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HELDER AUGUSTO PARAENSE DE OLIVEIRA SERRA

VIRTUAL REALITY FOR POST-STROKE REHABILITATION: USER STUDIES AND GAME DEVELOPMENT

REALIDADE VIRTUAL PARA REABILITAÇÃO PÓS-AVC: ESTUDOS DE UTILIZADORES E DESENVOLVIMENTO DE JOGOS

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Departamento de Eletrónica,
Telecomunicações e Informática

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Engenharia Informática, realizada sob a orientação científica da Professora Doutora Beatriz Sousa Santos, Professora Associada do Departamento de Electrónica, Telecomunicações e Informática da Universidade de Aveiro e do Professor Doutor Paulo Dias, Professor Auxiliar do Departamento de Eletrónica Telecomunicações e Informática da Universidade de Aveiro.

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palavras-chave

realidade virtual, design centrado no utilizador, acidente vascular cerebral, reabilitação, monitorização de mãos, grupo focal

resumo

O AVC é uma das principais causas de invalidez e morte no mundo, e a reabilitação é uma parte relevante da vida dos sobreviventes do AVC. A fisioterapia é necessária para recuperar algum movimento durante a fase aguda, mas também para manter a força muscular e evitar a deterioração e fraqueza durante a fase crónica. A pandemia global causou escassez de atividades de reabilitação, e jogos de Realidade Virtual (RV) poderiam ser usados como um tipo complementar de terapia para reabilitação de AVC com o uso em casa. Esta dissertação propõe um Estudo com Utilizadores para melhor compreender as necessidades e preferências de sobreviventes do AVC e o desenvolvimento de protótipos de jogos para melhor averiguar o potencial de jogos sérios baseados em RV. Com este objetivo, um Questionário e um Grupo Focal foram feitos com os sobreviventes e, com base em seus resultados, dois protótipos de jogos baseados em RV foram desenvolvidos, focados nos movimentos que os sobreviventes precisam realizar, além de fornecer um modo equivalente à Terapia do Espelho. Este estudo descobriu que sobreviventes de AVC em estágio crónico estão mais interessados em aplicações baseadas em atividades do mundo real, especialmente atividades que eles costumavam realizar antes do início dos sintomas. O feedback negativo também é um problema que eles preferem evitar com base nas condições de saúde mental comumente associadas ao AVC. Os protótipos do jogo foram testados com base em usabilidade e pontuaram alto com os participantes saudáveis na Escala de Usabilidade do Sistema quando executados normalmente, mas pontuaram baixo quando seus movimentos foram espelhados, embora talvez os sobreviventes estejam mais acostumados a esse tipo de exercício. O desempenho dos protótipos de jogos precisa de melhorias, mas eles foram considerados fáceis de usar e aprender. O próximo passo será a avaliação de versões melhoradas por sobreviventes de AVC.

keywords virtual reality, user-centered design, stroke, rehabilitation, hand tracking, focus group

abstract Stroke is one of the leading causes of disability and death in the world, and rehabilitation is a relevant part of the life of stroke survivors. Physical therapy is necessary to recover some movement during the acute phase, but also to maintain muscle strength and avoid deterioration and weakness during the chronic phase. The global pandemic caused shortages of rehabilitation activities, and Virtual Reality (VR) games could be used as a complementary type of therapy for stroke rehabilitation to be used at home. This dissertation proposes a user study to better understand the needs and preferences of stroke survivors and the development of game prototypes to better ascertain the potential of VR-based serious games. With this goal, a Questionnaire and a Focus Group were done with survivors, and based on their results, two VR-based game prototypes were developed, focused on the movements that survivors need to perform as well as providing an equivalent to Mirror Therapy. This study found that stroke survivors in chronic stage are more interested in applications based on real-world activities, especially activities they used to perform before the onset symptoms. Negative feedback is also an issue they prefer to avoid based on mental health conditions commonly associated with stroke. The game prototypes were tested concerning usability and were scored high with healthy participants on the System Usability Scale when performed normally, but low when their movements were mirrored, though perhaps survivors are more used to this kind of exercise. The performance of the game prototypes needs improvement, but they were considered easy to use and to learn. The next step will be an evaluation of the improved versions by stroke survivors.

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1 Introduction

Stroke is one of the leading causes of disability and death in the world. Even though the incidence of stroke decreased from 1990 to 2010 (Feigin et al., 2014), it is still the second most common cause of death (Lozano et al., 2012). Disability-adjusted life-years (DALYs, which are the sum of years lost due to premature death and years lived with disability) due to stroke are increasing, making it the third leading cause of DALYs lost worldwide (Murray et al., 2012), a jump from the fifth place two decades before. Considering the increase in DALYs, measuring the Quality of Life of stroke survivors is important, and maximizing recovery leads to better Quality of Life (Nichols-Larsen et al., 2005).

Rehabilitation is a relevant part of the life of stroke survivors. Much of the recovery the patients can achieve is in the acute (up to two weeks) and subacute (up to six months) phases, with little improvement in the chronic phase (more than six months), as can be seen in figure 1. Physical therapy is necessary to recover some movement during the acute phase, but also to maintain muscle strength and avoid deterioration and weakness during the chronic phase. Social isolation is also a common problem for stroke survivors, often resulting in depression and anxiety (O'Keefe et al., 2014). Therefore, maintaining motivation during the rehabilitation is paramount for survivors.

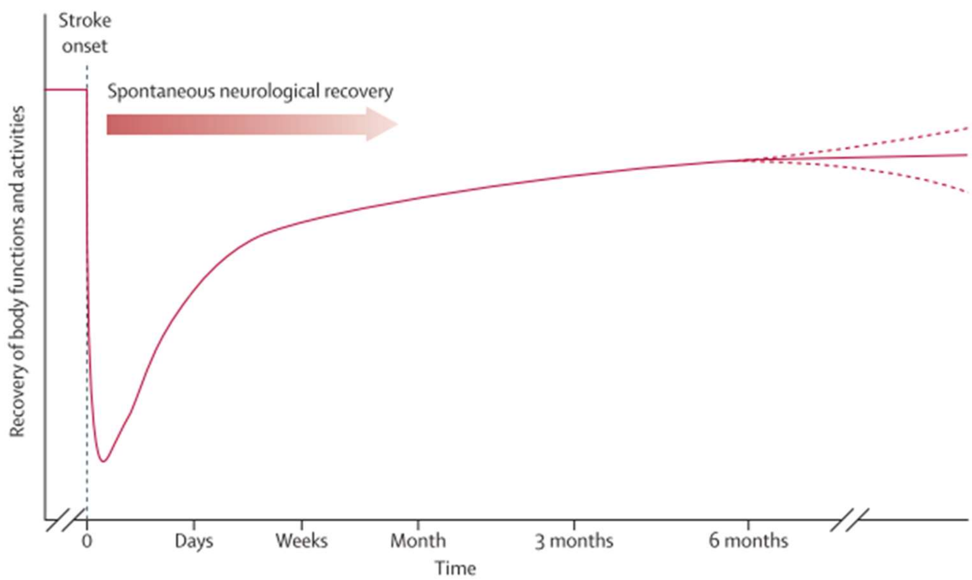

Figure 1: Hypothetical pattern of recovery after stroke. (Langhorne et al., 2011)

COVID-19 also had a severe impact on rehabilitation. With the pandemic having a priority in patient care in hospitals, people with disabilities experienced a negative impact on their treatment, due to a shortage of rehabilitation activities and an estimate of more than 1 million people per day being denied rehabilitation in Europe (Negrini et al., 2020). Virtual Reality (VR) games can be used as a complementary type of therapy for stroke rehabilitation and have the potential to be used at home in situations like the pandemic (Amorim et al., 2020).

