial to the tests, since the target audience will also most likely have that same level of skills.

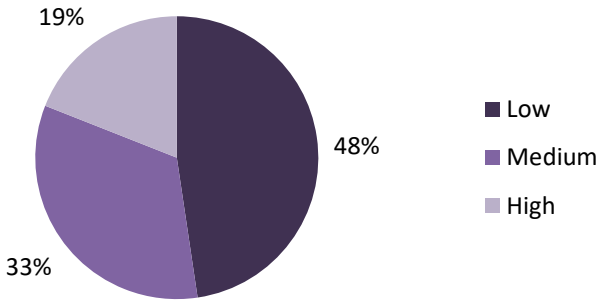

Figure 42 - Graph with participants VR experience

6.1.2.2 Presentation of task results

On the competition of the tasks, the test administrator took note, for each task, on the participant's performance through the following metrics:

- **Task effectiveness:** How much of a task was completed and whether it required any assistance. Subtasks were only considered here to calculate the percentage of completion of a task. Thus, the percentage of completion of a task was calculated by dividing the number of completed subtasks by the total number of subtasks of that task;
- **Time:** How long it took to complete the task in minutes and seconds;

- **Errors:** The number of errors collected by the game and displayed at the end of the level. They increased every time a player placed the wrong object on the correct indicator or the correct object on the wrong indicator;
- **Mistakes:** The number of mistakes players made prevented them from progressing in the game. These were usually caused by difficulty understanding the game logic.
- **Assistances:** The number of assistances requested by the participants during the task. It was considered assistance every time a participant requested help to complete a task.

Only four people were not able to complete both tasks successfully. The reasons were: participant 1 exceeded the time limit in task A, participant 6 and 11 gave up during task B after struggling too much to complete it and participant 19 had a bug in the stove that kept them from progressing any further. Hence, only 8 participants managed to complete task A without assistance and of those only 2 completed both tasks without assistance. The results were mostly positive. And, besides the potential struggle caused by some bugs (like the one on the stove, where it would not cook the burger, or the Oculus hand recognition, that was malfunctioning due to the light coming from the window), stress to perform successfully, rush to finish the test and motion sickness, participants manage to easily do everything they were required to. Figure 43 shows the completion rate for both tasks in each participant. If a bar is completely presented in light purple, it means that both tasks required assistance, if it is completely in dark purple, it means that both tasks were completed without any assistance, and if the bottom half is in dark and the top half is in light purple, it means that task A did not have assistance, but task B did.

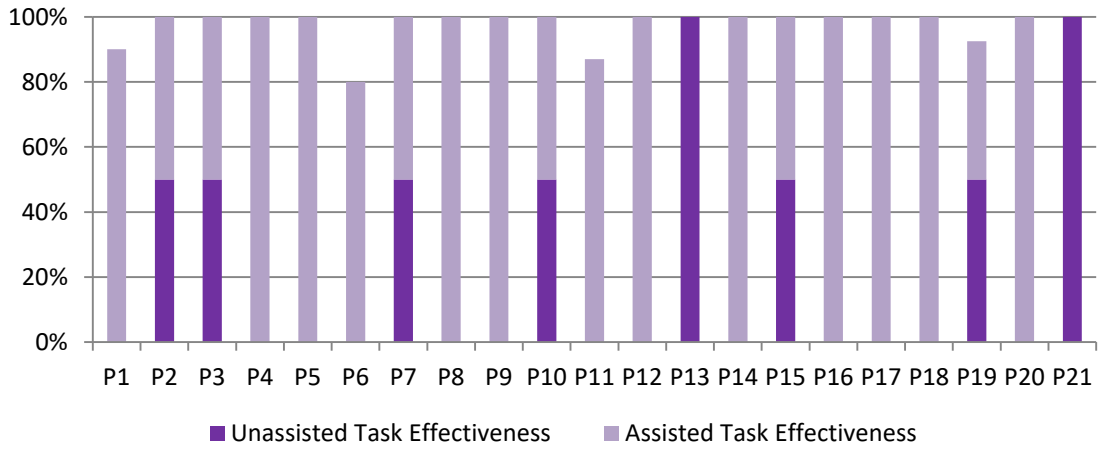

Figure 43 - Unassisted and assisted task effectiveness per participant

The vertical bars in black and white, displayed in the next four graphs (Figure 44, Figure 45, Figure 46 and Figure 47), show an increase in black or a decrease in white, in participants' performance from task A to B. It is expected that by training their skills, their performance will

also increase, still task B has a higher level of difficulty, so not obtaining better results in task B does not necessarily mean that they did not improve their skills.

In regards to time, it was expected that an experienced player would need less than 2 minutes to complete task A and less than 4 minutes for task B. So, participants had a limit of 20 minutes to complete each task, which was supposed to be reasonable amount with extra time if they struggled a lot. Still, one participant managed to reach the 20 minutes when on task A and had to stop without completing it. The same did not happen for task B, since that participant managed to complete it in less than 19 minutes. On a quick note, some participants did not complete the level, so they would have taken more time than they did. Thus, the average time for both tasks was 16 minutes, which proves that a total of 40 minutes was more than enough to complete both levels.

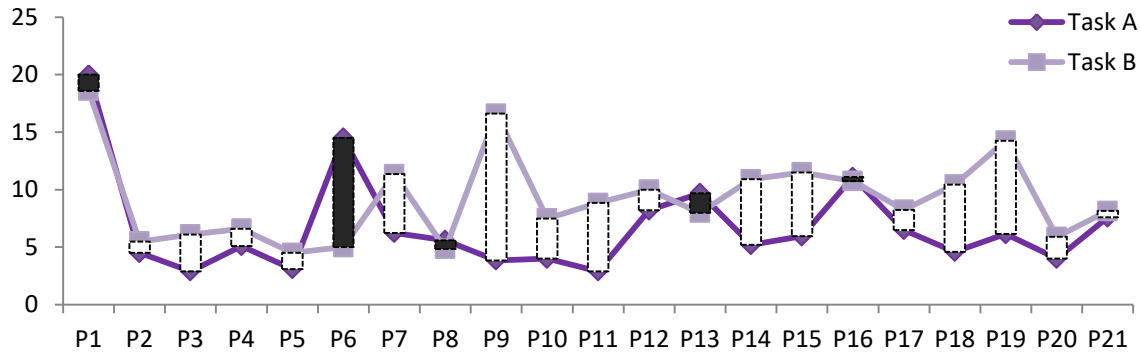

Figure 44 - Time to complete tasks A and B per participant

Task B presented several subtasks integrated on the assembly of a hamburger. These seemed to have caused a lot of issues for participants to understand what they had to do. It was common for them to forget about the task list, once they saw the tablet with the recipe, and start to guess what they had to do next. Also, they often forgot about the position indicators and just started to incorrectly assemble the hamburger. Consequently, the number of errors increased on task B in part for these reasons. The results for both tasks had a minimum of 0 and a maximum of 32 with a mean of 8.3 errors.

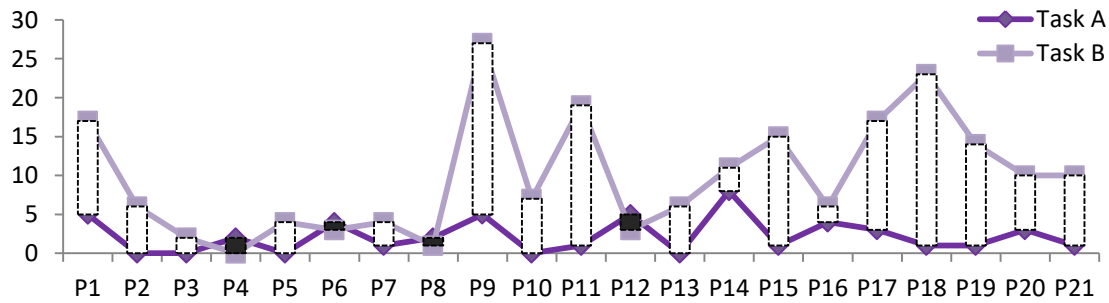

Figure 45 - Errors made while completing tasks A and B per participant

Only two participants had a decrease in the number of mistakes made in task B compared to task A. Mistakes were more often in the second task, due to an increase in difficulty and an increase in participants' confidence in their skills. The most common mistakes were about confusions between the mug, the cup and the coffee pot and between the burger and the ham, failed attempts to guess what the next task would be, difficulty in understanding that objects must be placed on their indicators, not just at random places at the table, confusion with the top and bottom halves of the burger bun, and failed attempts to assemble the hamburger. These mistakes resulted in the need to ask for assistance to proceed with the game. The summary of mistakes made in A and B had a minimum of 0 and a maximum of 8, and an average of 3.1 mistakes.

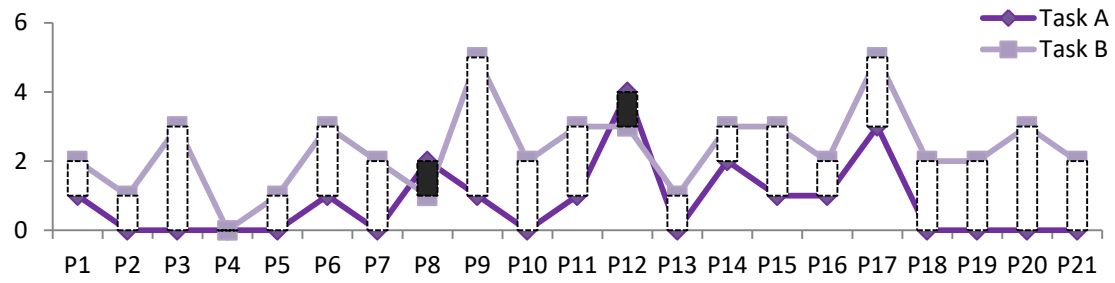

Figure 46 - Mistakes made while completing tasks A and B per participant

Overall, with the exception of participant 9, who struggled to complete task B, participants made an effort to complete the game without any help, maintaining a small number of requested assistances. Consequently, 8 participants did not request assistance more than once in both tasks. And, 2 participants had a decrease in the number of assistances from task A to B. The results combined had a minimum of 0 and a maximum of 16, with an average of 3.7 assistances.

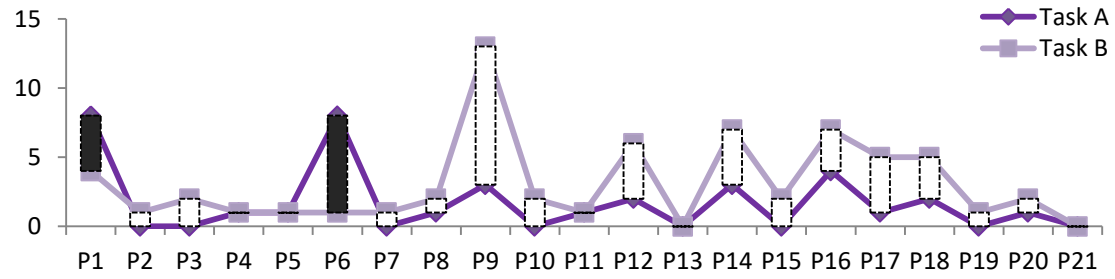

Figure 47 - Assistances requested on tasks A and B per participant

6.1.2.3 Presentation of questionnaire results

The data collected on the questionnaire regarding the system UX and satisfaction was categorized by answer and displayed in bar graphs. Then, participant's answers were analyzed together with their game performance to take conclusions on the prototype functionality.

A. UX results

As it can be seen in Figure 48, the vast majority of the participants strongly agreed that moving around the game was easy. From observing them during gameplay it was noticed that participants did not struggle to walk back and forward to move in the game and did not struggle to teleport around the kitchen. Yet, at first, some participants struggle a bit to understand how the teleportation worked.

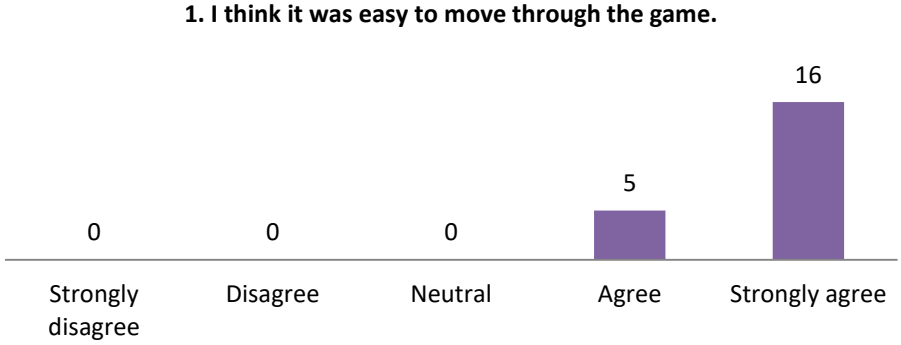

Figure 48 - Participants answers on questionnaire - UX statement 1

All game interactions were designed to be simple so that patients could focus on what they have to do rather than how they need to do it. Upon observation during the test stage, participants did not display much struggle to interact with the different components, so the answers (Figure 49) were mostly positive.

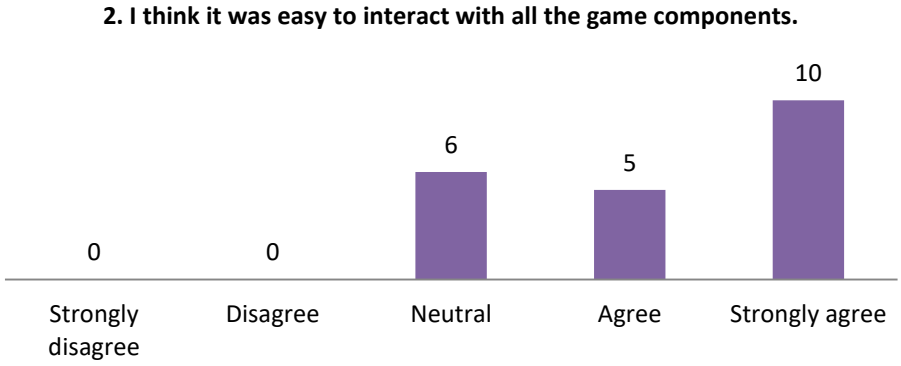

Figure 49 - Participants answers on questionnaire - UX statement 2

All participants agreed with statement 3 (Figure 50) and for the most part of tests this was confirmed. With the exception of the mug that was often mistaken as a cup and ham that was a few times mistaken as the meat burger, participants understood immediately what each object represented, even though the objects where not very realistic.

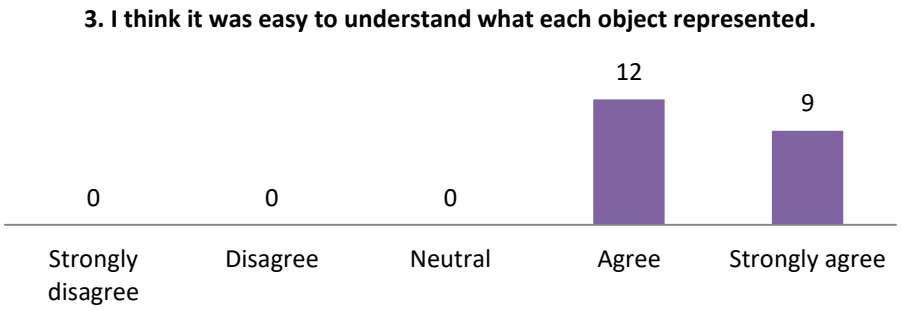

Figure 50 - Participants answers on questionnaire - UX statement 3

Overall, people felt immersed to the point to even try to close doors with parts of their body or avoided bumping their bodies to the furniture, both things that do not affect the game in any way. Some participants also stated that they felt like they were actually inside a kitchen. Still, opinions on this statement were truly diverse, as seen in Figure 51, showing that they felt immersed, but their experience could be improved with more realistic scenarios.