The use of VR-based therapy might also be fundamental to increase motivation for rehabilitation exercises (a problem that arises commonly when using conventional rehabilitation) and to increase the likelihood of survivors continuing their rehabilitation (Dias et al., 2019; Kern et al., 2019). VR serious games have already proved to be effective in upper limb rehabilitation (Amorim et al., 2020). They have also presented positive effects on Quality of Life (Shin et al., 2016). This thesis focuses on the development of a VR-based solution for rehabilitation centered on the users' needs using a Head-Mounted Display, namely the Oculus Quest 2, for immersion and hand tracking.

1.1 Goals and Contributions

This dissertation proposes a user study to better understand the survivors and the development of game prototypes to better ascertain the potential of VR-based serious games for physical rehabilitation of survivors of stroke focused on their upper limbs. These serious games should help survivors' rehabilitation through arms and hands movements to improve and maintain their physical strength while improving their quality of life. The entertainment capabilities of the software should help motivate them (Amorim et al., 2020; Dias et al., 2019). One of the objectives of this thesis is to use a user-centered methodology that involves the survivors in the development process to better understand their needs, goals, and concerns. To do that, a Questionnaire and a Focus Group meeting with the collaboration of Portugal AVC were conducted to characterize stroke survivors and their peculiarities, needs and concerns, as studying about them and their disability can only scratch the surface of their hardships, but talking and listening to them can help elucidate how to best address their issues.

The main objectives of this thesis are presented below:

- Do demographical and Focus Group studies with survivors.
- Develop serious game prototypes for rehabilitation focused on the users' needs using the Oculus Quest 2 and its Hand Tracking.
- Test the games with survivors and assess their usability.

The contributions expected for this work are:

- A study of the state-of-the-art of VR and its use for physical rehabilitation.
- A characterization of stroke survivors based on their preferences and limitations, and differentiation of their needs based on if they are on the acute or chronic stage.
- A study with a novel device, the Oculus Quest 2, and its most important feature for stroke survivors, the Hand Tracking without additional costs.
- A game developed in the Unity Game Engine that includes the concept of Mirror Therapy in VR.

1.2 Dissertation Outline

This dissertation is divided in six chapters, not including this one:

- Chapter 2 describes the state-of-the-art associated to this project, the definition of stroke, VR, and Mirror Therapy, the usage of VR as a supplemental therapy for physical rehabilitation, and a discussion on improving motivation of survivors with VR.
- Chapter 3 starts by describing the Questionnaire used for characterizing the survivors of stroke and presenting its results, followed by the definition of Qualitative Research and the Focus Group meeting with the members of Portugal AVC, which has presented important findings for the development of the game.
- Chapter 4 describes all the technology used in the development of this project, as well as presents the game that was developed through all its stages, from design to final prototype.
- Chapter 5 defines the tests of the game done with survivors, its results and analysis.
- Finally, Chapter 6 summarizes the conclusions drawn from the studies with survivors, the development and testing stages, and discusses the future work that can be done to improve upon this project.

2 Related Work

This chapter will present the topics relevant to this study regarding stroke and the importance of rehabilitation for the survivors' quality of life, followed by a discussion of the hurdles of motivating patients. The usage of gamified experiences as a tool for motivation, and the need of a user-centered approached are discussed afterwards, and it ends with information on how Virtual Reality (VR) technology has evolved throughout the years to help as a supplemental method of physical therapy.

2.1 Post-stroke Physical Rehabilitation

Stroke is defined as an ischemic or hemorrhagic death of the cells in the brain, spinal cord or retina, with clinical or imaging evidence of permanent injury (Sacco et al., 2013). It was estimated that 16.9 million people in the world suffered with first stroke in 2010, while there were 33 million survivors and 5.9 million stroke-related deaths. This data presented an absolute increase from numbers of 1990 based on 119 studies from 1990 and 2010 (Feigin et al., 2014).

Figure 2 presents all the possible effects of a stroke on the individual. A multidisciplinary team care is important for stroke rehabilitation. That means medical, nursing, physiotherapy, occupational therapy, speech therapy, and social-work staff coordinating work (Langhorne et al., 2011). Rehabilitation needs to be progressive, dynamic and goal-oriented, with the objective of attaining the best possible quality of life to the survivor (Hebert et al., 2016). There is an increase of young age adults suffering from stroke (George et al., 2011), which means that many survivors are still dependent on work and far from retirement, and their daily-living needs might be different from those of older age.

Two types of therapy are commonly used in post-stroke physical rehabilitation: Constraint-Induced Movement Therapy (CIMT) and Mirror Therapy. The former applies motor skill learning principles and neuroplasticity (the ability of the neurons to grow and reorganize). This can be used for increasing movement complexity and motivation. There is evidence that the CIMT approach is superior to other standard motor skill practices (Hatem et al., 2016).

Mirror Therapy is a therapy for pain or disability that affects one side of the body more than the other. It can be used in upper limb rehabilitation, for instance, by hiding the affected limb behind a mirror. The patient can perform movements and watch as if their affected limb is mirroring their non-affected one. There is evidence that this kind of therapy presents good results in upper limb impairment and its effects may persist through the chronic phases (Hatem et al., 2016). Figure 3 shows an example of Mirror Therapy.

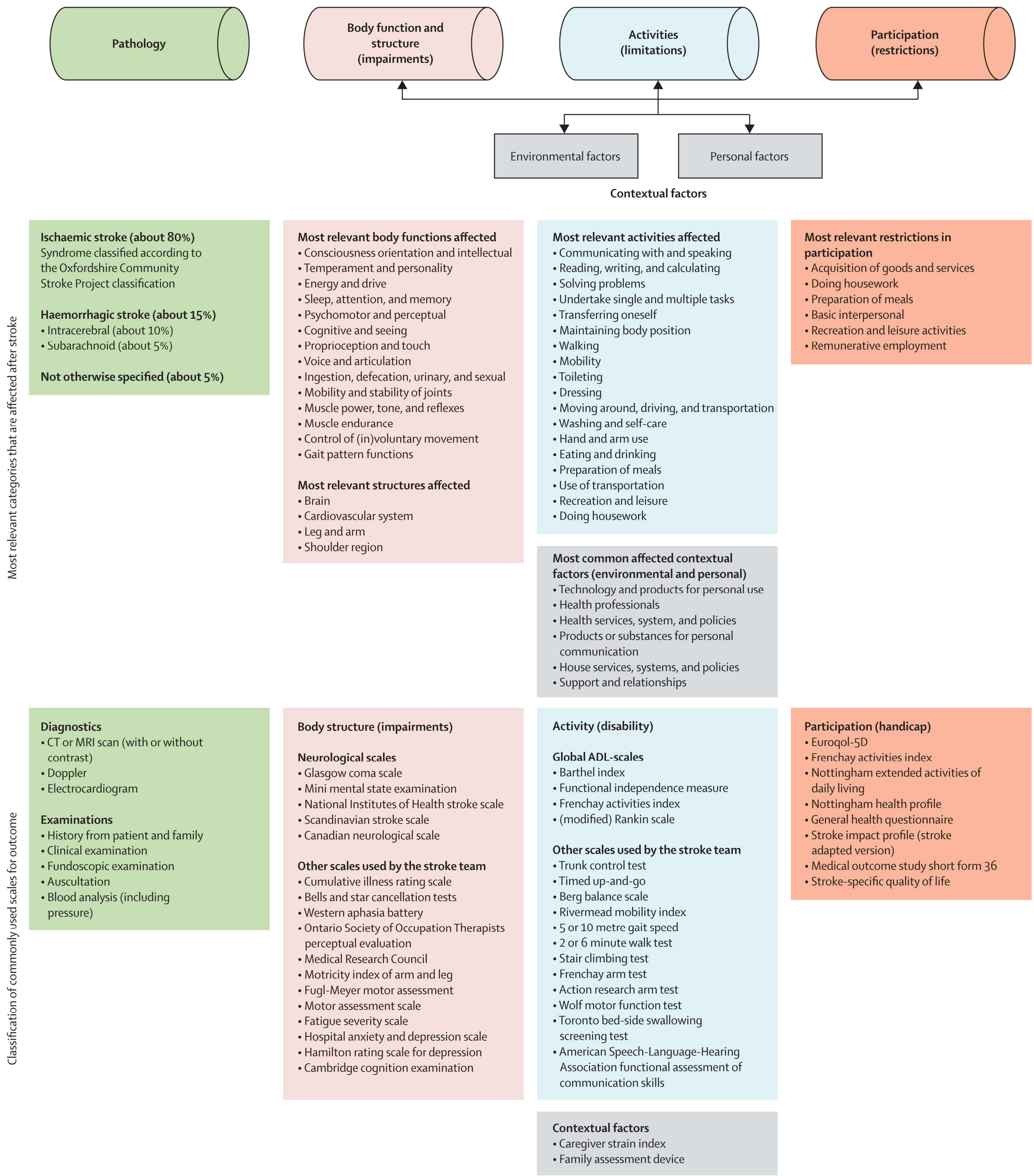

Figure 2: The international classification of function, disability, and health framework for the effect of stroke on an individual (Langhorne et al., 2011).

2.2 Virtual Reality in Rehabilitation

VR is a computer-generated digital environment with which the user can interact and feel the experience as if it were real. This interaction can occur in real time through sight and hearing, with a few studies using the other senses as well (Jerald, 2015). It can be immersive, by utilizing technology like Head Mounted Displays (HMDs) or tactile feedback (haptic gloves, for instance). It can also be non-immersive when the virtual environment (VE) is presented in a monitor or a TV, like most video games.

Figure 3: An example of Mirror Therapy[1]. The person watches the mirror to imagine their hidden arm making the same movement as their non-affected one.

VR has already been used in rehabilitation for many years, with motion sensors like the Wii Remote made by Nintendo (Saposnik et al., 2010), or the Microsoft Kinect (Ma et al., 2018; Pedraza-Hueso et al., 2015), being used to aid physical therapy with non-immersive games to increase user engagement and motivation (figures 4 and 5). These are devices released more than 10 years ago and, since then, new technologies were introduced that helped shape the studies of rehabilitation with virtual reality. Other devices, such as the Armeo®Power[2] and the HTC VIVE Pro[3] are used for semi and fully immersed experiences, respectively (figure 6).

New advancements in VR technology, such as standalone devices like the Oculus Quest[4], provide new opportunities for developers to engage with an audience in a field that used to have a high cost of entry. Previous HMDs were more expensive as they required computer hardware with powerful graphics cards, or even setups with multiple cameras placed in the area to track the users and the HMD.

[1] https://uk.saebo.com/shop/saebo-mirror-box/. Accessed on: 16/10/2021
[2] https://www.hocoma.com/solutions/armeo-power/. Accessed on: 16/10/2021
[3] https://www.vive.com/eu/product/vive-pro/. Accessed on: 16/10/2021
[4] https://www.oculus.com/quest-2/. Accessed on: 16/10/2021

Figure 4: The Nintendo Wii being used for rehabilitation. On the left[5], a patient plays Wii Bowling. On the right[6], the Wii Remote controller held by the patient.

Figure 5: The Microsoft Kinect being used for rehabilitation. On the left[7], a patient plays a rowing game. On the right[8], the Microsoft Kinect camera that tracks the patient.

Figure 6: Armeo®Power[9] on the left and the HTC VIVE Pro[10] on the right.

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[5] https://pin.it/1KF3bVj. Accessed on: 16/10/2021

[6] https://en.wikipedia.org/wiki/Wii_Remote. Accessed on: 16/10/2021

[7] https://bit.ly/3mIzewF. Accessed on: 16/10/2021

[8] https://bit.ly/3Fy33Zd. Accessed on: 16/10/2021

[9] https://www.medicalexpo.com/pt/prod/hocoma/product-68750-438436.html. Accessed on: 16/10/2021

[10] https://www.vive.com/eu/product/vive-pro/. Accessed on: 16/10/2021

A method of positional tracking where the sensors required for identifying the position of the HMD and its accessories are inside the device is called Inside-out Tracking. This method uses the relational position of the device according to the environment in which the user is located, and it can be done with or without markers placed in the environment. Oculus Quest utilizes a markerless inside-out tracking method by creating a 3D map of the environment with the aid of computer vision to identify the surroundings, pinpointing landmarks in the environment and using this information to identify possible obstacles. This technology is called Oculus Insight and is based on Simultaneous Localization and Mapping (SLAM) technique (Hesch et al., 2019).

The importance of this method of tracking is precisely the possibility of untethered devices like Oculus Quest. Previous efforts in VR such as Oculus Rift S, though utilizing the same form of tracking, depend on a PC for rendering and running the applications. Oculus Quest, on the other hand, is completely standalone and wireless. It is built (as of Oculus Quest 2) with a state-of-the-art Qualcomm Snapdragon XR2 System-on-a-Chip, made specifically for Augmented Reality (AR), VR and Mixed Reality (XR) with AI capabilities and full 6 Degrees of Freedom (6DoF) (*Introducing Oculus Quest 2, the Next Generation of All-in-One VR - About Facebook*, 2020).

The advantage of being an all-in-one device is that it is easier to setup and use, giving freedom to users on how and where they want to experience VR, even at home without the need of complicated setups of other devices. And that is of extreme importance for physical rehabilitation, as the space limitations are less of a concern and the focus of the applications can be solely on the patients and their needs. In addition, Oculus Quest now has the capability of Hand Tracking with no extra hardware required (Oculus, 2019), and this opens up more possibilities for rehabilitation.

VR applications have a significant potential for rehabilitation as they might meet the four basic principles of rehabilitation: intensity, task-oriented training, biofeedback, and motivation; which are of extreme importance for successful rehabilitation programs (Dias et al., 2019). Because of that, research on new technologies for usage on physical rehabilitation continues.

2.3 Motivation in Stroke Rehabilitation

Another important aspect of rehabilitation is that it can be uncomfortable, painful, take a long time, and are not entertaining. Many patients lose motivation during the treatment, with abandonment being a concern of physicians and physical therapists. VR can be used as a powerful tool for increasing user engagement and motivation, as the VE can help stimulate patients and distract them from the nature of the tasks being done (Dias et al., 2019). At the same time, the ability to create any possible VE imaginable and immerse users in it is paramount for this type of application. The challenge that can be presented to users, as well as the repetitiveness of the tasks being less noticeable, might stimulate users to engage for longer periods and with more success in rehabilitation.

Motivation and reinforcement are important for rehabilitation and VR can help patients to maintain their treatment, as well as even improve their results (Levin et al., 2015). Visual and sound cues help immerse users in the VE and present them with feedback that improves user experience. It is also important, however, that the VR solution chosen for the rehabilitation does not hinder the treatment. A main concern with HMDs is their weights (Dias et al., 2019; Silva, 2017). Another one is cybersickness, a very common issue with VR (Reski & Alissandrakis, 2020; Silva, 2017). Because of these, it is important that the device chosen is lightweight, has a high resolution and refresh rate, has adjustable interpupillary distance (IPD), and the application developed takes in consideration how to properly convey movement to reduce motion sickness (Stanney et al., 2020).