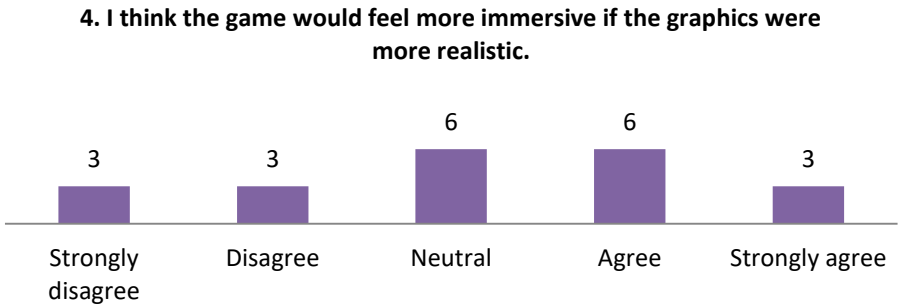

Figure 51 - Participants answers on questionnaire - UX statement 4

Figure 52 shows that most participants strongly agreed that the game provided them with enough tips so that they would know what they had to do, and although for the majority of the gameplay this was verified, there were some moments where the participants had to request the help of the administrator so that they could proceed through the game. The vast majority of assists requested for simple actions like help to find an object, in which the users would end up figuring out on their own, but there were times where users made mistakes and could not progress in the game without assistance. This shows that, although the participants believe that the game provides enough tips, there is still some improvement to be made.

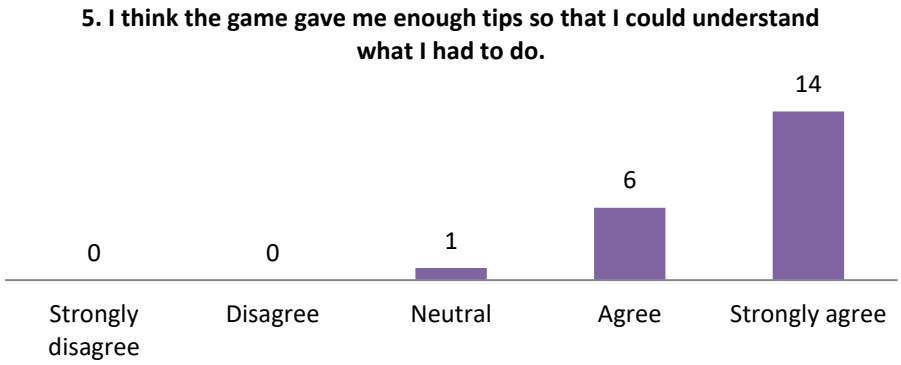

Figure 52 - Participants answers on questionnaire - UX statement 5

On the game design stage, breakfast and lunch were designed so that they would be separate in two levels of difficultly, in which breakfast was designed to be an easier level than lunch. Yet, although most participants agreed with this (Figure 53), some of them stated that they did not feel that way. Even though they had more complex things to do at lunch, they had practiced at breakfast so were also more skilled at the game.

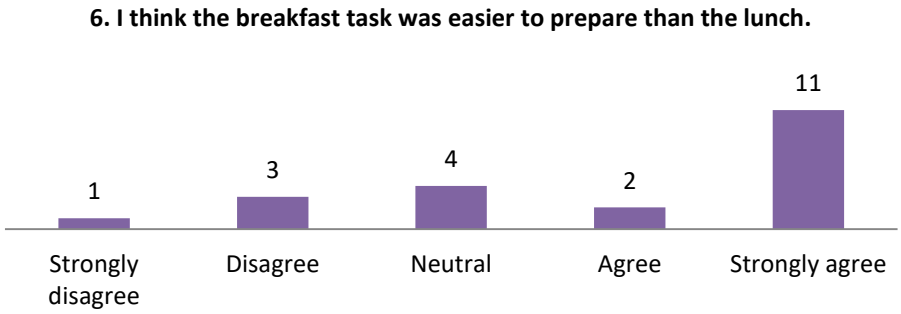

Figure 53 - Participants answers on questionnaire - UX statement 6

It is expected that users will get used to the game mechanics and improve their skills as the gameplay time increases. Results (Figure 54) were diverse, but mostly positive. As expected, participants agreed and showed an improvement during the tests. By the end of the game, players were moving around faster, already knew where some objects were, could find new objects quicker and would execute tasks quicker.

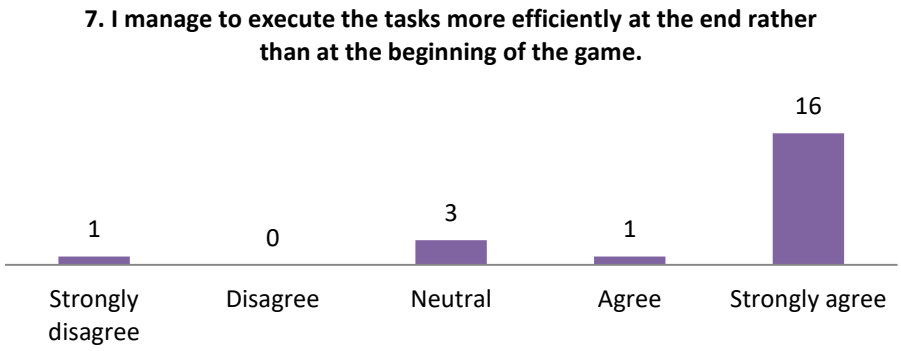

Figure 54 - Participants answers on questionnaire - UX statement 7

Although this is one of the concerns and disadvantages of the immersive VR, during the tests none of the participants complaint about feeling any motion sickness. The questionnaire revealed that two participants (Figure 55) did in fact experience some of these symptoms, yet they did not inform the administrator so they were probably light.

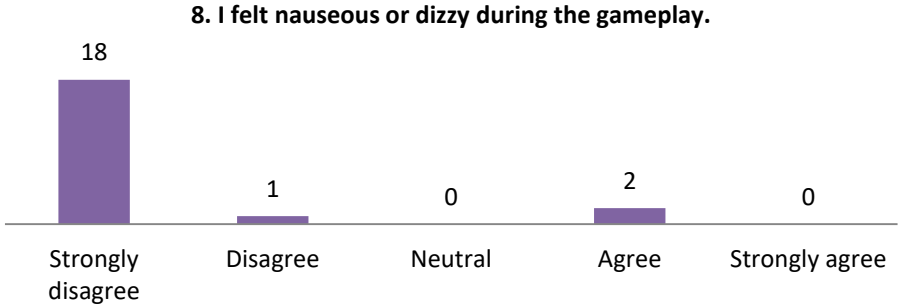

Figure 55 - Participants answers on questionnaire - UX statement 8

The game was designed to be relaxing and fun, yet it is common for players to feel stressed from not being able to progress as fast as expected or from making mistakes. Overall, results showed (Figure 56) this and players seemed to be having fun while playing, only displaying a few signs of stress when they could not find objects or could not understand why they were making a mistake.

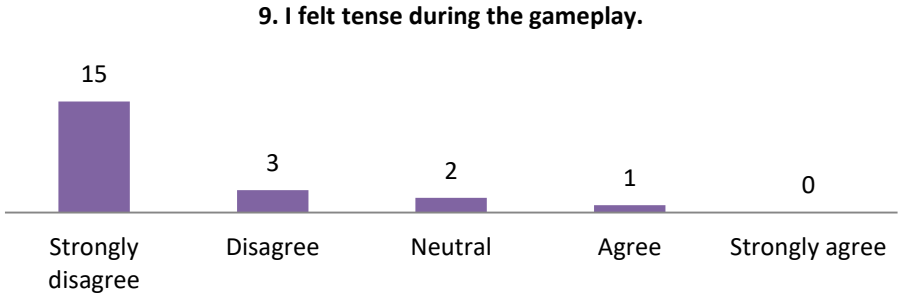

Figure 56 - Participants answers on questionnaire - UX statement 9

Questionnaire results revealed a disagreement between participants on statement 10 (Figure 57). This statement means that participants wanted to complete the tasks and worked hard for it. Still, some participants got the idea that it means that they had to put a lot of physical effort while playing. Consequently, the different results may be a cause of this misunderstanding or just because not everyone wanted to complete the game successfully.

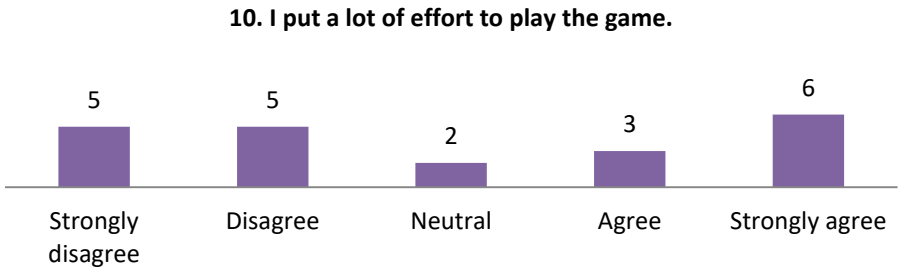

Figure 57 - Participants answers on questionnaire - UX statement 10

B. Satisfaction results

Overall, the reactions towards the game were positive and participants expressed joy while playing it. Some participants said they were sad when the game ended and wished to keep playing it for a bit longer. One participant stated he could be playing it all day. Thus, answers were mostly positive. Answers to the first statement can be seen in Figure 58.

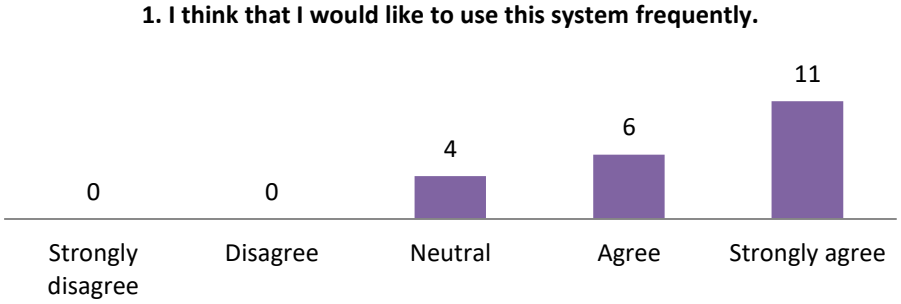

Figure 58 - Participants answers on questionnaire - Satisfaction statement 1

In general participants understood well what they had to do and manage to complete the tasks with little to no help. Players managed to move within the scene and between scenes effortlessly, the game logic was simple and tasks were easy to complete. Participant's answers and performance proved that (Figure 59).

Figure 59 - Participants answers on questionnaire - Satisfaction statements 2 and 3

From the participants performance it was observed that the explanation on the tutorial plus some assistance during the game was enough for them to play the game successfully. It is then perceived that the game requires either a more complex tutorial or the therapist to teach players how to play at first, but then players would not require the presence of anyone to assist them. Their answers also agree with that, as shown in Figure 60.

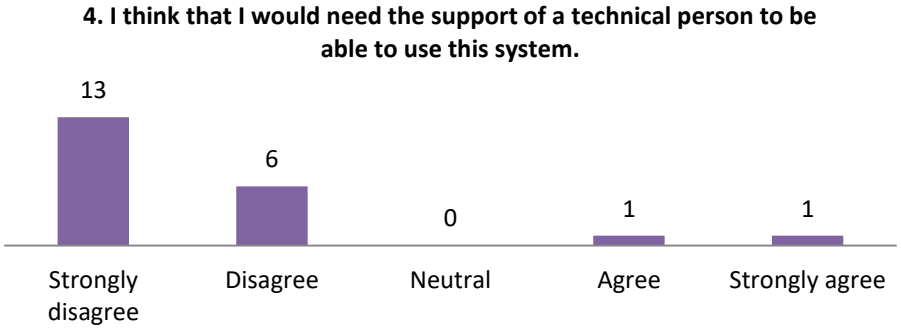

Figure 60 - Participants answers on questionnaire - Satisfaction statement 4

Besides some bugs the game did not display any inconsistency and was designed so that all the components would be integrated with each other. Figure 61 shows that participants mostly agreed that the system functioning was well integrated and was not too inconsistent. The only participant that found the system inconsistent was probably because of all the work that still needs to be done.

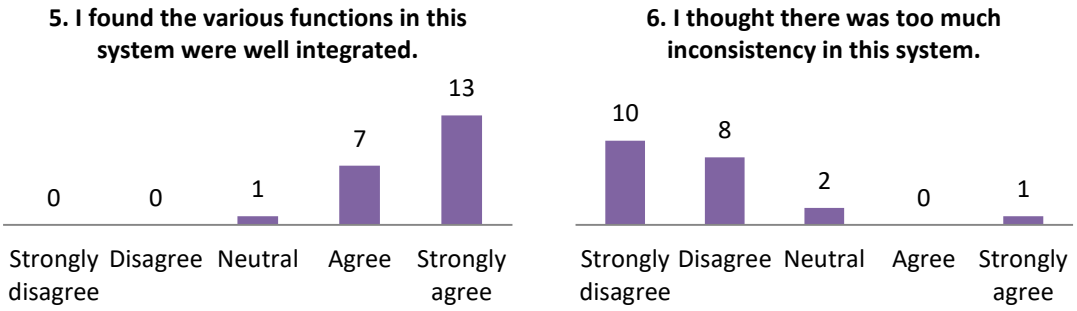

Figure 61 - Participants answers on questionnaire - Satisfaction statements 5 and 6

The game itself was simple and easy to learn, yet how quick users learn to use a system will always depend on how experienced they are. Most participants seemed to have some experience with games and learned rather quickly to use the prototype, even those who did not seem so experienced were quick to learn how to use it. The controllers were the thing that took a bit more time to understand how they worked. From the responses (Figure 62) and the observations, most users will probably learn how to use this system quickly.

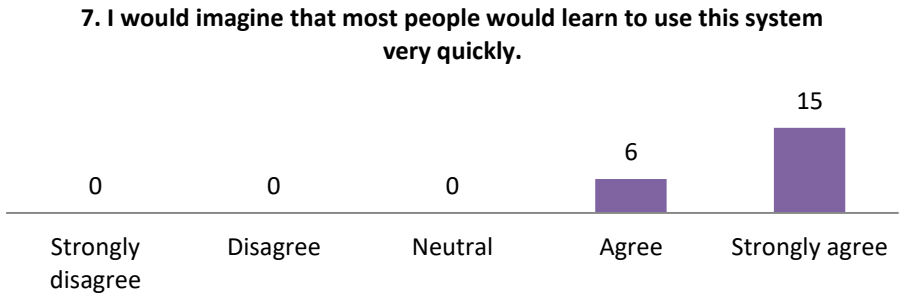

Figure 62 - Participants answers on questionnaire - Satisfaction statement 7

Due to the capabilities of VR, the game interactions were made so that they are done the same way they are done in real life. Thus, the system does not feel weird to use because people use it naturally and all participants agree with that (Figure 63).

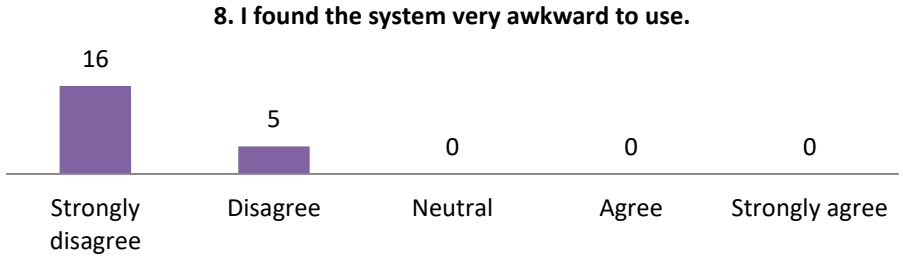

Figure 63 - Participants answers on questionnaire - Satisfaction statement 8

Participants seemed confident while playing mostly because the game was easy and fun. In fact, some of the players got so confident that they started to guess what the next task would be. This either resulted in time saved or in a mistake. Figure 64 shows that they felt confident while playing.