In (Silva, 2017) research was done with stroke patients at the Rovisco-Pais Rehabilitation Center. They utilized the Leap Motion Sensor[11] with the Oculus Rift Dk2 HMD and presented a series of three mini games developed for rehabilitation, comparing them with the HMD and using a monitor screen. The fully immersive experience was the preferred one with more than 80% of the participants choosing it as their preference. 100% of the 11 patients said they thought this type of application can be useful for rehabilitation, and 10 out of the 11 said they would use it at home.

Another study utilizing VR for rehabilitation had the participants walk in a treadmill (figure 7) while using an HMD (Kern et al., 2019). This work studied the usage of fully immersive VR and gamification for gait rehabilitation, with the objective of increasing motivation. When compared to the non-VR experience, the participants experienced a significantly higher interest in the VR solution, which was attributed to the autonomy and relatedness experienced with the software.

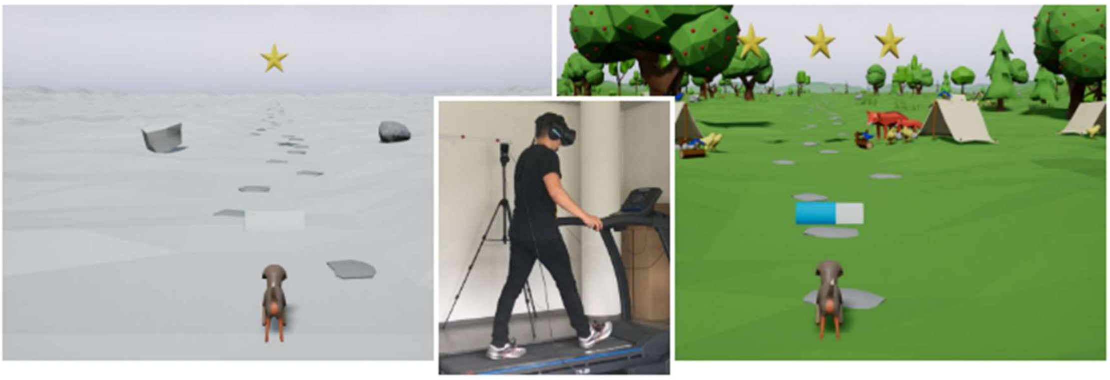

Figure 7: The patient engages with VR for gait rehabilitation. They walk in a game with procedurally generated environments alongside a dog companion, with the objective of reaching goals represented by the stars, being rewarded with more of the world being generated (like a tree). Image Source: (Kern et al., 2019)

In research with patients and occupational therapists, (Hung et al., 2016) found that novelty and audio/visual effects are the most required features to help motivate patients. Though, it was also found that there are limitations in current game-based rehabilitation systems. The biggest

[11] https://www.ultraleap.com/. Accessed on: 16/10/2021

concerns were the costs of these systems and the limited choice of games. At the same time, commercial games usually do not require all the range of movements necessary for rehabilitation.

2.4 Conclusions

In this chapter, the main topics and related work that informed study the work presented in this dissertation were discussed by presenting the state-of-the-art research. Stroke and post-stroke rehabilitation were defined and discussed with important data that shows the increase in the number of incidents and survivors. Virtual reality has come a long way from non-immersive VR to fully immersive with the use of HMDs, and consequently became a supplemental solution for physical rehabilitation with the increase of motivation as a main factor. Motivating patients to continue their rehabilitation and attain a better quality of life is one of the main goals of this research, as well as having a user-centered approach, and because of that, receiving feedback from the survivors to better understand their motivations and needs is of extreme value, which is the topic of the next chapter.

3 Study with Stroke Survivors

This chapter presents a questionnaire and a Focus Group performed during this work to better assess what they know about serious games for physical rehabilitation, video games as a tool for motivation in therapy, Virtual Reality (VR) in rehabilitation – be it non-immersive or immersive –, and what types of experiences and exercises have a better chance of motivating these survivors to keep working on their rehabilitation even in the chronic stage post-stroke. Furthermore, these studies also help characterizing the participants for a better understanding of their expectations, limitations, and needs.

The first study consists of an online, anonymous questionnaire focused on finding out the profile of individuals living post-stroke and associated to Portugal AVC, a non-governmental organization for people who survived stroke, or family and friends. After describing the rationale for this study and analyzing its results, this chapter presents the main results of a Focus Group that was done with eight of the participants. The findings of both studies helped shape the VR-based serious game developed in this research.

3.1 Questionnaire

3.1.1 Objectives

The Questionnaire was created to obtain information before the development of the VR solution for physical rehabilitation, allowing survivors in the chronic stage to keep exercising and rehabilitating their upper limbs even when away from healthcare facilities. The main goal is to help provide better quality of life and their independence when doing daily, common tasks.

Hence, it is important that the VR application can be a motivating experience. To help understand this group of users, the Questionnaire has questions regarding their preferences in leisure and exercising activities, how much time they spend on these, what activities they would like to do, and their experience (or lack thereof) in video games and VR.

Another part of the Questionnaire was the presentation of four different types of experiences in video games. The participants were expected to watch snippets of gameplay of four games (one for each type of experience), and answer questions about them to better assess the kinds of games that attract them the most. In the end, learning about what motivates them to play a game, be it a specific genre or the difficulty of the tasks, was the main objective to guide this research in the development of the game.

3.1.2 Type of experiences

Every type of media can be categorized in different ways. Music, Movies and Books are usually sold based on the genres they are placed in. Genre is a long discussion that is present in every type of media. In video games, it has been discussed for many years, and is mostly recognized as marketing keywords to attract a specific audience for a commercial game. The types of experiences selected for this study are based mostly on the type of interaction between the user and the video game, and how this interaction is perceived in the virtual world. The categorization follows the one presented by (Wolf, 2002):

- **Simulation**, in which the game aims to portray real-world tasks as close as possible, usually in a gamified manner for the purpose of entertainment. It is very common for games in this genre to be based on jobs or mundane tasks.
- **Action**, in which, like Simulation, the interaction seems realistic, but the objectives are simpler: most commonly, hitting moving or stationary targets. This type of experience usually involves physics-related interactions, such as throwing objects which must move in a realistic way.
- **Adventure** games, on the other hand, are less focused on the way the user interacts with the game, and more about how the user interacts with the world they want to explore. The world must be enticing so users are motivated and curious to explore it.
- **Puzzle** games, on the other hand, focus on logic challenges for the users to solve. The interaction with the game or the exploration of the world are just means to solve problems, and the player is expected to learn how to manipulate the game to achieve their goals.

3.1.3 Preparation

The Questionnaire was divided in four sections: Demographics, Preferences, Game Experiences, and Motivation in Games. First, a prototype of the Questionnaire was created, and sent to friends and family of the author, as well as to the president of the survivors' association to collect feedback mainly concerning readability and understandability of the questions as well as to evaluate the overall length of the questionnaire. This was referred to as the Pre-test Questionnaire.

In Demographics, the information collected was regarding gender, age, the side of the body that was most affected by the stroke, dominant hand, and profession before and after the stroke. In Preferences, questions such as "What are your favorite hobbies?", "What physical activities did you use to practice before the stroke?", and "Do you have any experience with videogames?" were asked to better understand what the participants would find more pleasant to experience in a VR-based videogame focused on rehabilitation.

In the section of Game Experiences, four categories were presented, as previously stated. Each category presents a short video of around 30 seconds (at Pre-test, two of them had 1 minute), as to minimize survey fatigue and reduce the time needed to complete the questionnaire. For each video, five statements were presented about the video watched, such as "I can easily understand how to control this game" and "The objectives of this game are clear and easy to understand", and the responses were in a 5-point Likert Scale, being 1 "Strongly Disagree" and 5 "Strongly Agree".

The games were chosen as followed and can be seen in Figure 8:

- **For simulation**, the game chosen to be presented is House Flipper VR.[12] The objective of this game is to make home improvements, be it by painting walls, changing furniture, and decorating interiors. It basically is a simulation of a job.
- **For action**, the game chosen is Carnival Games VR.[13] It has a selection of short games like knocking bottles with a ball, throwing darts, or catching items in the air. Though easily appliable for simulation, this game is more focused on hitting targets.
- **For adventure**, the game chosen is New Pokémon Snap.[14] Its main objective is to travel through various locations while taking photographs of the wildlife and having them being appraised. The scenery is very important for this game, as it tries to portray the experience of a safari.
- **For puzzle**, the game chosen is The Room.[15] At this game, there is a large puzzle box that the player can interact with, to try and solve interconnected enigmas with the main goal of opening the box up to reveal the secret inside.

In the last section, Motivation in Games, five more statements in the 5-point Likert Scale were presented, now asking questions about what motivates people when playing videogames. Some of the statements were "Complete tasks within a time limit is necessary to increase challenge" and "I am interested in using videogames for rehabilitation if this helps me achieve better results". After that, the participants were asked to rank the four types of experiences in order of preference, from 1 to 4. To end the Questionnaire, two open answer questions were asked: one for game or activity suggestions that they find interesting; the last question, asking for any opinions, suggestions, or questions they had regarding the project.

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[12] https://www.youtube.com/watch?v=eO02RMVfTbA. Accessed on: 16/10/2021
[13] https://www.youtube.com/watch?v=4q0GV8UQYQQ. Accessed on: 16/10/2021
[14] https://www.youtube.com/watch?v=e-e-lev6iiA. Accessed on: 16/10/2021
[15] https://www.youtube.com/watch?v=Y2GY12htotA. Accessed on: 16/10/2021

Figure 8: The four games chosen to represent the types of experience (from left to right, top to bottom): House Flipper VR[16], Carnival Games VR[17], New Pokémon Snap[18], and The Room[19].

After the Pre-test, some questions were modified based on the feedback from participants and from the president of Portugal AVC. For example, in Demographics, the question about gender was changed to allow participants to input their own answer besides masculine and feminine, making the question more inclusive. In Preferences, the question about exercises was divided in two: exercises practiced before the stroke, and exercises that they wish they could practice now. At the same time, the question about how much time they dedicate to physical exercises was removed, because it is not the objective of this research to replace real exercise, so only the time spent in hobbies has any relevance.

Regarding Motivation in Games, after a meeting with the president of Portugal AVC, while talking about well-known videogames that might be useful to motivate the participants in playing them for rehabilitation, it was decided to include an open answer question for them to share which videogames they felt could be used for rehabilitation. The questions were prepared in brainstorming sessions and were based on what information the author expected to obtain to inspire the development of the project. The Questionnaire can be viewed in Appendix A.

[16] https://www.youtube.com/watch?v=eO02RMVfTbA. Accessed on: 16/10/2021
[17] https://www.youtube.com/watch?v=4q0GV8UQYQQ. Accessed on: 16/10/2021
[18] https://www.youtube.com/watch?v=e-e-lev6iiA. Accessed on: 16/10/2021
[19] https://www.youtube.com/watch?v=Y2GY12htotA. Accessed on: 16/10/2021

3.1.4 Participants

To obtain valuable feedback, the president of Portugal AVC was contacted so he could redirect the Questionnaire to survivors. After a meeting with him, the Questionnaire was sent to members of Portugal AVC. The president assured that all the receivers are in the chronic phase post-stroke (considered here at least 12 months after).

20 participants completed the Questionnaire. From this group there were 10 people who identify as the masculine gender, and 10 people who identify as the feminine gender. Figure 9 shows the distribution of the participants based on their age. More than half of the participants were of ages between 45 and 64, and 20% were 44 or younger. Furthermore, 12 people answered that they have hemiparesis (weakness or paralysis of an entire side of the body) on the right side of the body, while the rest have it on the left side. Most of the participants were already retired.

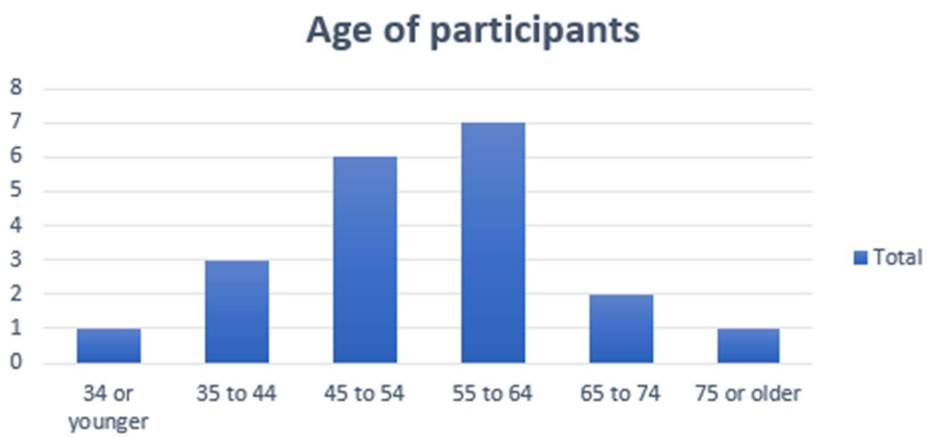

Figure 9: Distribution of the participants based on their age. A broad spectrum of people participated in the Questionnaire.

3.1.5 Results and Discussion

The results of the Questionnaire show a clear trend towards two types of experiences. The Simulation and Action games were the preferred options in a question that asked the participants to organize the games by order of preference (figure 10). The respondents were also asked if the scenarios of the games were pleasant, and if they felt motivation to try the games presented. Their responses were based on the 5-point Likert Scale as mentioned above.

The Simulation game had a median of 4 (out of 5) when asked if the scenario was pleasant, and 4 (out of 5) if the participants were willing to play it (figure 11). The Action game, subsequently, had a median of 4 and 3.5, respectively (figure 12). The understanding with these results is that the participants were more interested in the Simulation experience because it was based in an activity that they recognize and is considered more mature than simple, entertaining games, like the Action experience, which was based on carnival activities.

At the same time, it might be considered that the age of the participants is also related to their preferences and what they perceive as entertaining: more than half of them (13) were of ages between 45 and 64 years old. This might explain why the Adventure experience, which was the least realistic game presented, drastically underperformed, with only one participant selecting it as their preferred game. Meanwhile, the Puzzle experience was the worst performant when asked if it was easy to understand how to play. This most likely explains why this experience was the most selected as least favorite, being placed in fourth place ten times.

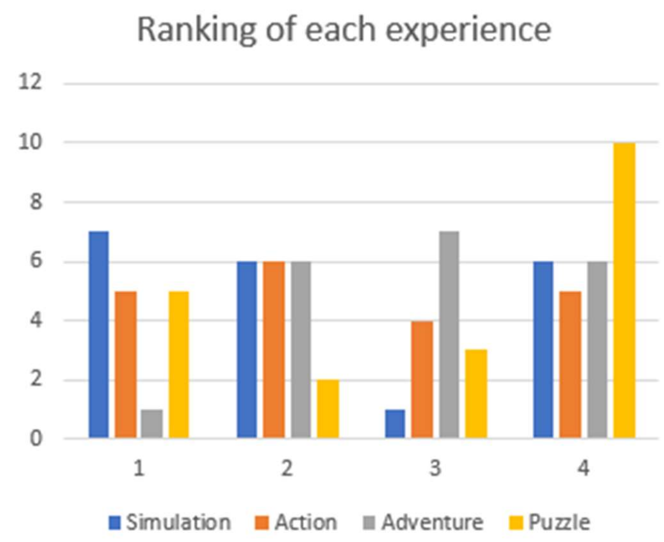

Figure 10: How the participants ranked the experiences by order of preference. 1 is most preferred, 4 is least preferred. It shows how many times for each ranking each experience was chosen.