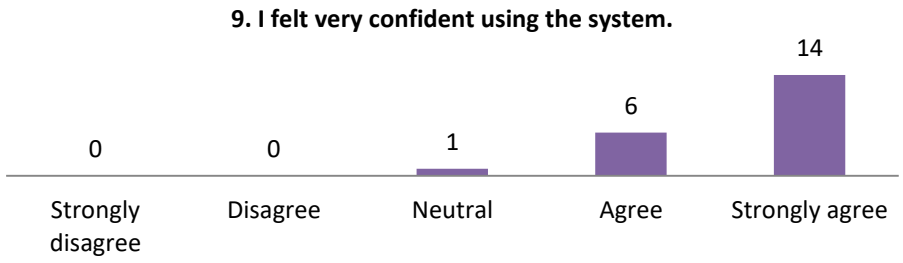

Figure 64 - Participants answers on questionnaire - Satisfaction statement 9

Controls were simple, as well as tasks so users did not have to learn much besides what was thought them in the tutorial. Previous experience with games did also affect their learning curve in the game. Results showed that participants did not consider they had to learn a lot to play the game (Figure 65).

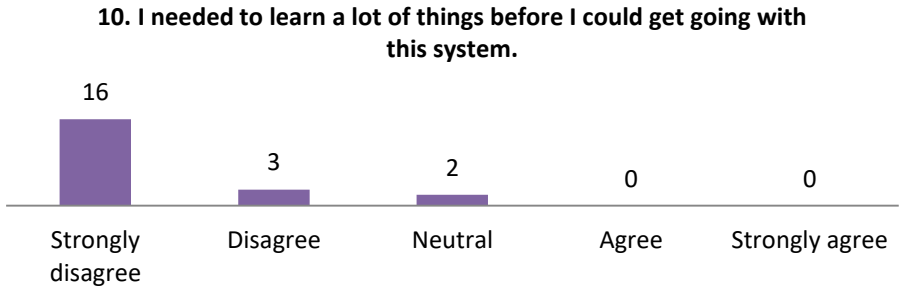

Figure 65 - Participants answers on questionnaire - Satisfaction statement 10

SUS is an instrument composed of 10 questions, used to assess the usability of various products such as services, hardware, and software, among others. The SUS instrument is rated from 0 to 100. A score below 70 means that the system has usability problems and above 71.4 classifies the system as having good usability (Bangor, Kortum, & Miller, 2009). The average score observed in the present investigation (88.7) indicates that the prototype has good usability and according to the study presented by Bangor et al, (2009) the usability is classified above the "Excellent" level.

C. Suggestions

Participants were encouraged to leave suggestions of improvement at the end of the questionnaire. Not all participants submitted suggestions. The suggestions obtained were both to improve particular aspects of the game and to provide ideas to add new features to the game. All the suggestions can be summed up as follows:

- Provide more help when performing a task in the wrong way;
- Modify the mug to make it more evident that it is a mug;
- Make it possible to grab objects which fell on the floor;
- Make it clearer on how to operate the stove and cook the burger;
- Use audio to indicate the tasks and provide help;
- Visual indications of what is being done wrong and how to fix it;
- Let players chose the direction the camera will face on teleportation;
- Task list more accessible or carried out by the player;
- Haptic feedback on object interaction.

6.1.3 Testing Results from a medical perspective

The game usability can easily be tested with regular users, but to test its safety and efficacy in therapy it needs to be evaluated by medical professionals. Thus, there was an extra interview with the two participants who worked in the healthcare field. One was a healthcare assistant and the other was a doctor. None of the participants is specialized in schizophrenia, but they both were aware of the condition and have had contact with schizophrenia patients before. The participants were interviewed on five questions meant to get their perspective on the game, its efficiency, its complexity, its safety and its potential automation. The interview questions and respective answers resulted as follows:

When questioned "What is your opinion on the system?":

- **Healthcare assistant said:** *The game is simple and it is easy to understand what you have to do. If they receive the same explanations from the therapist, the game explains well the rest so patients are able to play it easily. There is only an initial struggle to understand how the controllers work, but after people get that they can easily play it. Also, I believe that even some of the elderly people I take care of would be able to play the game. Although, they might struggle with the controllers a bit at first.*
- **Doctor said:** *The game seems okay and it could be a great help for patients. I would suggest that the game could be customized to the patient restrictions. For instance, if any color or object affects them in any way, they should be able to change them. There is also always the concern that the positive symptoms may reappear and they might need help with that. Also, in a future stage of the project, it would be interesting to adapt and test the system in people with autism. I believe it could also be beneficial to them.*

When question "Do you believe the system can benefit cognitive treatments for negative symptoms?":

- **Healthcare assistant said:** *Yes. I believe the game could benefit them in some way. The game makes sense and helps people execute tasks in an orderly manner.*
- **Doctor said:** *Yes, it could be a great help to them.*

When questioned "Did any of the components seem too difficult for patients to understand?":

- **Healthcare assistant said:** *Only the controllers could be difficult to adapt to if they are not used to playing games.*
- **Doctor said:** *No. The system is easy to use in general, but it can depend on the degree of their condition. Yet, I feel that if they require any assistance while playing, they could have some kind of phone with which they could call someone to help them complete the*

task. For example, if they could not find an object. And, that person could represent someone they interact with on a daily basis like their mom, for instance.

When questioned "Do you believe any component could potentially be dangerous for the patient?":

- **Healthcare assistant said:** *Maybe grabbing the hamburger with their hands instead of using any tool, because they could burn themselves if they replicate that in real life.*
- **Doctor said:** *No. I don´t see anything in particular. It concerns me that they might get anxious and get stuck more easily. So once again, if they had a phone where they could request help, it could also help with that. Being able to exit the kitchen to relax could also help.*

When questioned "Do you believe it will be necessary to have a therapist always present while the patient plays?":

- **Healthcare assistant said:** *No, I do not think it will be necessary. Maybe on the first 2 or 3 times they might need help from someone else, but then they could play it without any help.*
- **Doctor said:** *At first it will be necessary for a therapist to explain the game, but then they could play it by themselves at home.*

6.2 Development Guidelines

The resulting guidelines are a combination of all the research done for this study. It takes into consideration the information obtained from the concepts addressed in the Serious Games Taxonomy (Rego, Moreira, & Reis, 2010), principals addressed in the book The Art of Game Design (Schell, 2008) and the results from the five game therapies gameChange (Lambe, et al., 2020), MASI-VR (Adery, et al., 2019), VR-VRTP (Sohn, et al., 2016), Soskitrain (Calafell, Maldonado, & Sabaté, 2014) and VRVTS (Tsang & Man, 2013). Also, the observations and results from the development and testing of the prototype.

In reality, these guidelines are just the foundation of what the developers should take into consideration when developing game therapies of this kind. Thus, they should be adapted as they seem to fit better the purpose of their study.

Section 1 Considerations towards the target audience

(a) Age: Aim for a large age group, as people of all ages take part in therapy;

(b) Common jobs: Consider training skills that will also be useful at their workplace;

(c) Habits: Learn their daily routine and try to integrate their responsibilities and hobbies, so that they can practice them and see their usefulness;

(d) **Technology experience:** Remember that not all players will have advanced skills in computers and games to be able to easily complete complex tasks;
(e) **Language:** Add multiple languages to increase the amount of people who can play the game.

Section 2 Considerations towards schizophrenia

(a) **Color**
  (i) **Color pallet:** Keep the main color neutral to avoid triggering positive symptoms;
  (ii) **Color contrast:** Respect Principles of color contrast to increase legibility;
  (iii) **Color blindness:** Avoid the combination of color that is difficult to be distinguished by color blind people. They might not be able to distinguish red from green, for instance.
(b) **Audio:** Make sure players always know the purpose behind the audio and where it is coming from, as voices out of context can easily be mistaken with auditory hallucinations.
(c) **Flashing images:** Avoid adding flashing images and lights. This is already a concern in games and other types of media, due to the chance that they might cause seizures. But they might also trigger positive symptoms.
(d) **Stress:** Avoid adding stressful elements to the game. Let players take their time to complete actions, add some relaxing music and keep a calm environment, for instance.

Section 3 Considerations towards accessibility

(a) **Eyesight:** Make everything that is written legible and accompanied by audio and/or symbols. Take into consideration that some users might have poor eyesight and/or use glasses. They may need to read without their glasses;
(b) **Movement:** Avoid the need for jumps or fast reactions and avoid placing objects in elevated positions. Although one of the big strengths of VR is the ability for players to move in the real world, consider people with reduced mobility. The game should be played even when standing or sitting in one position;
(c) **Visual and auditory cues:** Provide multiple forms of cues together, by combining visual and auditory forms of presenting information.

Section 4 Considerations towards therapy

(a) **Portability:** Chose portability over capability. Games will not need to run the best graphics, so it is preferable to use a standalone device rather than a pc-powered one and allow therapy to be taken home;
(b) **Automation:** Add a virtual therapist to assist the player when the real therapist can not be present in the game session and to reduce the therapist's number of things they need to be paying attention to;

(c) **Progress monitoring:** Keep track of player's performance during the game and over time. Display the immediate results and save them to be evaluated over a period of time to see their improvement;
(d) **Replayability:** Let players play levels how many times they need, as they might want to improve their performance.

Section 5 Considerations towards guidance

(a) **Tutorial:** Integrate a game tutorial in which players can learn the basics of the game;
(b) **Instructions:** Add a quick way in which players can easily remind themselves on the basics of the game;
(c) **Feedback:** Implement multiple forms of feedback, such as visual, auditory and/or haptic, so that players always know the result of their actions;
(d) **Hints:** Provide hints whenever players are taking too long to complete an action or when they have made multiple mistakes in a row.

Section 6 Considerations towards the adaptation Mode

(a) **Configuration:** Implement different parameters, like time or difficulty, to adapt to the sessions and player's needs.
(b) **Adaptability:** Make the game adapt to players as they play. This can be achieved by increasing and decreasing difficulty as the game progresses and based on the player's performance.

Section 7 Considerations towards immersivity

(a) **Play time:** Limit gameplay time to no more than 30 minutes, the recommended maximum play time without breaks, by splitting the game in levels and/or by saving the players progress so that they can continue from where they stopped;
(b) **Motion sickness:** Avoid making the player feel sick by darkening the edges of the screen and allowing teleportation. Also, do not make them move too fast or fall;
(c) **Space:** Do not make the game require too much free space for the player to move in the real world. The recommended play area is usually about 2 by 2 meters;
(d) **Movement:** Implement other ways to move besides walking in the real world, like teleportation and/or by using the Thumb Stick.
(e) **Interaction equipment:** Choose between controllers and hands. Chose controllers if you want precision and the game requires a high level of manipulation of objects. Or, choose hands if you want natural interaction and the game is more focused on social interactions.

Section 8 Considerations towards the art style:

(a) Aesthetic: Choose a visual that matches the theme of the game, preferably minimalistic and neutral.

(b) Environment: Make the environment match the aesthetic and the theme, with real proportions and that it transmits the feeling of safety. Also, make it look close what player are used to in daily living;

(c) Realism: Keep objects, proportions and interactions close to what they actually look like in reality, since if they differ too much, they might be teaching the player useless skills;

(d) Customization: Let players customize aspects of the game, like the UI, so that it can better fill their needs.

Section 9 Considerations towards social interactions

(a) Social: Include characters to add a social dimension to help patients deal with asociality;

(b) Characters

(i) Behavior: Keep characters friendly and try to establish a connection between the player and them, as persistent or confrontational characters might cause symptoms of paranoia;

(ii) Aspect: Keep them looking like regular people, as figurine characters might cause symptoms of hallucinations;

(iii) Amount: Keep the number of characters in each scene low, as they might trigger symptoms of anxiety;

(iv) Customization: Allow players to customize themselves or other characters to get a deeper sense of embodiment and connection with the game.

(c) Multiplayer: Let players play with other patients, as it might help increase motivation, enjoyment and avoid unrealistic interactions with standardized characters.

7. Conclusions and Future Work

7.1 Discussion

Overall, this study showed that immersive VR games can be used in addition to therapy to help patients stay motivated and obtain better long-term results.

The analysis confirms that participants enjoyed to play with the prototype, found it easy to play and understood well its goal, which can be considered positive results. The data suggests that the game developed would be effective and safe to be used in therapy.

In line with the hypothesis for the testing stage, the game proved to be a good strategy to help people follow a stream of tasks. It was also considered safe to be used by the target audience in therapy sessions. It was hypothesized as well, that patients would find task B more difficult to complete than task A, and more realistic graphics would have minor impact on how immersed the player feels. Yet, the results on these two hypotheses were inconclusive, but suggesting that they might be contrary to was expected.

Obtained results build on existing evidence that eHealth strategies can be used as an additional treatment to join mental health traditional forms of therapy and pharmacological treatments, with a more modern approach. The data contributes to a clearer understanding of its potential to help treat schizophrenia. Thus, these results should be considered when considering the development of related game therapies. While previous research has focused only on the development of such games without basing their design choices in any regulations, this research aimed at understanding what should be the fundaments of such systems. And, results manage to demonstrate that the definition of development guidelines helps standardizing these systems, makes them more effective, and makes them more often used as an addition to therapy.

In terms of study limitations, the methodological choices were constrained by the time and available hardware and software to both develop and test the prototype. Ideally, and according to the four stages DBR model (Reeves, 2006), the implementation and testing stage should be an iterative cycle in which iteration changes to prototype are made and tested to validate them. However, time only allowed for one phase of testing, to which the final conclusions had to be taken. The reliability of the resulting data was also impacted by the sample, which ideally

should be composed of medical professionals and schizophrenia patients. Yet, it is beyond the scope of this study to perform tests with actual patients.

Further research is needed to validate this research's conclusions on samples of schizophrenia patients. Also, future studies should consider the produced development guidelines, when considering the development of such game therapies.

7.2 Conclusion

In recent years, technology has become a fundamental instrument in our daily life. People use technology for numerous distinct reasons to make use of the enormous benefits it provides. For instance, people use applications and smart watches to help them take care of their health. What is now called eHealth. Not only for personal reasons, but hospitals also make use of modern technologies to take care of patients, perform surgeries and for several types of treatments. In particular, eHealth is starting to be integrated in the treatment of mental illness to accomplish what traditional forms of therapy and medication cannot. One of the most recent trends is the use of VR game therapies as additional behavioral and cognitive treatment options. Studies on this subject have been showing promising long-term results and the possibility of increasing the supply of these treatments, as they can be automized and performed at home. In the case of VR therapies targeting schizophrenia, these showed that when used regularly it can help patients improve useful life skills, worsened by their negative symptoms, motivate them to attend therapy, with a more positive mindset, and decrease the time needed for the recovery of their regular life. When targeted at the right skills and adjusted at the patients' needs, VR game therapies can improve their life in the long term. To develop such games effectively it is necessary to pay attention to the target audience traits, to the schizophrenia specific needs, to the integration of accessibility options, to the therapy requirements, to the integration of guidance, to the usefulness of the adaptation mode, to the possibility of it being immersive, to the chosen art style and to the integration of social interactions.

In conclusion, this research was aimed at the study of eHealth strategies used in treatment of schizophrenia negative symptoms and the development of an immersive VR game therapy, in order to define development guidelines to help create more effective treatments of this kind. Certainly, the main goal was achieved.

7.3 Future Work

It is expected that this work can inspire and be used as a foundation for future research in the subject. Due to the inherited limitations, the study left plenty of opportunities for self-improvement and possibilities to be explored in new research projects.

Based on the findings, the following list offers a broad range of issues that could be addressed as a follow-up to this research.