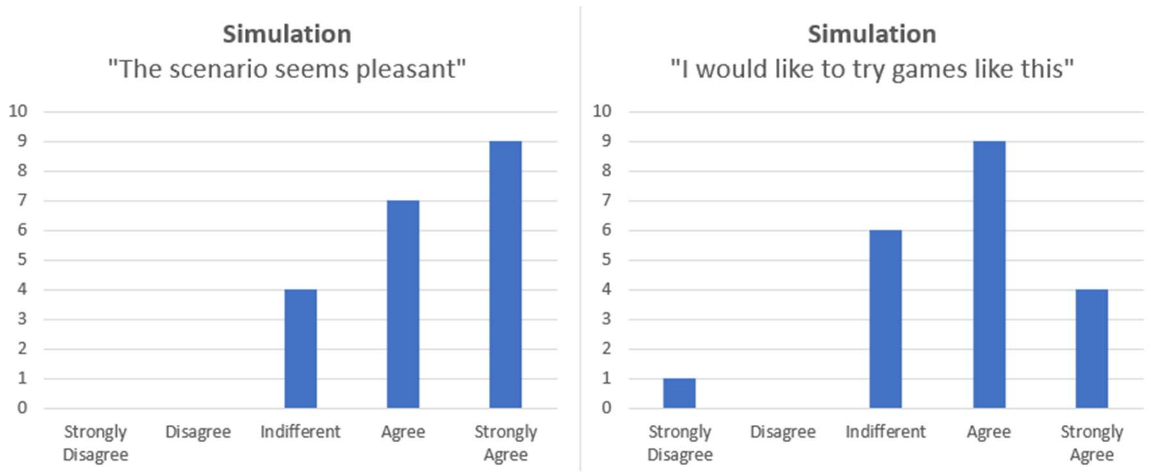

Figure 11: What the participants thought of the Simulation experience based on the game presented. On the left, how pleasant the scenario portrayed was. On the right, how motivated they are to try it.

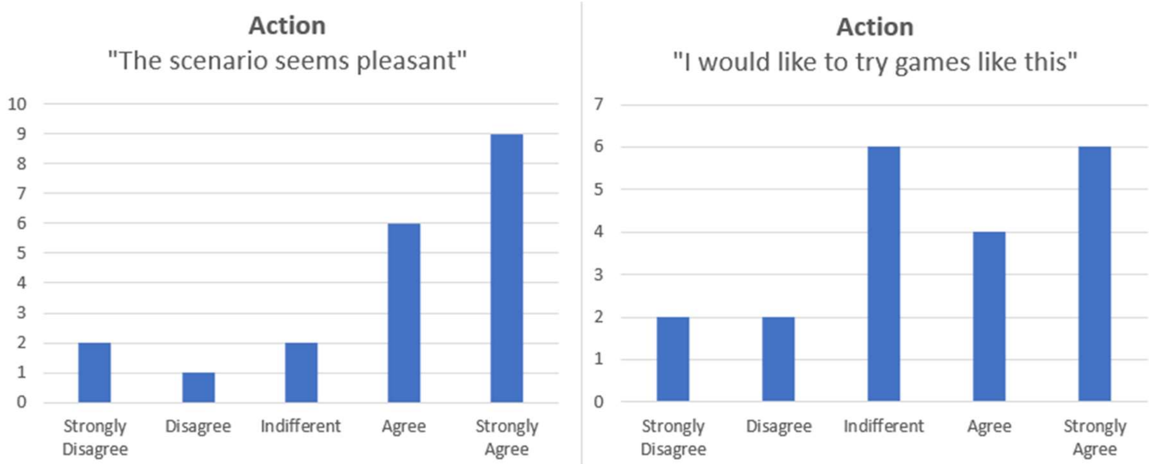

Figure 12: What the participants thought of the Action experience based on the game presented. On the left, how pleasant the scenario portrayed was. On the right, how motivated they are to try it.

Concerning the question about hobbies, most participants chose activities that are passive, like watching TV or listening to music. This is not a surprising finding, but it shows that there is potential for replacing part of the time dedicated to these activities by the use of VR games. Three other activities were chosen by more than 25% of the participants: playing tabletop games, cooking, and gardening. These are common activities found in commercial games, which means there is a market for games centered around these activities, which proves that these can be gamified to entice survivors to try VR games. Alongside the question of their hobbies, it was also asked how much time they spend per week on them (figure 13). As previously said, these are competing activities that can be substituted by VR games focused on rehabilitation.

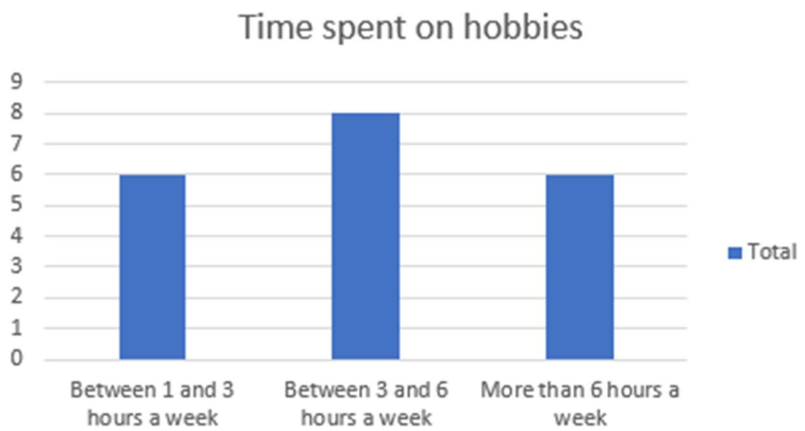

Figure 13: Distribution of the participants based on their time spent on hobbies.

3.2 Focus Group

3.2.1 Quantitative vs. Qualitative Analysis

In health care research, an often-used process for understanding of a question is PICO, a mnemonic that means “Population-Intervention-Comparison-Outcome”. This can be classified as Quantitative Research, primarily focused on quantifying outcomes that can be generalized for a larger population. Qualitative Research, on the other hand, has open-ended questions and are focused on a deeper understanding of a subject, and one of the tools that can be used for this type of research is the mnemonic SPIDER (Cooke et al., 2012), that means “Sample-Phenomenon of Interest-Design-Evaluation-Research type” (Korstjens & Moser, 2017). A direct comparison is made in table 1.

Table 1: Main differences between quantitative research and qualitative research (Moser & Korstjens, 2018).