- **Updates on the house:** There are several features that could be added to the house. For instance, updates on the kitchen like building custom furniture and adding other more appliances, utensils and food, would give a fresh look to the room and allow the preparation of other recipes. Also, the development of the other divisions, like the living room, bedroom and bathroom would add new challenges to the game.
- **Other types of tasks:** It would be interesting to test other types of tasks. For instance, to tasks about washing the dishes, eating and more complex recipes. If the house had more rooms, it could have tasks to clean the house, make the bed or take care of personal hygiene.
- **Customization:** Not only can this feature be useful, but it can be fun as well. There are different areas that customizations could be implemented in, like on the interface, so that it matches the player's needs, on the interior design, so that patients feel like the environment is more like their own house, and on the characters, so that players can both feel like they identify with the main character and feel familiarized with other characters. Game customization is an advantage because it provides a layer of accessibility and players enjoy customizing characters and other features.
- **Virtual therapist:** Automating the game with a virtual therapist would make it accessible to a larger number of patients, since there would not be a need for a real therapist to be present every time the patient wants to play the game.
- **Social interactions:** Adding other characters so that patients can have social interactions with can help them improve their social skills, reduce social anxiety and feel less lonely while playing. Furthermore, a multiplayer mode would create the possibility for two patients to attend a therapy session together, and help each other complete tasks and train social skills.
- **Login and database storage:** The prototype developed only displayed the player's performance at the end of the level without storing it anywhere for further reference. Thus, storing that data in a database would allow the therapist to study the patients' performance over time to see if they are improving. To achieve that, it would be necessary to implement an account management system, where patients could login to their accounts to access their data.
- **Therapist application:** During the testing stage, the test administrator had to rely on the oculus casting service to watch what the player was doing in the game and did not have any control over it. So, it would be beneficial to have an application in which the therapist could connect to the game, change adaptation mode settings before and during the game, watch the gameplay in real time and check the patient's performance of all sessions.

- **Further tests:** Finally, all these new alterations would need to be tested as well. Additionally, having the opportunity to test the game with a sample of schizophrenia patients would help to validate it. Although the opinion of regular people and medical professionals is essential to corroborate the game's efficiency, it is impossible to know for sure without testing it with the target audience.

8. References

Adery, L. H., Ichinose, M., Torregrossa, L. J., Wade, J., Nichols, H., Granholm, E., Sarkar, N., Park, S. (2019). The Acceptability and Feasibility of a Novel Virtual Reality Based Social Skills Training Game for Schizophrenia: Preliminary Findings. *Psychiatry Research 270*, 496-502.

Amado, I., Herné, L., Orriols, E., Desombre, C., Santos, M., Prost, Z., Krebs, M., Piolino, P. (2016, April 20). A Serious Game to Improve Cognitive Functions in Schizophrenia: A Pilot Study. *Frontiers in Psychiastry, 7*(64), 1-11.

Aniwaa. (2021, August 6). *Types of VR headsets: PC VR, standalone VR, smartphone VR*. Retrieved from Aniwaa: https://www.aniwaa.com/guide/vr-ar/types-of-vr-headsets/

Bangor, A., Kortum, P., & Miller, J. (2009). Determining what individual SUS scores mean: adding an adjective rating scale. *Journal of Usability Studies, 4*, 114-126.

Barello, S., Triberti, S., Graffigna, G., Libreri, C., Serino, S., Hibbard, J., & Riva, G. (2016). eHealth for Patient Engagement: A Systematic Review. *Frontiers in Psychology*.

Barranha, R., Teixeira, T., Quarenta, J., & Doellinger, O. (2021). Living conditions of patients with schizophrenia spectrum disorders in the region of 'Tâmega e Sousa' (Portugal). *International Journal of Psychiatry*, 441-447.

Breuer, J., & Bente, G. (2010). Why so serious? On the Relation of Serious Games and Learning . *Journal for Computer Game Culture*, 7-14.

Button, T. (2017, July 3). *Meaningful and Fun Social Groups for Students Grades K-12.* Retrieved from Slide Player: https://slideplayer.com/slide/3371180/

Calafell, M. R., Maldonado, J. G., & Sabaté, J. R. (2014). A virtual reality-integrated program for improving social skills in patients with schizophrenia: A pilot study. *Journal of Behavior Therapy and Experimental Psychiatry*, 81-89.

Correll, C. U., & Schooler, N. R. (2020). Negative symptoms in schizophrenia: a review and clinical guide for recognition, assessment, and treatment. *Neuropsychiatric disease and treatment, 16*, 519-534.

Dimitra, K., Konstantinos, K., Christina, Z., & Katerina, T. (2020). Types of Game-Based Learning in Education: A Brief State of the Art and the Implementation in Greece. *European Educational Researcher*, 87-100.

Eysenbach, G. (2001). What is eHealth? *Journal of Medical Internet Research, 3*.

Fajnerova, I., Rodriguez, M., Spaniel, F., Horacek, J., Vlcek, K., Levcik, D., & Stucchlik, A. (2015). Spatial navigation in virtual reality - from animal models towards schizophrenia: Spatial cognition tests based on animal research. *International Workshop on Virtual Rehabilitation*, (pp. 44-50). Valencia, Spain. Retrieved from IEE.

Freeman, D., Haselton, P., Freeman, J., Spanlang, B., Kishore, S., Albery, E., Denne, M., Brown, P., Slater, M., Nickless, A. (2018, August). Automated psychological therapy using immersive virtual reality for treatment of fear of heights: a single-blind, parallel-group, randomised controlled trial. *Lancet Psychiatry, 5*, 625-632.

Girnyak, M. (2021, February 12). *Mixed Reality Examples in Business, Gaming, and E-learning*. Retrieved from Post Industria: https://postindustria.com/mixed-reality-examples-in-business-gaming-and-e-learning/

Heizenrader. (2019, September 11). *The 3 Types of Virtual Reality*. Retrieved from Heizenrader: https://heizenrader.com/the-3-types-of-virtual-reality/

Hesse, K., Schroeder, P. A., Scheeff, J., Klingberg, S., & Plewnia, C. (2016). Experimental variation of social stress in virtual realityeFeasibilityandfirst results in patients with psychotic disorders. *Journal of Behavior Therapy and*, 129-136.

Lambe, S., Knight, I., Kabir, T., West, J., Patelf, R., Lister, R., Rosebrocka, L., Roviraa, A., Garnishf, B., Freemanf, J., Clark, D. M., Waitea, F., Freemana, D. (2020). Developing an automated VR cognitive treatment for psychosis: gameChange VR therapy. *Journal of Behavioral and Cognitive Therapy*, 33-40.

Lim, M. H., & Penn, D. L. (2018). Using Digital Technology in the Treatment of Schizophrenia. *Schizophrenia Bulletin*, 1-2.

Machado, L. S., Moraes, R. M., & Nunes, F. L. (2009). Serious games para saúde e treinamento imersivo. *Abordagens práticas de realidade virtual e aumentada*.

Machado, L. S., Moraes, R. M., Nunes, F. L., & Costa, R. M. (2010). Serious Games Based on Virtual Reality in Medical Education. *Revista Brasileira de Educação Médica*, 254-262.

Martins, A. I., Rosa, A. F., Queirós, A., Silva, A., & Rocha, N. P. (2015). European Portuguese Validation of the System Usability Scale (SUS). *Procedia Computer Science, 67*, 293-300.

Michalakis, G., Pavlou, M., Georgianns, G., Liapis, V., Terzi, I., Tsagarakis, A., Asimakopoulou, R., Bitzas, B., Moustakas, K. (2020). Another day at the office: Visuohaptic schizophrenia VR simulation. *2020 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops*, 515-516.

Noble, S. (2021, August 6). *The 8 best smartphone virtual reality headsets of 2021*. Retrieved from aniwaa: https://www.aniwaa.com/buyers-guide/vr-ar/best-smartphone-vr-headset/

North of 41, . (2018, March 20). *What really is the difference between AR / MR / VR / XR ?* Retrieved from Medium: https://medium.com/@northof41/what-really-is-the-difference-between-ar-mr-vr-xr-35bed1da1a4e

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W. (2021). The PRISMA 2020 statement: an updated guideline for reporting. *International Journal of Surgery*, 1-9.

Park, K., Ku, J., Choi, S., Jang, H., Park, J., Kim, S. I., & Kim, J. (2011). A virtual reality application in role-plays of social skills training for schizophrenia: A randomized, controlled trial. *Psychiatry research*, 166-172.

Park, M. J., Kim, D. J., Lee, U., Na, E. J., & Jeon, H. J. (2019). A Literature Overview of Virtual Reality (VR) in Treatment of Psychiatric Disorders: Recent Advances and Limitations. *Frontiers in Psychiatry*, 1-9.

Patsi, C., Yfantidou, G., Antoniou, P., Gkoraki, V., & Lagiou, K. (2016). Perceptions of people with schizophrenia regarding digital interactive games. *Journal of Physical Education and Sport. 16 Supplement issue*, 650-655.

Plechatá, A., Fajnerová, I., Hejtmánek, L., & Sahula, V. (2017). Development of a virtual supermarket shopping task for cognitive remediation of memory and executive functions in schizophrenia. *International Conference on Virtual Rehabilitation (ICVR)* 1-2. Montreal, Canada: IEE. Retrieved from IEE.

Reeves, T. (2006). Design research from a technology perspective. In N. Nieveen, *Educational design research* (pp. 64-78). London: Routledge.

Rego, P. A., Moreira, P. M., & Reis, L. P. (2010). Serious Games for Rehabilitation: A Survey and a Classification Towards a Taxonomy. *Sistemas y Tecnologías de Información. Actas de la 5ª Conferencia Ibérica de Sistemas y Tecnologías de Información*, 349-354.

Rego, P. A., Moreira, P. M., & Reis, L. P. (2018). Proposal of an Extended Taxonomy of Serious. *GAMES FOR HEALTH JOURNAL: Research, Development, and Clinical Applications, 7*(5), 302-309.

Rocha, U. (2015). Concepção e Desenvolvimento de Jogos sérios para Terapia Ocupacional e Treino de Marcha e Equilíbrio. *SBC – Proceedings of SBGames 2015*, 271-274.

Schell, J. (2008). *The Art of Game Design: A book of lenses.* CRC press.

Shaw, T., McGregor, D., Brunner, M., Keep, M., Janssen, A., & Barnet, S. (2017). What is eHealth (6)? Development of a Conceptual Model for. *Journal of Medical Internet Research, 19*.

Sohn, B. K., Hwang, J. Y., Park, S. M., Choi, J. S., Lee, J. Y., Lee, J. Y., & Jung, H. Y. (2016, November). Developing a Virtual Reality-Based Vocational Rehabilitation Training Program for Patients with Schizophrenia. *Cyberpsychology, Behavior, and Social Networking*, 686-691.

Sotos, P. F., Caballero, A. F., & Jimenez, R. R. (2020). Virtual reality for psychosocial remediation in schizophrenia: a systematic review. *The European Journal of Pshychiatry*, 1-10.

Stapleton, A. J. (2004). Serious games: Serious opportunities. *Australian Game Developers Conference* (pp. 1-6). Melbourne, Australia: VIC.

Susi, T., Johannesson, M., & Backlund, P. (2007). *Serious Games – An Overview* . University of Skövde, Sweden: School of Humanities and Informatics.

Torres, F. (2020, August). *What is Schizophrenia?* Retrieved from American Psychiatric Association: https://www.psychiatry.org/patients-families/schizophrenia/what-is-schizophrenia

Tsang, M. M., & Man, D. W. (2013). A virtual reality-based vocational training system (VRVTS) for people with schizophrenia in vocational rehabilitation. *Elsevier journal: Schizophrenia Research*, 51-62.

University of Toronto. (2021, September 1). *What is VR? - Virtual Reality in the Classroom*. Retrieved from University of Toronto: https://guides.library.utoronto.ca/c.php?g=607624&p=4938314

World Health Organization. (2022, January 11). *Schizophrenia*. Retrieved from World Health Organization: https://www.who.int/news-room/fact-sheets/detail/schizophrenia

Zawadzki, J. A., Girard, T. A., Foussias, G., Rodrigues, A., Siddiqui, I., Lerch, J. P., & Wong, A. H. (2013). Simulating real world functioning in schizophrenia using a naturalistic city environment and single-trial, goal-directed navigation. *Frontiers in Behavioral Neuroscience Volume 7*(180), 1-10.

Appendix A – Systematic Review

Review

Therapeutic use of VR Serious Games in the Treatment of Schizophrenia Negative Symptoms: A Systematic Review

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Abstract: Schizophrenia is a chronic brain disorder that affects 1 in every 300 people worldwide. This study intends to perform a systematic review to describe the state-of-the-art of interventions of patients with negative symptoms of schizophrenia, that make use of Virtual Reality (VR) games as a complement to therapy, and to analyze the key features of such games. Literature research was conducted in three databases, namely IEEE (Institute of Electrical and Electronics Engineers), Scopus and PubMed, to identify relevant publications dated from 2010 to 2021. Studies were included if they fulfilled the inclusion/exclusion criteria. Of the initial 74 publications found, only 11 satisfied the eligibility requirements and were included in this study. Results were then organized and displayed in a flow diagram. Overall, studies' results revealed good outcomes regarding the use of VR in therapies, with an increase in social skills and a decrease in anxiety symptoms. The use of such technology in therapy has proven to be effective, although it still lacks features to provide better long-term results.

Keywords: Virtual Reality; Game Design; Serious Games; Schizophrenia.

1. Introduction

One of the key characteristics of schizophrenia has been recognized as psychosocial impairment, which includes a deficit in social cognition and social behavior [1]. Symptoms such as depression, cognition, and even social functions have all been found to be influenced by the use of VR environments [2]. This way, by using an immersive VR environment, it's possible to create realistic situations, which could possibly trigger negative symptoms in patients, but in a secure simulation, enabling users to build their confidence and better cope with their struggles.

VR is an interesting tool that has started to be used in remediation therapies[1]. Although it is typically used as an exposure technique for specific phobias, VR has been recently applied with encouraging results to the study and treatment of schizophrenia [3]. It can offer the potential for a significant therapeutic benefit [4], since patients are more willing to enter challenging situations and experiment with alternative ways of responding [5]. Patients can put on a headset and be immersed in multiple situations ranging in difficulty, which may cause them different levels of psychological distress [6].

Individuals, not only in their own life activities, but also in treatment, may be hesitant about face-to-face engagement [7]. Causes of this anxious withdrawal may be many: social anxiety, negative self-image, panic attacks and lack of confidence [5]. Studies have shown that psychosocial interventions in schizophrenia have positive effects on disease symptoms, treatment compliance, quality of life, social cognition, social functioning and employment [1], generating positive perceptions and pleasant emotions.

It was reported an improvement on relationships and peer motivation [8] on group therapy sessions with digital games, where they can play together. The power of VR interventions thus far has been most evident in the treatment of anxiety disorders [5]. Yet, some studies also noted an improvement in general psychopathology, negative symptomatology and daily functioning [1].

The success of a rehabilitation program depends on various factors [4], not simply exposure to a troubling situation is key for clinical change, but actively testing out fears with the dropping of defense behaviors [5]. The sense of embodiment seems to be one of the most important factors in a VR application, especially when it focuses on the increase of empathy. The user must feel self-located inside the virtual environment, perceive feedback from the environment as it was from his own sensations and recognize himself as the cause of the actions [9].

VR therapy can be as effective, if not more effective, than treatments delivered in traditional formats [5]. Nonetheless, there's still an initial reluctance to work with VR in patients with schizophrenia [1] due to the old misconceptions that games are only about having fun and can´t be used to develop practical skills. As a consequence, the existing rehabilitation games lack the entertainment factor and should be updated to meet a greater number of key parameters, causing them to become more useful therapeutic instruments [4]. For instance, most VR therapy systems still require the presence of a therapist to administer the treatment, thereby restricting the treatment scalability [5], also, the effectiveness of computer games for rehabilitation could be enhanced by the incorporation of a social dimension [4,10]. Furthermore, to the best of our knowledge, there has been no study published where games use collaboration or competitiveness as a significant part of the schizophrenia rehabilitation process.

To conclude, there is yet a long way into developing a solution for VR game therapies. The aim of the present study is to conduct a systematic review of the interventions based on VR targeted at patients with negative symptoms of schizophrenia, and also on the characteristics of such interventions. From such review an analysis of the presence or absence of key components of those interventions will be made.

2. Serious Games

Serious games are becoming a prominent study topic, fueled by advancements in game production and computer graphics hardware, which are in turn fueled by the popularity of video games [4]. This has led to a view of games as educational technologies and, consequently, as having application beyond the realm of entertainment [11]. Although the term serious game still has a broad range of definitions, it is agreed that the main purpose of these games goes beyond mere entertainment [4,12-14], they're essentially designed to make players learn something and, if possible, have fun while doing it [14]. For the purpose of this article, serious games are defined as digital games that, through some form of simulation, allow users to build knowledge and learn new skills in a more engaging and possibly fun way.

Games provide powerful and meaningful contexts for learning [11], it can also have positive impacts on the players' development of a number of different skills [14]. In addition, games have been demonstrated to help enhance motivation in rehabilitation sessions, which is a big issue in treatment sessions due to the exercise's repetitive nature [4].

The fact that everything takes place in a simulation allows players to develop specific skills [12-14] and experience situations that are difficult to reproduce in the real world, for reasons regarding safety, cost and time [14]. When combined with immersive VR, serious games are able to easily computationally simulate realistic virtual environments, in order to recreate scenes and situations experienced in everyday life [13]. These VR based-methods can offer patients immersive experiences that are engaging and rewarding for them [4]. This way, the growing diffusion of serious games also expands

the advances of VR to society by bringing applications that motivate the assimilation and construction of new concepts in contexts similar to those in the real world [13].

3. Schizophrenia Symptomatology

There's recurring evidence substantiating the fact that negative symptoms are apart from positive symptoms. While positive symptoms are often the reason why people get diagnosed with the illness, negative symptoms have been reported as among the most common first symptoms of schizophrenia, furthermore they can occur at any phase [15].
In comparison, positive symptomatology is characterized as an excess or distortion of normal function and can include, for example, delusions and hallucinations. On the contrary, negative symptomatology is characterized as a diminution or absence of normal behaviors and can include a decrease of motivation and interest [15].
In depth, according to Correll et al. [15] the negative domain consists of five symptoms: blunted affect (a diminution in facial expressions), alogia (a decrease in the number of words spoken), avolition (a reduction in goal-oriented activities), asociality (poor relationship management), and anhedonia (a decreased experience of pleasure). This domain can also be subdivided into primary and secondary negative symptoms. However, these symptoms can be hard to distinguish, still recognizing the differences between the two is crucial for clinical trial design and researchers to know how to differentiate them. Fundamentally, primary symptoms are the ones intrinsic to the disease and usually can't be managed with the currently available treatments, on the other hand, secondary symptoms are the ones that occur as a result from positive symptoms, affective symptoms, medication side effects and other related factors [15].
At last, there is still a medical need for effective pharmacologic therapies to address negative symptoms. Thus, technologically advanced interventions aimed at addressing attitudes, behaviors, and psychosocial functioning can be really beneficial when used in conjunction with the already available treatments [15].

4. Materials and Methods

A systematic review on therapeutic studies was made, using VR serious games, targeted at schizophrenia negative symptomatology, as well as, other relevant therapies. The systematic review strategy was conducted according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines [16].

4.1. Eligibilty Criteria

From the search results, were selected for revision those which were written in English and included at least one of the keywords mentioned below. Preferentially, studies should be focused on the development of 3D VR game therapies for the treatment of schizophrenia negative symptoms, although initially other apparently suitable publications were also selected for revision. For instance, systematic reviews, duplicated studies, partially available studies and the development of VR games for other rehabilitation purposes, were initially revised, but not included in the final revision.

Studies were excluded if they were:

1. Literature reviews;
2. Not specifically targeted at schizophrenia;
3. Not focused on negative symptoms;
4. Not game-based therapies or using a game developed previously by other study or entity.

4.2. Information Sources and Search Strategy

The three databases used to gather the dissertations, articles and other publications of interest were IEEE, Scopus (Elsevier) and PubMed (National Library of Medicine). Articles published from January 2010 to October 2021 were reviewed to obtain the most relevant and updated research. The 2010 start date was chosen since it represents a relevant milestone in terms of the development of virtual reality technologies. In addition

to the technological improvements in the systems, the availability of high-speed internet connection, combined with the reduction in costs of the devices, led to an increase in its use.

Then, the following keywords were combined to look for studies of interest in those databases: "Virtual Reality" or "VR" and "Schizophrenia" or "Negative symptomatology".

4.3. Data Extraction

To support the selection of the articles, a specific Excel spreadsheet was prepared for data extraction and to help in identifying the accomplishment of inclusion or exclusion criteria. Data extraction was completed by two authors (BM and PAR). Where different decisions occurred, these were discussed and the respective papers were reassessed.

4.4. Data Items

In the analysis performed on the selected articles, the following data items were extracted: sample, duration, therapy targets, interaction, immersion, scenery, adaptation, progress monitoring, feedback, portability and automation.

4.5. Risk of Bias Assessment

Since the present review does not aim to study the effectiveness of interventions, an assessment of the risk of bias was not performed.

5. Results

The eleven resulting studies were then analyzed according to what we consider to be serious games key components. Some of the selected criteria followed the guidelines proposed in Rego et al. [17].

5.1. Study Selection

The steps followed in Figure 1 describe the search process driven from the combination of the three chosen databases with the selection and exclusion criteria, which resulted in a total of 74 records being found. Still on the Identification step, after combining the selected articles, those which were duplicated were excluded (n = 20). Then, while on Screening phase, articles were read and discarded if the exclusion criteria applied (n = 35). Finally, the remaining 19 records were evaluated for eligibility and excluded for particular reasons, resulting in a total of 11 studies included in the review. The studies were independently screened by two authors (BM and PAM) without the use of any automation tools.

5.2. Classification criteria

Since no specific criteria has been defined on the development of VR game therapies for schizophrenia, current available studies often overlook key parameters that can make the difference on whether the game is going to be effective or not. Therefore, current studies on the subject were analyzed and compared with each other, following the proposed taxonomy on serious games by Rego et al. [17], to find out which ones implement the most parameters and how these are implemented.

From the analysis made eleven parameters were selected, related to the testing trials and to the game therapies, for comparation purposes. The selected classification criteria include: sample (the number of subjects tested), duration (the duration of game testing in sessions, weeks and/or months), therapy target (the target skills the game is supposed to improve), interaction (the interaction modality), immersion (whether is immersive or not), scenery (essentially the game environment, but also genre and storyline), adaptation (game difficulty settings), progress monitoring (whether or not the system can collect performance data during gameplay), feedback (game response to user actions), portability (whether the game therapy can be administered outside of the health facility) and automation (whether or not the game is automated).

Table 1 illustrates the classification made for the selected VR therapies using the mentioned eleven parameters.

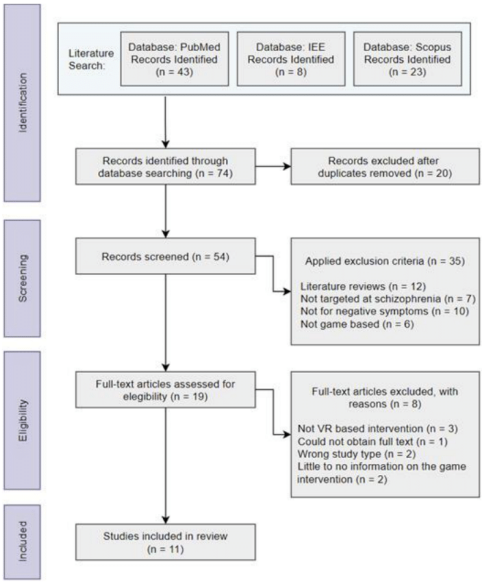

Figure 1. Steps followed to collect and select articles for revision.

5.3. VR game interventions description

5.3.1. Social skills training VR (SST-VR) Role-play [18]

Conversation skills training, assertiveness skills training and emotion expression skills training are the three types of skills chosen to base each task to be completed by the patient in role plays of everyday situations. This intervention sample was divided into two groups, one that experimented with the immersive VR sessions and the other the traditional sessions, meaning just the patient and therapist role playing. The main purpose of the study was to find advantages of the use of VR in social rehabilitation compared to the traditional forms of rehabilitation.

5.3.2. VR Vocational Training System (VRVTS) [19]

The vocational role playing happens in a virtual boutique. This scenario was chosen for the study due to the identification of a salesperson as someone who requires social skills to interact with customers and handling conflicts, as well as problem solving skills. In order to level up in their position, the participants had to complete three levels of difficulty, all with a final competence test.

The study's intention was to investigate the efficacy and effectiveness of VR for enhancing vocational traits. This way, the study divided its sample into three training groups: VR, therapist administered and conventional, one digital based and the others not, still the content and structure was similar.

5.3.3. Virtual city [20]

Patients and their matched controls completed the same eight individual tasks on the virtual city. Four tasks tested their ability to find different targets around the city and the other four tested their ability to return to a specific location. This way, the study aimed at developing a VR game to function as meaningful measure of cognition and complement cognitive tests during clinical trials for schizophrenia treatments.

Table 1. The selected VR therapies classification

Game therapy name	Authors, Year	Sample	Duration	Therapy targets	Interaction	Immersion	Scenery	Adaptation	Progress monitoring	Feedback	Portability	Automation
SST-VR [1] Role-play	Park et al., 2011 [18]	91 inpatients from a mental health hospital	10 sessions, twice a week over 5 weeks	Behavioral	HMD, joystick, voice and motion tracker	Yes	House, shop and street	--	--	Mixed	--	--
VRVTS [2]	Tsang et al., 2013 [19]	95 inpatients who attended a vocational rehabilitation program	10 sessions, once a week over 5 months, lasting for 30 minutes	Cognitive	Keyboard, mouse and joystick	No	Shop	--	--	Mixed	--	Yes
Virtual city	Zawadzki et al., 2013 [20]	33 patients from mental health center	1 session	Cognitive	Joystick	No	City	--	Yes	--	--	--
Soskitrain	Calafell et al., 2014 [3]	12 outpatients from an adult mental health service	16 sessions, twice a week over 8 weeks	Behavioral	HMD, voice and facial recognition	Yes	Shop and bar	--	Yes	--	--	--
Virtual Morris water maze and Carousel maze	Fajnerova et al., 2015 [21]	29 first episode schizophrenia patients	1 session	Cognitive	Joystick	No	Maze	--	--	--	--	--
Social VR Simulation	Hesse et al., 2016 [22]	26 patients with psychotic disorders	2 sessions in 2 weeks	Cognitive	HMD, joystick and voice	Yes	Office	--	--	System interface	--	Yes
VR-VRTP [3]	Sohn et al., 2016 [23]	11 outpatients from a mental health center	8 sessions, once a week over 8 weeks, lasting for 60 minutes	Behavioral	Keyboard, mouse and voice	No	Convenience store and supermarket	--	Yes	System interface	--	Yes
Seroius Game to Improve Cognitive Functions in Schizophrenia	Amado et al., 2016 [24]	7 patients with schizophrenia institutionalized for many years	12 sessions, once a week over 3 months, lasting for 90 minutes	Cognitive	Joystick	No	City	--	--	--	--	--
vSST [4]	Plechatá et al., 2017 [25]	26 subjects without any neurological or psychiatric diagnosis	1 session	Cognitive	--	--	Supermarket	Configuration	Yes	--	--	--
MASI-VR [5]	Adery et al., 2019 [26]	17 outpatients from day facilities	10 sessions, twice a week over 5 weeks	Behavioral	Keyboard and mouse	No	Shop and bus stop	Configuration	Yes	Mixed	Home Assisted	Yes
gameChange	Lambe et al., 2020 [5]	11 patients with lived experience of psychosis	6 sessions, with the duration of 30 minutes	Cognitive	HMD	Yes	Shop, street, bar, bus and doctor's office	Configuration	--	System controlled	Home	Yes

[1] Social Skills Training; [2] VR Vocational Training System; [3] VR Vocational Rehabilitation Training Program; [4] virtual Supermarket Shopping Task; [5] Multimodal Adaptive Social Intervention in VR

5.3.4. Soskitrain [3]

This VR game consists of seven activities based on chosen targeted social interactions, namely: criticism, social assertiveness, confrontation expression, heterosocial contact, interpersonal warmth, conflict by parents, interpersonal loss and positive expression. Thus, the game allows users to practice social interactions with virtual characters, encourages learning of social skills and provides feedback on the user's actions. Also, in order to assess patient's performance, the game uses their committed errors, assertive behaviors and time as score.

This study aimed at reporting the results achieved with their VR game, when used as complement to schizophrenia interventions, in hopes it would improve social cognition and performance of patients.

5.3.5. Virtual Morris water maze and Carousel maze [21]

This VR game intervention was designed to demonstrate the deficit of spatial cognition in schizophrenia. It contemplates two levels, the Stable arena and the Rotating arena, designed to make users navigate towards several hidden goal positions placed on the floor of the enclosed arenas. The Stable arena had a virtual four goals navigation task to find and remember certain positions using three orientation cues. The Rotating arena was similar to the previous one, but with two possible frames, one in which both the arena and player rotate and the other in which there's a static room, that moves in respect to the player's position.

5.3.6. VR Vocational Rehabilitation Training Program (VR-VRTP) [23]

Two scenarios were developed, believed to be more likely to employ people with schizophrenia, a convenience store and a supermarket. Before entering a specific scenario, patients received training in presenting a good image, including training in greeting posture, smiling, and common verbal greetings. Each trial included practical situations commonly encountered when working on the chosen field of work. The game provided feedback as well as scores to give a sense of accomplishment as users progress. Likewise, the VR based vocational game was built so that schizophrenia patients could learn skills to be applied in a real-life context.

5.3.7. Serious Game to Improve Cognitive Functions in Schizophrenia [24]

A virtual city inspired by Paris was developed as the scenery for this serious game. The existing several different places, located so that they could be easily found, such as a bank, a supermarket, a restaurant, a pharmacy, a park and others, could be used as visual landmarks to orient their navigation. Patients were expected to cooperate by sharing strategies, solve problems, plan actions and use the 2D and the 3D map, to reach their common goal, depending on the instruction they had to follow. Thus, this study implements a method expected to improve schizophrenia cognitive skills, especially memory, planning and executive functioning.

5.3.8. Social VR Simulation [22]

The game's social interaction consisted of two tasks in a fixed order. The first required that participants had to ask their virtual co-workers for help handling a new program, while the second required them to collect money for a gift to the boss. It was necessary to go up to every one of the five coworkers twice, once to receive neutral/cooperative feedback and the other to receive negative/rejection feedback. Therefore, patients were matched with healthy controls to delineate psychological mechanisms for paranoid ideations and test psychological interventions against paranoia.

5.3.9. virtual Supermarket Shopping Task (vSST) [25]

Each round was divided in two stages: Acquisition, where players are given a shopping list to memorize during a certain amount of time, and Recall, where they're required to pick up the items from the list at the supermarket in a random order. There

were five consecutive rounds, each with increasing difficulty, meaning increasing the number of items to memorize and collect. Completing the tasks successfully meant not making Intrusion errors, by picking up the wrong item, and Omission errors, by missing some of the items from the list. The development of this virtual supermarket game is aimed at testing and training the memory and executive functions of patients with schizophrenia.

5.3.10. Multimodal Adaptive Social Intervention in VR (MASI-VR) [26]

Every game session required the participant to complete twelve social missions. Those were ordered by difficulty (four easy, four medium and four hard) determined by the number of conversational inquiries and responses required for mission completion. Once the missions started, users were free to explore the virtual space and engage with the available avatars. Additionally, players had to perform social interactions, with no negative consequences, in other words, if they selected the wrong response, they would get feedback and the chance to try again.

In this way, the study examined the feasibility and acceptability for improving social functioning in schizophrenia by making patients start conversations with strangers in order to ask for information.

5.3.11. gameChangeVR therapy [5]

The VR therapy begins in the coach's room, where users meet their virtual automated coach. All levels require the patients to carry out simple tasks such as ordering drinks, finding objects and speaking to people. As the game progresses, levels become busier and noisier, displaying anxiety triggering elements such as CCTV cameras, police officers and people staring or in their way. This way, it intends to test the patients' fearful cognitions while limiting their ability to use safety seeking behaviors, by challenging users to try to do something different.