Quantitative research	Qualitative research
Investigation question: PICO Quantitative research asks «how much», «how many», «how often», The investigation question remains the same throughout the research process.	Investigation question: SPIDER Qualitative research asks «what», «how», and «why» During the research process the research question might change to a certain degree because data collection and analysis sharpens the researcher´s lens. In the methods section you need to describe how and explain why the original research question was changed.
Sample and selection: The sample size is larger and calculated with statistical rules in a way to get a representative sample of the population. The ideal is random recruitment. Once the sample size is determined, it is intended to maintain this size until the end of the study; if that is not possible (due to drop-offs, serious secondary effects, …) in the method section you must explain the reasons.	Sample and selection: Small samples (6-12 participants in focus group) and no randomization in the selection process. The choice of participants should be made by individuals or groups who have knowledge on the phenomenon and can articulate and reflect, are motivated to communicate at length and in depth with the investigator and represent the stakeholders. The sample could change during the research process and the size is only closed when information saturation is reached (when it is expected that adding new participants does not add new information but yields redundant information). You should review the sampling plan regularly and adapt when necessary.
Comparison between intervention group and control group	There is no control group
Manipulation of the context occurs	Observation in natural context
Focus on quantification of predefined variables	Open to new findings
The aim is generalization of the results to the population	No intention of generalization. The aim is to achieve a deeper understanding of the phenomena
There is an effort to avoid researchers’ influence (blinding effect)	Researchers’ influence is inevitable

As seen in the table 1, qualitative research is ideal for better understanding the target audience. In times like the global pandemic, it is easier to coordinate with small samples, and during conversation with survivors, new findings can be seen, and new questions might arise and be answered. An example of a SPIDER-type question can be “What motivates post-stroke patients in their rehabilitation”. This type of question was considered when preparing the meeting with members of the association. Due to the limited sample size of the meeting, and the necessity of a deeper understanding after the results of the Questionnaire, it was decided to prepare a script to lead the conversation of this focus group.

3.2.2 Preparation

The main objective of the Focus Group meeting was learning what the participants thought about the use of VR Serious Games as a supplemental method of rehabilitation. Due to that, it was important to first present them the technology and how it is an evolution of previous VR tools used in physical rehabilitation, like the Nintendo Wii game console and the Microsoft Kinect tracking camera.

Therefore, the script created for the meeting, which happened online because of the global pandemic, was divided in the following sections:

1. Introduction of the engineers and the physician participating in the meeting, adding that any information gathered would be confidential, as well as their identities and any personal details pertaining. They all gave their consent to being recorded for future transcription of the meeting.
2. A presentation was given about the technology, the history of its usage in rehabilitation as a supplemental method and its potential benefits. This phase was around ten minutes in time. They were presented to the concepts of Serious Games, Gamification, Immersion in VR, the technologies used in the past and the new technologies that can be used today, like the Oculus Quest 2, and how Hand Tracking can be used to help the rehabilitation.
3. After the presentation, a section for opinions and questions started. This phase was around 50 minutes in time. Most of this section was dedicated to hearing the participants opinions on the presentation they saw, their knowledge about the subject, their concerns, and how they felt the technology should be used. The input from the engineers and the physician was mostly in response to questions, to elucidate concepts, and encourage discussion.

More than 15 questions were prepared for the last section of the meeting (all the questions and other details can be found in Appendix B). As a Qualitative Research, it was expected that it was of utmost importance to keep the fluidity of the conversation, so more questions than possible for the time allocated were prepared. Some questions were deemed more important than others, so those were the ones focused on during the meeting.

Two questions were centered around two videos of commercial games, with the intention of gauging the participants' interest and understanding what kind of experiences better resonated with the audience. The games **Hand Physics Lab**[20] and **Pekoe**[21] were chosen (figures 14 and 15). The first is a game made specifically for showing the movements of the hands (be it with a controller or with free hands) to solve puzzles, while the second is described as a "cozy cat-filled tea-making simulator".

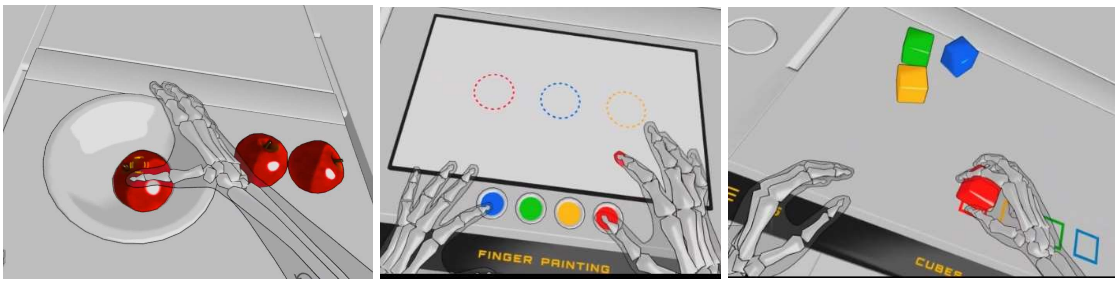

Figure 14: Hand Physics Lab[22]. From left to right: Apple picking, color painting, and cube matching minigames.

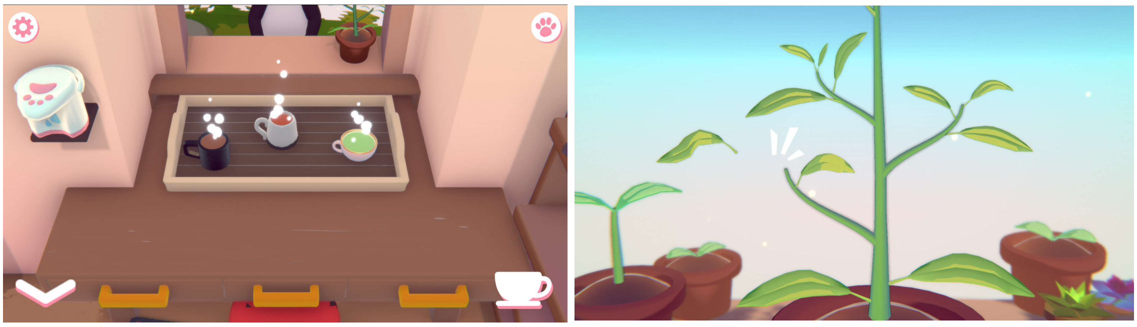

Figure 15: Pekoe[23]. From left to right: serving three mugs of tea to customer and picking tea leaves.

These two games were selected because of how different their objectives are, and for showing a First-Person view of the environment, as well as their potential in explaining to the participants the possibilities of VR (even though the second game is not a VR game, it has similar characteristics, and is the type of experience that was most regarded in the Questionnaire, i.e., a Simulation game).

[20] https://www.youtube.com/watch?v=OWqI11M0-sI. Accessed on: 16/10/2021
[21] https://store.steampowered.com/app/1626350/Pekoe/. Accessed on: 16/10/2021
[22] https://www.youtube.com/watch?v=OWqI11M0-sI. Accessed on: 16/10/2021
[23] https://store.steampowered.com/app/1626350/Pekoe/. Accessed on: 16/10/2021

3.2.3 Participants

There were 12 people participating in the meeting: three engineers (the author and the two professors), one physician specialized in rehabilitation of post-stroke patients, and eight stroke survivors from Portugal AVC. From the survivors, five were men and three were women, all of them adults with ages ranging from 30 to 64 years old. All of them at least had heard about VR technologies being used in rehabilitation, with at least two people having experienced the Nintendo Wii and the Armeo® exoskeleton[24].

3.2.4 Results and Discussion

Four questions and two videos were presented to the participants during the meeting. Three main findings were made, as well as other interesting details. These findings are:

- *Fail States* or negative feedback can be detrimental to the patient's motivation.
- Accessibility in video games is intrinsic to the patient's motivation.
- Patients at the chronic stage are more motivated by video games based around real-world tasks.

One of the participants referred to the common psychological effects the stroke can cause in patients, mainly because of the severity of the disease and the sequelae that affect their quality of life. Thus, depression is commonly a barrier that prevents patients from following through with their rehabilitation. Considering this, negative feedback, which is usually present in video games as an important tool for challenging users, can be a demotivator for depressed patients. Some type of leniency or positive reinforcement should be considered instead.

Regarding accessibility, participants also mentioned two conditions that might occur after stroke: epilepsy and hemispatial neglect (due to the damage to one hemisphere of the brain, one side of the field of vision might be attention impaired) (Rossetti et al., 1998). This, in turn, led to the question of Accessibility in video games. As the focus of this study are survivors of stroke, Accessibility is already considered during design and development.