This study describes the process of developing an automated VR game therapy targeting highly prevalent anxious avoidance of everyday situations by patients, with the use of a virtual coach who explains the psychological principles and guides the person through the treatment.

5.4. Samples

The number of tested subjects encloses all patients who're a part of the target audience, excluding healthy controls.

The sample size varied from 7 [24] to 95 [19] participants, mostly schizophrenia patients from mental health facilities. Together with the subjects diagnosed with schizophrenia, several studies performed simultaneously trials with their matched healthy controls [19,20,22-24] to validate the experiment's efficiency. The sample from Table 1 doesn't include any number of healthy controls.

5.5. Duration

The duration corresponds to the length of testing in months and weeks the testing lasts and the number of therapy sessions during that period of time. With the exception of the single trial studies, the duration of each therapy study varied from 2 weeks [22] to five months [19], with a frequency of about once or twice a week and about half an hour to one hour for each session. Also, while some studies only conducted a single trial [20,21,25], others had a pre-assessment [3,19,22-24,26], to evaluate the patient diagnosis, choose the subjects that would benefit the most from the experiment and to compare with the trial outcomes, and/or a post-assessment [3,18,19,23,24,26], after a few months of the end of the initial therapy sessions, to check for long term results.

5.6. Therapy targets

Social therapy interventions are often based on two critical human skills, behavioral social communication skills and/or cognitive social communication skills. While behavioral skills refer to verbal and non-verbal social behaviors like conversation, facial expression recognition, attention and manners, cognitive skills refer to executive

functions like flexible thinking, processing information and emotional regulation. Some of the studies specifically described their study as targeted at behavioral or cognitive skills. Those that didn't were considered behavioral or cognitive if they mostly focused on skills belonging to one or the other, as described above.

From the articles reviewed, four focused on behavioral skills and the remaining on cognitive skills. Although some studies took a more general approach targeting several different parameters of those skills, some others were very specific in their purpose. Some of that therapy targets were anxiety and avoidance [5], vocational [22, 19] and paranoia [24].

5.7. Interaction

Interaction refers to the different types of interaction modalities used in systems that allow users to interact with them. The most common ways of interacting with games are the mouse and keyboard, for pc-based, and the joystick, for both pc-based and console-based games. Other than these commonly known controls, there're other less known emerging technologies. In the case of immersive systems, these require the use of a Head Mounted Display (HMD) and most often the use of VR joysticks, but they can also be developed to use regular joysticks or even hand recognition. More advanced types of interaction may also integrate voice, face or motion recognition.

5.8. Immersion

With the increase of VR popularity, it's common to hear people referring to immersive VR as just VR, but in fact there're three categories: non-immersive VR, semi-immersive VR and fully immersive VR. Since none of the reviewed articles include any semi-immersive systems or equipment, only the remaining two categories will be taken into consideration.

When considering serious games interventions targeting mental issues, there's still no scientific evidence to whether or not using immersive therapies is more beneficial. Both immersive and non-immersive VR programs can incorporate strategies for optimal learning via personalized exercises and rapid feedback [26]. On that note, it's natural that only about half of the studies were immersive, since using the immersivity factor can bring both advantages and disadvantages. While it can help them feel an increase of empathy, feel self-located in the virtual environment and recognize themselves as the cause of actions, patients are also more likely to experience side effects, such as dizziness and nausea. Non-immersive systems are easier to set up at home, allowing more intensive [26] and accessible treatments.

5.9. Scenery, storyline and genre

There're plenty of serious games with abstract concepts focusing only on the development of a skill through the execution of certain exercises over and over again. The problem with these types of games is that they often can get boring and repetitive. Well, since the main reasons to include a game in a therapy is to keep the patients engaged while developing functional skills, it's beneficial if games have a narrative based on real life events.

The scenery is the virtual locations where everything happens, it can be as simple as a room or as complex as a whole new world. The storyline is the narrative the game follows, for example, the storyline can follow life events of the main character. The genre is a categorization in which the game falls into, for instance, if the game genre is simulation, it means it involves controlling the life of a single or a group of characters, on the other side, if the game genre is sports, it means it simulates sports with teams made of real or generated players.

All the game therapies studied were targeted at either cognitive or behavioral skills and were meant to help patients develop skills to be used in daily life activities. As such, the predominant chosen game genre in the studies was Simulation, with the exception of Fajnerova, et al. [21], which chose to develop an RPG (Role Playing Game). Life Simulation games focus on replicating real life activities in a simplified way so that

players can learn a desired skill. It's really useful especially when it simulates situations that are too expensive or too difficult to reproduce in real life.

The adopted scenery and storyline also followed the same concept of simulating real life situations. In terms of scenery, public places, like shops, were selected due to how often they appear in patients' lives, the amount of people present there and the amount of job opportunities, allowing developers to easily integrate different types of tasks. The storyline also included completing daily activities, like interacting with people, completing job related tasks and memory related errands.

5.10. Adaptation

As suggested by Rego, Moreira, and Reis [17], the game system can have an adaptation mechanism defined before gameplay (Configuration), during gameplay (Adaptability), in both of the previous moments, or no adaptation (none). Pre-game play adaptation allows the therapist or the patient itself to set up the game attributes before the game session starts, according to personal needs of the patient. It could be for example setting specific parameters like time or just choosing the overall difficulty between easy, medium or hard. As for during gameplay adaptation, the system is able to adjust its difficulty automatically, as the game progresses, and based on the user performance. Common criteria used to measure a player's performance are score, mistakes and others similar ones.

Adaptation plays an important role in serious games, since it's not beneficial to make the patient consistently play something that's either too easy or too difficult. It's also a tool, which the therapist can manipulate to increase the therapy efficiency to help patients develop different skills.

From the examples included in this review, only three studies [5,25,26] implemented Adaptation, all in a form of pre-gameplay. For instance, Plechatá et al. [25] explains that the vSST allows users to adjust the level difficulty by increasing the number of objects and the customization of several parameters. Also, although it's not considered Adaptation, some of the games [5,18,19,21,22,26] have different levels which differ in difficulty.

5.11. Progress monitoring

Games with this feature are able to collect data regarding patient performance. The type of data gathered depends a lot on the therapy target and the game itself. Yet, these games often collect basic information such as time spent completing a task, accuracy/inaccuracy when performing the required actions and level score. In regards to serious games, progress monitoring works as an excellent tool to both help the therapist analyze the session results and keep better track of the patients' progress, as well as to help motivate the patient itself.

When evaluating the reviewed articles, games were considered to monitor the player's progress if they stored and displayed data like score or time. Thus, about half of those papers mention some form of progress monitoring, but in some of them it isn't clear whether the data is collected by the researchers or automatically by the game.

5.12. Game feedback

Game feedback is provided to users as a way to show them if they're or aren't progressing successfully through the game. Whether we think of a game or application, every user's action needs to result in some form of feedback to help guide users through the steps they need to perform in order to achieve a certain goal.

In regard to types of feedback, those can be based on [17]:

1. **System interface:** when it's presented in the form of cause-effect – the user does something and the system reacts accordingly;
2. **System controlled**: when the game measures the user's performance – the user receives hints that guide them through the game;

3. **Therapist controlled**: when it's not automatically generated by the system – the therapist is the one controlling feedback so it's totally personalized to fit the therapy goals, or even a mixed of those;
4. **Mixed**: when the system uses two or more of the above types of feedback.

The most common type was system interface [18,19,22,23,26], but there were also references to system controlled [5,26] and therapist controlled [18,19] feedback. In addition, feedback can be provided in the form of visual, auditory, haptic or a mixture of these. Most of the games mentioned had either visual, auditory or both representations, but none mentioned any form of haptic feedback.

5.13. Therapy portability

Game portability evaluates whether a game therapy can take place only at the hospital, clinic or other type of health facility where the treatment is taking place, or if it can also be administered at the patient's home. In case it can be administered outside the hospital/clinic, it's considered 'Home Assisted', if there's a need to have the therapist presence throughout the therapy session to guide and assess the patient, it's considered 'Home', if there's some sort of in game therapist that automates the process, otherwise is categorized as 'Clinic'. This evaluation can also depend on the necessary equipment and its set up, for instance a non-immersive game requires less equipment and it's generally easier to set up, making it more accessible to be used at home.

In the reviewed game therapies, only two made any kind of reference to their portability. From those, gameChange [5] was developed with the intention to make its therapy completely portable. Adery et al. [26], refer that non-immersive systems like MASI-VR can easily be used at home, so the game could be used as an adjunct social intervention, together with more intensive treatments requiring skilled therapists and in-person attendance, but don't specifically classify it as portable.

5.14. Automation

Up to date, there's still not many studies which rely on the use of automated therapy interventions. Such a feature enables treatments to be delivered automatically by a virtual coach, without the need for a trained therapist to be present [5]. Automated psychological therapy has the potential to produce large clinical benefits and to greatly increase treatment provision for mental health disorders, at large scale and low cost.

From the reviewed articles, those considered automated, were the ones that implemented some kind of virtual therapist, whose purpose is guiding users throughout the game. That said, only one refers to its intervention as automated by including a virtual coach [5], but it's not the only one that uses some form of automation to enhance the game experience. Other studies implement what they call a personal assistant [22] or game narrator [26] that gives instructions, tips and/or feedback, to help guide the player through the game.

Additionally, a more efficient strategy for automating game therapy would use an Artificial Intelligence (AI) system. With the help of AI, the virtual therapist would be able to better understand users' needs and help them accordingly. Yet none of the studies make any reference to the use of AI.

5. Discussion

To sum up the results, the included studies had a sample comprehended between 7 [24] and 95 [19] and the duration of tests was consisted of multiple sessions lasting 30 to 60 minutes, once or twice a week, and from two weeks [22] to five months [19]. Cognitive behavioral skills were most commonly chosen as the therapy target for studies. As for interaction equipment, the games that were immersive used a HMD [3,5,18,22] and those that weren't used either mouse and keyboard [19,23,26] or a joystick [19-21,24]. The games were all based on the simulation real life activities like socially interacting with a stranger on the street, look for a store in a small city and perform work related tasks. As for the adaptation, only three games [5,25,26] had integrated pre-gameplay adaptation. About half of the games monitored the player's progress. The most common type of

feedback was system interface [18,19,22,23,26]. Only two studies [5,26] made any reference to having implemented game portability. And, only three studies [5,22,26] implemented an automated game.

In terms of outcomes, these were mostly positive and most hypotheses were confirmed. In terms of results, those were varied and dependent of what each study was aiming at achieving refutes with their therapy system. Overall, all studies were able to reduce some negative symptoms, by increasing the lacking skills [3,26]. In terms of cognitive skills, they registered an increase in memory, attention, confidence and recognition of their own emotions and difficulties, as well as a reduction in anxiety and withdrawal [3,19,23,24]. In terms of behavioral skills, they registered an increase in organization, work performance and assertive behaviors, as well as, an increase in social and conversational skills and a decrease in social avoidance [3,18,19,24].

Still, some of them didn't register enough improvements or didn't register any improvement at all in skills like vocal, most likely due to the lack real-life speaking involved in the game, nonverbal social skills, because players did not need to use facial expressions or gestures while playing, and time management, due to a bad performance in time-based actions.

In particular, three articles decided to prove the cognitive deficit caused by negative symptoms in people with schizophrenia. Plechatá et al. [25] was able to demonstrate that all the patients tested were impaired in all the assessed cognitive domains, confirming their deficit in cognitive abilities. Hesse et al. [22] verified that it's possible to trigger stress and paranoid ideation with the use of VR, which also proves the need of an appropriate design target at this specific group of people. They also verified that when the stress levels were too high, the symptoms would last must longer. And, Zawadziki et al. [20] demonstrated that individuals with schizophrenia have significantly more difficulties in navigation related tasks.

Some studies also assess patient's feedback regarding the game therapy. When compared with traditional therapy sessions, with no use of any kind of VR, patients rated the training programs as more interesting, useful, engaging and motivational [18,19,26]. Overall, patients rated the systems as a stress-free environment, easy to use, helpful and immersive [5,19].

Also, five papers revealed they had plans to perform more trials to test the systems in a bigger sample and to test some updates that were added based on the results found [5,20,24-26].

Regarding other systematic literature reviews, it's safe to say that they took a different approach than ours. For instance, Sotos et al. [1] studied VR for psychosocial remediation in schizophrenia and described the interventions based on the sample, duration, type of study, immersivity, therapy targets and evaluation instruments. Bisso et al. [27] studied VR applications in the schizophrenia spectrum and described the interventions based on the therapy target, country of development, study design, sample by number and by patient's diagnosis, Diagnostic and Statistical Manual (DSM), type of VR therapy, duration by number of sessions, time of each sessions and treatment time, and principal outcome assessment. And Pavlidou and Walther [28], studied VR as a tool in the rehabilitation of movement abnormalities in schizophrenia and didn't perform a characterization of the available interventions in terms of study trials or game design.

The goal of this study was to characterize the game interventions based on the proposed taxonomy for serious games of Rego et al. [17]. Thus, when it comes to other similar reviews, this study adds further characterization on game design and technological aspects of the available interventions, that are not present on the other reviews.

Lastly, it is important to consider several limitations when interpreting the results. Studies were not included if they were not published in the English language, which may influence the outcomes of our results dissemination of output data. Additionally, most of characteristics used to characterize the analyzed studies were based in model proposed by Rego et al. [17].

6. Conclusions

In conclusion, up to date VR game therapies seem to not be able to fully replace traditional face-to-face therapies. However, when combined with regular therapy, VR systems can be really beneficial to help obtain longer lasting results and keep patients motivated. Studies proved this with the great results they achieved, showing an improvement in both cognitive and behavioral social skills.

Nonetheless, despite how much these systems have evolved up until now, VR systems still come with some limitations. For instance, the use of virtual characters to interact with the patient needs to be programmed in advance, restraining their behavior to unrealistic standardized actions. Additionally, patients are always dependent on the required equipment, which can be as simple as a standalone VR headset or as complex as a desktop, plus two joysticks, plus a VR headset and a bunch of cables. When it comes to immersive systems, the required HMD can become a hassle, since it covers about half of the patient's face, which can prevent a proper evaluation of facial expressions, and when there's a need for electric wires, these can disturb the patient's movement, posture and consequently its evaluation as well. Still, whether or not the game is immersive or has realistic graphics seems to have little impact on the patient's performance, as long as they can stay engaged in the activities. And, level difficulty adaptation is still either presented in the form of configuration or not presented at all, when it would be more helpful if the game was able to adapt to the player's performance, promoting an efficient learning experience.

Finally, from the obtained results we were able to identify some interesting research opportunities. For instance, no study referenced the use of AI, nonetheless, this fast-growing technology has a lot of potential to be used to automate VR systems. Also, it has been shown that group therapy can be beneficial for patients with anti-social disorders. So, the development of multiplayer serious games could provide a much better user experience without the need to make use of unnatural character interactions. Instead, they would interact with actual people, which can potentially help them get the expected results faster. The problem of group therapy remains in finding a way to conciliate patients, with different illness severities, that progress at different velocities. At last, when verifying whether or not the selected game therapies had implemented our selected key features, we realized that frequently those were not present.

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References

1. Sotos, P.F.; Caballero, A.F.; Jimenez, R.R. Virtual reality for psychosocial remediation in schizophrenia: a systematic review. *The European Journal of Pshychiatry* **2020**, 1-10.
2. Park, M.J.; Kim, D.J.; Lee, U.; Na, E.J.; Jeon, H.J. A Literature Overview of Virtual Reality (VR) in Treatment of Psychiatric Disorders: Recent Advances and Limitations. *Frontiers in Psychiatry* **2019**, 1-9.

3. Calafell, M.R.; Maldonado, J.G.; Sabaté, J.R. A virtual reality-integrated program for improving social skills in patients with schizophrenia: A pilot study. *Journal of Behavior Therapy and Experimental Psychiatry* **2014**, 81-89.
4. Rego, P.; Moreira, P.M.; Reis, L.P. Serious Games for Rehabilitation: A Survey and a Classification Towards a Taxonomy. *Sistemas y Tecnologías de Información. Actas de la 5ª Conferencia Ibérica de Sistemas y Tecnologías de Información* **2010**, *I*, 349-354.
5. Lambe, S.; Knight, I.; Kabir, T.; West, J.; Patelf, R.; Lister, R.; Rosebrocka, L.; Roviraa, A.; Garnishf, B.; Freemanf, J.; et al. Developing an automated VR cognitive treatment for psychosis: gameChange VR therapy. *Journal of Behavioral and Cognitive Therapy* **2020**, 33-40.
6. Freeman, D.; Haselton, P.; Freeman, J.; Spanlang, B.; Kishore, S.; Albery, E.; Denne, M.; Brown, P.; Slater, M.; Nickless, A. Automated psychological therapy using immersive virtual reality for treatment of fear of heights: a single-blind, parallel-group, randomised controlled trial. *Lancet Psychiatry* **2018**, *5*, 625-632.
7. Lim, M.H.; Penn, D.L. Using Digital Technology in the Treatment of Schizophrenia. *Schizophrenia Bulletin* **2018**, 1-2.
8. Patsi, C.; Yfantidou, G.; Antoniou, P.; Gkoraki, V.; Lagiou, K. Perceptions of people with schizophrenia regarding digital interactive games. *Journal of Physical Education and Sport. 16 Supplement issue* **2016**, 650-655.
9. Michalakis, G.; Pavlou, M.; Georgianns, G.; Liapis, V.; Terzi, I.; Tsagarakis, A.; Asimakopoulou, R.; Bitzas, D.; Moustakas, K. Another day at the office: Visuohaptic schizophrenia VR simulation. *2020 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops* **2020**, 515-516.
10. Rego, P.A.; Moreira, P.M.; Reis, L.P. A serious games framework for health rehabilitation. *International Journal of Healthcare Information Systems and Informatics (IJHISI)* **2014**, *9*, 1-21.
11. Stapleton, A.J. Serious games: Serious opportunities. In Proceedings of the Australian Game Developers Conference, Melbourne, Australia, 2004; pp. 1-6.
12. Machado, L.S.; Moraes, R.M.; Nunes, F.L.S. Serious games para saúde e treinamento imersivo. *Abordagens práticas de realidade virtual e aumentada* 2009.
13. Machado, L.S.; Moraes, R.M.; Nunes, F.L.S.; Costa, R.M.E.M. Serious Games Based on Virtual Reality in Medical Education. *Revista Brasileira de Educação Médica* **2010**, 254-262.
14. Susi, T.; Johannesson, M.; Backlund, P. *Serious Games – An Overview* School of Humanities and Informatics: University of Skövde, Sweden, 2007.
15. Correll, C.U.; Schooler, N.R. Negative symptoms in schizophrenia: a review and clinical guide for recognition, assessment, and treatment. *Neuropsychiatric disease and treatment* **2020**, *16*, 519-534.
16. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. The PRISMA 2020 statement: an updated guideline for reporting. *International Journal of Surgery* **2021**, 1-9.
17. Rego, P.A.; Moreira, P.M.; Reis, L.P. Proposal of an Extended Taxonomy of Serious. *GAMES FOR HEALTH JOURNAL: Research, Development, and Clinical Applications* **2018**, *7*, 302-309.
18. Park, K.; Ku, J.; Choi, S.; Jang, H.; Park, J.; Kim, S.I.; Kim, J. A virtual reality application in role-plays of social skills training for schizophrenia: A randomized, controlled trial. *Psychiatry research* **2011**, 166-172.
19. Tsang, M.M.Y.; Man, D.W.K. A virtual reality-based vocational training system (VRVTS) for people with schizophrenia in vocational rehabilitation. *Elsevier journal: Schizophrenia Research* **2013**, 51-62.
20. Zawadzki, J.A.; Girard, T.A.; Foussias, G.; Rodrigues, A.; Siddiqui, I.; Lerch, J.P.; Grady, C.; Remington, G.; Wong, A.H.C. Simulating real world functioning in schizophrenia using a naturalistic city environment and single-trial, goal-directed navigation. *Frontiers in Behavioral Neuroscience Volume 7* **2013**, 1-10.
21. Fajnerova, I.; Rodriguez, M.; Spaniel, F.; Horacek, J.; Vlcek, K.; Levcik, D.; Stucchlik, A. Spatial navigation in virtual reality - from animal models towards schizophrenia: Spatial cognition tests based on animal research. In Proceedings of the International Workshop on Virtual Rehabilitation, Valencia, Spain, 2015; pp. 44-50.

22. Hesse, K.; Schroeder, P.A.; Scheeff, J.; Klingberg, S.; Plewnia, C. Experimental variation of social stress in virtual realityeFeasibilityandfirst results in patients with psychotic disorders. *Journal of Behavior Therapy and* **2016**, 129-136.
23. Sohn, B.K.; Hwang, J.Y.; Park, S.M.; Choi, J.S.; Lee, J.Y.; Lee, J.Y.; Jung, H.Y. Developing a Virtual Reality-Based Vocational Rehabilitation Training Program for Patients with Schizophrenia. *Cyberpsychology, Behavior, and Social Networking* **2016**, 686-691.
24. Amado, I.; Herné, L.; Orriols, E.; Desombre, C.; Santos, M.; Prost, Z.; Krebs, M.; Piolino, P. A Serious Game to Improve Cognitive Functions in Schizophrenia: A Pilot Study. *Frontiers in Psychiastry* **2016**, *7*, 1-11.
25. Plechatá, A.; Fajnerová, I.; Hejtmánek, L.; Sahula, V. Development of a virtual supermarket shopping task for cognitive remediation of memory and executive functions in schizophrenia. In Proceedings of the International Conference on Virtual Rehabilitation (ICVR), Montreal, Canada, 2017; pp. 1-2.
26. Adery, L.H.; Ichinose, M.; Torregrossa, L.J.; Wade, J.; Nichols, H.; Granholm, E.; Sarkar, N.; Park, S. The Acceptability and Feasibility of a Novel Virtual Reality Based Social Skills Training Game for Schizophrenia: Preliminary Findings. *Psychiatry Research 270* **2019**, 496-502.
27. Bisso, E.; Signorelli, M.S.; Milazzo, M.; Maglia, M.; Polosa, R.; Aguglia, E.; Caponnetto, P. Immersive Virtual Reality Applicationsin Schizophrenia Spectrum Therapy:A Systematic Review. *International Journal of Environmental Research and Public Health* **2020**, *17*, 5.
28. Pavlidou, A.; Walther, S. Using Virtual Reality as a Tool in the Rehabilitation of Movement Abnormalities in Schizophrenia. *Frontiers in Psychology* **2021**, *11*, 7.

Appendix B – Informed Consent

Informed Consent

Declaração de consentimento informado

Conforme a lei 67/98 de 26 de outubro e a "Declaração de Helsínquia" da Associação Médica Mundial
(Helsínquia 1964; Tóquio 1975; Veneza 1983; Hong Kong 1989; Somerset West 1996, Edimburgo 2000;
Washington 2002, Tóquio 2004, Seul 2008, Fortaleza
2013)

Designação do Estudo: Immersive VR eHealth strategies: VR games to treat schizophrenia negative symptoms

Eu, _____ abaixo assinado, fui informado de que o Estudo de Investigação acima mencionado se destina a obter dados sobre a satisfação e o desempenho na utilização do protótipo de um jogo sério que visa estimular e/ou reabilitar funções cognitivas e comportamentais, através da reprodução de um conjunto de tarefas da vida diária. Sendo um jogo em realidade virtual (VR) imersiva será jogado através da utilização de uns óculos de VR e dois comandos de controlo (para a mão esquerda e direita), tendo-me sido explicado em que consistem e quais os possíveis efeitos.

Sei que neste estudo está previsto o preenchimento de um questionário após a utilização da plataforma. Foi-me garantido que todos os dados relativos à identificação dos participantes neste estudo são confidenciais e que será mantido o anonimato.

Sei que posso recusar-me a participar ou interromper a qualquer momento a participação no estudo, sem nenhum tipo de penalização por este facto.

Compreendi a informação que me foi dada, tive oportunidade de fazer perguntas e as minhas dúvidas foram esclarecidas.

Aceito participar de livre vontade no estudo acima mencionado.

Também autorizo a divulgação dos resultados obtidos no meio científico, garantindo o anonimato.

Data Assinatura

___/___/_____ _____

Appendix C – Questionnaire

Development of VR Games to treat schizophrenia negative symptoms

No âmbito do trabalho de mestrado em multimédia, realizado na Faculdade de Engenharia da Universidade do Porto (FEUP), sob a orientação da Professora Paula Rego e do Professor António Coelho, pretende-se testar a usabilidade do protótipo desenvolvido como parte da dissertação intitulada "Immersive VR eHealth strategies: VR games to treat schizophrenia negative symptoms".

Este questionário visa recolher dados sociodemográficos dos utilizadores escolhidos para testar o sistema em estudo, bem como dados relativos à sua experiencia de utilização e satisfação com o sistema em estudo. Os dados fornecidos serão tratados de forma agregada, bem como será mantida a confidencialidade.

Agradecemos a disponibilidade e colaboração.

Beatriz Miranda
Mestrado em Multimédia, FEUP

*Obrigatório

1. Foi-me garantido que todos os dados relativos à identificação dos participantes neste estudo são confidenciais e que será mantido o anonimato. Ao proceder com o preenchimento deste questionário autorizo a utilização dos meus dados de forma anónima para o estudo da usabilidade do sistema que me foi apresentado.

   Marcar apenas uma oval.

   ◯ Autorizo a divulgação dos resultados obtidos no meio científico, garantindo o anonimato.

Informação básica

Esta secção destina-se a recolher informação básica dos participantes.

2. Género *

   Marcar apenas uma oval.

   ◯ Feminino
   ◯ Masculino
   ◯ Outro

3. Idade *

Marcar apenas uma oval.

- ◯ < 10 anos
- ◯ 11 a 20 anos
- ◯ 21 a 30 anos
- ◯ 31 a 40 anos
- ◯ 41 a 50 anos
- ◯ 51 a 60 anos
- ◯ 61 a 70 anos
- ◯ 71 a 80 anos
- ◯ > 80 anos

4. Educação *

Marcar apenas uma oval.

- ◯ Sem nível de escolaridade
- ◯ Básico - 1ºciclo
- ◯ Básico - 2ºciclo
- ◯ Básico - 3ºciclo
- ◯ Secundário e pós-secundário
- ◯ Superior

5. Ocupação profissional/académica *

_____

6. Experiência com computadores *

Marcar apenas uma oval.

- ◯ Nunca utilizei ou utilizo muito raramente um computador
- ◯ Utilizo um computador para desempenhar tarefas básicas
- ◯ Utilizo o computador com regularidade para desempenhar tarefas complexas

7. Experiência com Realidade Virtual (VR) *

Marcar apenas uma oval.

- ◯ Nunca tinha experimentado antes
- ◯ Experimentei menos de 5 vezes antes
- ◯ Já experimentei diversas vezes antes

8. Necessidades especiais

Marcar apenas uma oval.

- ◯ Sim
- ◯ Não

Experiência de utilização

Esta secção destina-se a perceber se os diversos elementos do jogo funcionaram conforme esperado.
Indique o quão está de acordo com as seguintes afirmações.

9. 1. Considero fácil movimentar-me pelo jogo. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

10. 2. Considero fácil interagir com os componentes do jogo. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

11. 3. Achei fácil de perceber o que cada objeto representava. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

12. 4. Considero que o jogo seria mais imersivo com gráficos mais realistas. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

13. 5. Considero que o jogo me deu dicas suficientes para eu perceber o que tinha de fazer. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

14. 6. Considero que o pequeno almoço foi mais fácil de preparar do que o almoço. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

15. 7. Consegui executar as tarefas mais eficazmente no fim do que no inicio do jogo. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

16. 8. Senti em algum momento náusea ou tonturas enquanto jogava. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

17. 9. Senti-me tenso durante o jogo. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

18. 10. Esforcei-me bastante durante o jogo. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

Satisfação

Esta secção destina-se a avaliar a satisfação dos utilizadores quanto à utilização do sistema.
Indique o quão está de acordo com as seguintes afirmações.

19. 1. Acho que gostaria de utilizar este sistema com frequência. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

20. 2. Considerei o sistema mais complexo do que necessário. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

21. 3. Achei o sistema fácil de utilizar. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

22. 4. Acho que necessitaria de ajuda de um técnico para conseguir utilizar este sistema. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

23. 5. Considerei que as várias funcionalidades deste sistema estavam bem integradas. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

24. 6. Achei que este sistema tinha muitas inconsistências. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

25. 7. Suponho que a maioria das pessoas aprenderia a utilizar rapidamente este sistema. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

26. 8. Considerei o sistema muito complicado de utilizar. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

27. 9. Senti-me muito confiante a utilizar este sistema. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

28. 10. Tive que aprender muito antes de conseguir lidar com este sistema. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

Sugestões

Agradeço imenso a sua colaboração na realização desta fase de testes.

Esta secção destina-se a recolher sugestões de melhoria do sistema.

29. Sugestões de melhoria

Appendix D – Test Report

2022

Immersive VR eHealth Strategies: VR games to treat schizophrenia negative symptoms

ISO/IEC 25062 COMMON INDUSTRY FORMAT FOR USABILITY TEST REPORTS

TESTED BY: BEATRIZ MIRANDA

FEUP - MM

TABLE OF CONTENTS

1. Executive Summary

This report englobes the tests performed in May of 2022 to test the prototype developed as a part of the dissertation entitled “Immersive VR eHeath Strategies: VR game to treat negative symptoms”. This study’s goal is to understand the main requirements necessary to implement a serious game to be used in the treatment of negative symptoms. The tests were performed in 21 users and data was collected regarding the effectiveness, efficiency and satisfaction of the product.

2. Introduction

2.1. Product description

The product to be tested in its entirety is a VR serious game targeted at the treatment of negative symptoms in people with schizophrenia and is based on the reproduction of a set of activities of daily living. It’s meant to be used in a clinical facility as a part of the social and cognitive skills treatment administrated to patients diagnosed with schizophrenia.

2.2. Test objectives

To test the efficiency and implementation of the product, to look for flaws to improve and collect the user point of view regarding different aspects.

Also, to test the following hypothesis:

- The game is capable of helping people follow a stream of tasks;
- Task A is easier to complete than task B;
- Realistic graphics don’t affect much the immersive feel of the game;
- The game is safe to be used in therapy.

3. Method

3.1. Participants

Tests were not performed with the target users. Those are people diagnosed with schizophrenia who have their positive symptoms under control. Since these users have special needs, (like the possibility that the game might trigger their positive symptoms) it’s more difficult to test with them. Instead, tests were performed with 21 participants (6 female and 15 male, with age between 11 and 60 years old), all healthy users, being 2 of them related to the health sector. All participants were volunteers selected randomly accordingly to their availability, were considered healthy, had some computer experience and had little to no experience with VR systems. Table 1 presents the characterization of the participants in the tests in relation to: gender, age, education level, occupation area, computer experience and VR experience.

Table 1 - Sample Characterization

Participants	Gender	Age	Education	Occupation	Computer Experience	VR Experience
P1	F	51-60	Higher secondary	Healthcare assistant	Low	Medium
P2	M	21-30	Graduate	Student (MEI)	High	Medium
P3	M	21-30	Graduate	Student (MEI)	High	High
P4	M	21-30	Graduate	Student (MC)	High	Medium
P5	M	21-30	Graduate	Student (MEI)	High	Medium
P6	M	31-40	Graduate	Student (ECGM)	High	Low
P7	M	21-30	Post-secondary	Student (ECGM)	High	Low
P8	F	21-30	Graduate	Student (MC)	High	Medium
P9	M	11-20	Post-secondary	Student (EI)	High	Low
P10	M	11-20	Post-secondary	Student (EI)	High	High
P11	M	11-20	Post-secondary	Student (EI)	High	Medium
P12	M	21-30	Graduate	Student (MEI)	High	Low
P13	F	41-50	Graduate	Librarian	High	Low
P14	M	41-50	Graduate	Professor	High	High
P15	F	21-30	Post-secondary	Student (ECGM)	High	Low
P16	F	21-30	Post-secondary	Student (ECGM)	High	Medium
P17	M	21-30	Post-secondary	Student (ECGM)	High	Low
P18	M	21-30	Graduate	Student (ECGM)	High	Medium

P19	F	31-40	Graduate	Doctor	Medium	Low
P20	M	21-30	Post-secondary	Student (ECGM)	High	Low
P21	M	21-30	Post-secondary	Librarian	Medium	High

3.2. Context of product use in the test

The product was developed to be used in a clinical setting with the assistance of a health professional. Not being able to perform the current test on such facilities, the test will be conducted at an empty room at a university, with the assistance of the person in charge of performing the tests and without the presence of any health professional.

3.2.1. Tasks

Tasks were selected to test the way the game was implemented. They're based on daily living frequent interactions with common objects that must be performed with the limitations of the virtual world.

The test consists in the execution of two main tasks:

- Task A – Prepare the virtual breakfast
- Task B – Prepare the virtual lunch

Each task includes a predefined number of smaller subtasks required to be completed in order for the main task to be considered complete. These will test the participant's ability to move around the scene, interact with the User Interface, interact with game objects, follow a sequence of events and perceive the game's instructions.

3.2.2. Test facility

Tests were performed in a simple room with a table, two chairs and a reserved empty area of 2 by 2.5 meters where users tested the product, as they require to move around a bit. The arranged room was situated in a library which was mostly silent, yet occasionally there was some noise coming from the hallway which might have distracted the participants a bit. Still, it doesn't seem it affected the results in any way.

3.2.3. Participant's computing environment

Participants are required to use the Oculus Quest 2, currently with its OS in v39, to complete the test tasks. The device had the prototype installed on it directly from the Unity engine and didn't require the setup of any features, but it requires a Wi-Fi connection. Also, it's necessary for participants to complete a google forms questionnaire to collect data on the experiment. Participants should use their phone to complete it. The administrator laptop was also available in case they couldn't fill the questionnaire in their personal phone.

3.2.4. Test administrator tools

The administrator should have a laptop to take notes on the session and watch the participant's gameplay. Thus, notes should be taken in an Excel spreadsheet with columns for the patient's name, date, start and end time of the test, time spent on the tutorial, as well as how many bugs were found and any necessary notes, and also for each task the completion of assisted and unassisted task effectiveness, the time it took to complete it, how many errors and assistances, which bugs were found and any necessary notes. As for the participant's gameplay, the administrator should connect the VR headset to the oculus casting website (https://www.oculus.com/casting/) to watch it since only the player can see what's happening in the headset.

3.3. Experimental design

3.3.1. Procedure

The test administrator started by preparing the room, by setting up the laptop computer, the table and the two chairs. Followed by the opening of the Excel spreadsheet, to take notes during the test, and the opening the oculus cast website, to watch the participant's gameplay, where they had to connect to an oculus account. Then moved to setup of the headset, where they had to draw the virtual play area of 2 by 2.5 meters, connect to the oculus account, open the game and start casting it to the laptop. Upon completion of the setup tests can start to be performed in individuals.

Each test session started with a brief moment to help the participant feel relaxed, where the administrator presented themselves and introduced to the context and goals of the tests. Participants had to sign an informed consent to continue with the experiment. Then, the administrator explained what tasks the participant had to complete, how the VR headset works and the availability to for the participant to stop or ask for assistance at any moment.

The session then proceeded with a moment for the participant to explore the tutorial room they can move and interact freely to understand the basic game mechanics. When the participants felt ready to start playing, they could move to the game menu and select the breakfast scene where they must complete the task A and then task B.

Finally, participants had to complete a quick questionnaire regarding the game experience, where they could request assistance if they didn't get any question. The administrator receives the questionnaire, verifies its completion and thanks the participants for their cooperation.

Also, test sessions shouldn't last more than 45 minutes and should proceed as the following outline and timing:

- Introduction to the session (about 5 minutes)
- VR Tutorial (maximum of 5 minutes)
- Tasks (maximum of 30 minutes for both)
- Questionnaire (about 5 minutes)

3.3.2. Participant general instructions

Participants were initially instructed on what is the goal and context of the tests. They were presented the test schedule and then they received a brief explanation of the product they had to test, the tasks they needed to complete and basic controls to use it. Then the administrator proceeded to verify if the headset setup was still working as expected before giving it to the participant. They were then informed that the administrator was going to watch them complete the test and was available to assist them if needed. Also, they were informed that they could leave the game at any moment if they experienced any kind of nausea and/or dizziness. Finally, upon completion of both tasks, participants had to complete a questionnaire, with the assistance of the administrator, if necessary, and then they could leave.

3.4. Usability metrics

3.4.1. Effectiveness

The system effectiveness was evaluated through the completion rate and the number of errors, mistakes and assistances.

3.4.1.1. Completion rate

Each task is related to a level and has subtasks to complete. A task is considered complete if the participant completes successfully all the subtasks. A task was either considered assisted or unassisted depending on whether or not participants requested assistance to complete them. Equation 1 was used to calculate the completion rate of tasks A and B.

$$\text{Task effectiveness (\%)} = \frac{\text{Number of completed subtasks}}{\text{Number of subtasks}} \times 100 \quad \textbf{(1)}$$

3.4.1.2. Errors

Participant errors are automatically collected during gameplay and displayed at the end of each level. They consist of any interaction that wasn't requested by the game or that it's out of the assigned order. The game often requests players to place a certain object at a certain positions, so these errors can be caused by the placement of the wrong object on the wrong place. Errors might be caused by distraction or by difficulty to understand game requests.

3.4.1.3. Mistakes

Participant mistakes were collected in the form of task mistakes. Those were collected by the test administrator whenever the participants couldn't complete a task successfully or when they couldn't proceed with the game due to too many errors. Mistakes might be caused by a struggle to understand how the game works.

3.4.1.4. Assists

It's considered assistance whenever a participant requests any kind of help to proceed with the task. The test administrator must then help the participants in whatever they need so that they can procced to complete the task.

3.4.2. Efficiency

The efficiency was evaluated with the relationship between the success rate and the time it takes users to complete the assigned tasks. It also takes into consideration the standard deviation and the minimum and maximum of the obtained results.

3.4.3. Satisfaction

Participants' satisfaction was evaluated using the System Usability Scale (SUS) questionnaire with 10 questions regarding their opinion on whether they found the product easy to use, useful and satisfactory. Equation 2 shows how to calculate the total SUS score.

$$\begin{aligned} \text{Odd score} = \text{OS} &= \bar{x}1 + \bar{x}3 + \bar{x}5 + \bar{x}7 + \bar{x}9 - 5 \\ \text{Even score} = \text{ES} &= 25 - \bar{x}2 + \bar{x}4 + \bar{x}6 + \bar{x}8 + \bar{x}10 \\ \text{SUS score} &= (\text{OS} + \text{ES}) \times 2.5 \end{aligned} \quad \textbf{(2)}$$

3.4.4. User Experience

The user experience was evaluated, through 10 questions, regarding how the user felt about several aspects of the product, such as movement, esthetic, immersivity, feedback, progress and emotional.

4. Results

4.1. Data analysis

Data was collected through observation and through a questionnaire that the participants filled out. While participants where completing task A and B, the test administrator was observing their performance and taking notes on mistakes, assists, game performance and any relevant observations. Once a participant completed a task the game would display the number of errors and the time it took to complete it, so that the administrator could take note of that. After the completion of the tasks, participants would open the Google form to fill it with some personal information and their opinion on UX and satisfaction. Upon submission of that questionnaire, the administrator received the data immediately.

In terms of reduction and organization, data collected by the administrator had to be treated to be displayed in its correspondent table. As for time, errors and assists, these were collected and stored raw, since they didn't require any treatment. The task effectiveness was calculated from the number of assists and the number of completed sub tasks present in task A and B. As for mistakes, the administrator wrote down which ones the participant made and then counted them. The mean, standard deviation, minimum and maximum were calculated once all the tests

were completed. On the questionnaire data, the only data that required treatment was the participant occupation because it was an open answer. It was also calculated the mean, deviation, minimum and maximum of the satisfaction and user experience answers.

4.2. Presentation of the results

Task A – Prepare the virtual breakfast

User #	Unassisted Task Effectiveness [(%)Complete]	Assisted Task Effectiveness [(%)Complete]	Task time	Errors	Mistakes	Assists
P1	/	80%	20min00	5	1	8
P2	100%	/	4min54	0	0	0
P3	100%	/	2min52	0	0	0
P4	/	100%	5min06	2	0	1
P5	/	100%	3min07	0	0	1
P6	/	100%	14min32	4	1	8
P7	100%	/	6min45	1	0	0
P8	/	100%	5min37	2	2	1
P9	/	100%	3min50	5	1	3
P10	100%	/	4min02	0	0	0
P11	/	100%	2min48	1	1	1
P12	/	100%	8min12	5	4	2
P13	100%	/	9min42	0	0	0
P14	/	100%	5min10	8	2	3
P15	100%	/	5min55	1	1	0
P16	/	100%	11min06	4	1	4
P17	/	100%	6min32	3	3	1
P18	/	100%	4min39	1	0	2
P19	100%	/	6min10	1	0	0
P20	/	100%	4min01	3	0	1
P21	100%	/	7min36	1	0	0
Mean	100%	98.46%	6min47	2.39	0.81	1.71
Standard Deviation	0.00	5.55	250.72 (sec)	2.21	1.12	2.39
Min	100%	80%	2min48	0	0	0
Max	100%	100%	20min00	8	4	8

Task B – Prepare the virtual lunch

User #	Unassisted Task Effectiveness [(%)Complete]	Assisted Task Effectiveness [(%)Complete]	Task time	Errors	Mistakes	Assists
P1	/	100%	18min37	17	2	4
P2	/	100%	5min31	6	1	1
P3	/	100%	6min06	2	3	2
P4	/	100%	6min38	0	0	1
P5	/	100%	4min34	4	1	1
P6	/	60%	4min57	3	3	1
P7	/	100%	11min23	4	2	1
P8	/	100%	4min53	1	1	2
P9	/	100%	16min38	27	5	13
P10	/	100%	7min29	7	2	2
P11	/	75%	8min50	19	3	1
P12	/	100%	10min00	3	3	6
P13	100%	/	8min04	6	1	0
P14	/	100%	10min52	11	3	7
P15	/	100%	11min30	15	3	2
P16	/	100%	10min46	6	2	7
P17	/	100%	8min14	17	5	5
P18	/	100%	10min24	23	2	5
P19	/	70%	14min15	14	2	1
P20	/	100%	5min54	10	3	2
P21	100%	/	8min19	10	2	0
Mean	100%	95.00%	9min14	9.76	2.33	3.05
Standard Deviation	0.00	12.13	229.13 (sec)	7.58	1.24	3.17
Min	100%	60%	4min53	0	0	0
Max	/	100%	18min37	27	5	13

4.2.1. Performance results

Summary

User #	Total Unassisted Task Effectiveness [(%)Complete]	Total Assisted Task Effectiveness [(%)Complete]	Total Task time	Total Errors	Total Mistakes	Total Assists
P1	/	90%	38min37	22	3	12
P2	100%	100%	10min26	6	1	1

P3	100%	100%	8min58	2	3	2
P4	/	100%	11min44	2	0	2
P5	/	100%	7min41	4	1	2
P6	/	80%	19min26	7	4	9
P7	100%	100%	18min08	5	2	1
P8	/	100%	10min30	3	3	3
P9	/	100%	20min28	32	6	16
P10	100%	100%	11min31	7	2	2
P11	/	87%	11min38	20	4	2
P12	/	100%	18min12	8	7	8
P13	100%	/	17min46	6	1	0
P14	/	100%	16min02	19	5	4
P15	100%	100%	17min25	16	4	2
P16	/	100%	21min52	10	3	3
P17	/	100%	14min46	20	8	4
P18	/	100%	15min03	24	2	3
P19	100%	85%	20min25	15	2	1
P20	/	100%	9min55	13	3	1
P21	100%	/	15min55	11	2	0
Mean	100%	96.95%	16min01	12	3.14	3.71
Standard Deviation	0.00	6.31	399.88 (sec)	8.32	2.03	4.14
Min	100%	80%	7min41	0	0	0
Max	100%	100%	38min37	32	8	16

4.2.2. Satisfaction results

Satisfaction

User #	Scale 1	Scale 2	Scale 3	Scale 4	Scale 5	Scale 6	Scale 7	Scale 8	Scale 9	Scale 10
P1	5	1	5	1	5	1	5	1	5	2
P2	4	2	5	1	5	2	4	2	5	3
P3	5	3	4	1	4	3	5	1	5	1
P4	4	1	5	1	5	2	5	1	5	1
P5	3	3	5	1	5	1	5	1	5	1
P6	4	1	4	5	5	1	4	2	5	2
P7	4	1	5	2	3	2	4	1	4	1
P8	5	1	5	4	5	2	4	1	5	1
P9	5	1	5	2	4	3	5	1	4	1

P10	5	1	5	1	5	1	5	1	5	1
P11	5	1	5	1	4	5	5	1	5	1
P12	3	1	5	1	4	2	5	1	5	1
P13	5	3	5	1	5	1	5	1	5	1
P14	5	2	4	2	5	1	4	1	4	1
P15	4	2	5	1	5	2	4	2	5	3
P16	4	3	5	1	5	2	5	1	3	1
P17	3	3	5	2	4	2	5	2	4	1
P18	5	1	5	1	5	1	5	1	4	1
P19	5	1	5	2	5	1	5	1	5	1
P20	3	1	4	1	4	1	5	2	4	1
P21	5	1	5	2	4	1	5	1	5	2
Mean	4.33	1.62	4.81	1.62	4.57	1.76	4.71	1.24	4.62	1.33
Standard Deviation	0.80	0.86	0.40	1.07	0.60	1.00	0.46	0.44	0.59	0.66
Min	3	1	4	1	3	1	4	1	3	1
Max	5	3	5	5	5	5	5	2	5	3
Score	88.68									

4.2.3. User experience results

User experience

User #	Scale 1	Scale 2	Scale 3	Scale 4	Scale 5	Scale 6	Scale 7	Scale 8	Scale 9	Scale 10
P1	5	5	5	2	5	3	5	1	1	5
P2	5	3	4	4	4	2	5	1	1	3
P3	4	5	5	3	4	5	5	1	1	2
P4	5	4	5	3	5	4	5	1	2	2
P5	5	5	4	3	5	3	5	1	1	1
P6	4	3	4	4	5	5	5	1	1	4
P7	4	3	4	1	5	4	3	1	1	2
P8	5	4	5	2	5	2	5	1	1	4
P9	5	5	4	2	4	1	3	2	4	4
P10	5	5	5	4	5	3	1	1	1	5
P11	5	3	5	5	5	5	3	1	1	1
P12	5	5	4	3	5	5	5	1	1	1
P13	5	5	4	3	5	5	5	1	1	5
P14	4	4	5	4	4	5	5	1	2	2
P15	5	3	4	4	4	2	5	1	1	3

P16	5	5	4	5	5	5	5	1	3	1
P17	5	5	4	4	5	5	4	1	3	5
P18	5	4	4	1	4	5	5	1	2	5
P19	5	5	5	3	5	5	5	4	1	5
P20	4	3	4	1	3	5	5	4	1	1
P21	5	4	5	5	5	3	5	1	1	2
Mean	4.76	4.19	4.43	3.14	4.62	3.90	4.48	1.33	1.48	3.00
Standard Deviation	0.44	0.87	0.51	1.28	0.59	1.34	1.08	0.91	0.87	1.61
Min	4	3	4	1	3	1	1	1	1	1
Max	5	5	5	5	5	5	5	4	4	5