One participant brought to attention concerns about their Photosensitive Epilepsy. The Epilepsy Society states that the rate of flashing lights which can trigger seizures is between 3 and 30 Hz (flashes per second). Some people are sensitive at frequencies up to 60 Hz (*Photosensitive Epilepsy | Epilepsy Society*, n.d.). It is paramount that no rapidly moving flashing lights are present in the media. It is important, however, that a specialist is consulted prior to engaging in VR for those who have a history of epilepsy, considering the close distance from the screens to the eyes.

At the end of the meeting, the videos were presented, and it was unanimous between the participants that the game Hand Physics Lab might be more suited to patients in the acute or sub-

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[24] https://www.hocoma.com/solutions/arm-hand/. Accessed on: 16/10/2021

acute stage of the stroke. The tasks were considered too simple or rudimentary, and with no direct application to real life for those on the chronic stage. The game Pekoe, on the other hand, prompted responses from the participants regarding real, day-to-day tasks. They were not enthusiastic about the fantasy world of the game (specifically, serving tea to a talking cat), but the idea of preparing tea was considered closer to tasks they would do in their lives. The survivors were interested specially in doing activities they used to do and cannot do anymore because of the stroke, like swimming and going on walks.

3.3 Conclusions

This chapter presents the studies with survivors of stroke in preparation for the development of a game for physical rehabilitation. First, a Questionnaire was created and sent to the president of Portugal AVC so he could forward it to participants. This study provided an insight on what types of experiences the survivors are more likely to engage with. A Focus Group meeting was done afterwards with a smaller sample with the objective of obtaining understanding on how familiar the participants are with the technology, and how they believe it should be presented to them to improve motivation. It was found that they look for experiences that are closer to reality, with positive reinforcement, and accessibility options. With their concerns in mind, the development of a solution started and is discussed in the next chapter.

4 VR-based Game Development for Physical Rehabilitation

This chapter presents the tools selected to be used in the development of VR-based game prototypes, their design from the beginning and their evolutions based on the user study analysis. It also presents the developed application, its goals, how it functions, documentation, and presentation.

The game developed focuses on some hand movements important for rehabilitation. There is some leniency on performing the movements correctly, mainly on what concerns the full range of movement of the arm, as well as achieving the objective of gameplay.

4.1 Project Settings

The project was developed on top of various technologies. It is an immersive Virtual Reality (VR) game, which means that the user is immersed in a VE with the perception of being physically present there through the aid of image and sound stimuli. To accomplish that, the game was developed for the Oculus Quest 2 HMD, using the Unity game engine[25].

4.1.1 Oculus Quest 2

The Oculus Quest 2 was chosen because it is a standalone HMD, which means that it does not require a PC to function and, for having inside-out markerless tracking, it is untethered and needs little environment setup. The freedom of not having to use cables for the user to interact with the application and the fact that the HMD is standalone (no need for an additional PC as previous models) makes this device ideal and easy to setup for a type of user that might not be familiar with this technology. At the same time, this device is one of the cheapest HMDs available, and supports Hand Tracking without any additional hardware. The main device's characteristics are presented on table 2 and compared to other commercial HMDs, and the device itself can be seen on figure 16.

[25] https://unity.com/. Accessed on: 17/10/2021

The Oculus Quest 2 contains an LCD panel with 1832 x 1920 pixels per eye, which is on par with some high-end commercial HMDs despite the price difference. The refresh rate is also comparable with other devices. Its price, with everything needed to use its software, is dramatically lower than comparable devices, even without considering that it is a standalone device, while competitors need another hardware to execute. One of its main features is the Hand Tracking done with only inside-out tracking, by utilizing deep neural networks to track the hands position and features, like their joints. Figure 17 shows an example of an application with Hand Tracking.

Table 2: Specifications of the Oculus Quest 2 hardware compared to other devices.[26] [27]

	Oculus Quest 2	**Valve Index[28]**	**HTC Vive Pro 2[29]**	**PlayStation VR[30]**
Device Type	Standalone VR	PC-Powered VR	PC-Powered VR	Console-Powered VR
Resolution	1832 x 1920 per eye	1440 x 1600 per eye	2448 x 2448 per eye	960 x 1080 per eye
Maximum Refresh Rate	120 Hz	144 Hz	120 Hz	120 Hz
Tracking	Inside-out Marker-less	Inside-out Marker-based	Inside-out Marker-based	Outside-in
Weight	503 grams	809 grams	850g	600 grams
Starting Price	$299 complete	$499 headset-only $999 complete	$799 headset-only $1399 complete	$299 complete

Figure 16: Oculus Quest 2 with the Oculus Touch controllers.[31]

[26] https://developer.oculus.com/blog/introducing-oculus-quest-2-the-next-generation-of-all-in-one-vr/. Accessed on: 17/10/2021

[27] https://www.oculus.com/blog/introducing-oculus-air-link-a-wireless-way-to-play-pc-vr-games-on-oculus-quest-2-plus-infinite-office-updates-support-for-120-hz-on-quest-2-and-more/. Accessed on: 17/10/2021

[28] https://www.valvesoftware.com/en/index. Accessed on: 27/10/2021.

[29] https://www.vive.com/us/product/vive-pro2/overview/. Accessed on: 27/10/2021.

[30] https://www.playstation.com/pt-pt/ps-vr/. Accessed on: 27/10/2021.

[31] https://www.pcgamer.com/Oculus-is-doubling-the-Quest-2-base-storage-for-free/. Accessed on: 17/10/2021

4.1.2 Unity and Oculus SDK

Unity was selected as the game engine for development as it is considered easy to create prototypes and test ideas, it has a large community of developers around the globe, as well as many resources, assets, and tutorials at disposal. At the same time, it fully supports development for VR and the Oculus SDK, and it is easy to learn. Figure 18 shows the UI of Unity.

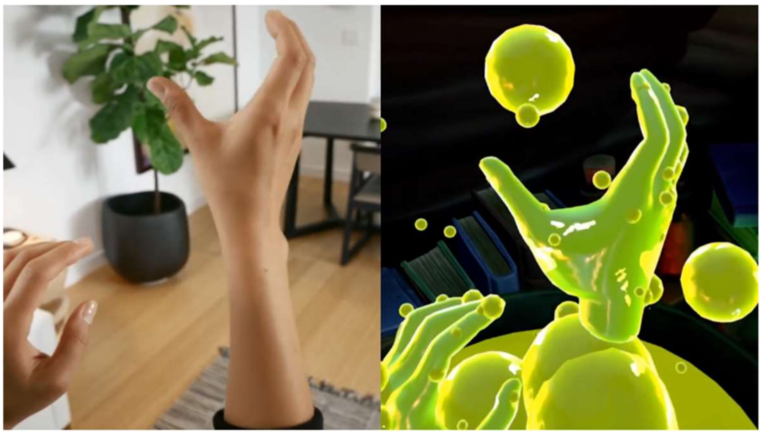

Figure 17: A hand gesture being tracked on the real world, on the left, and the virtual avatar mimicking the movement on the game world, on the right.[32]

Figure 18: Unity's user interface.

Unity can be used to create 2D and 3D environments for a variety of platforms. It is written in C++ and utilizes C# as a primary scripting API. Therefore, all coding of this project was done in C#, and some assets were downloaded from the Unity Asset Store. Assets with low polygon counts were chosen to maintain performance the smoothest possible, and all scenarios were selected with the intention of having a relaxing environment, which is important for rehabilitation.

[32] https://www.youtube.com/watch?v=2VkO-Kc3vks. Accessed on: 17/10/2021

As previously mentioned, Unity has integration with the Oculus SDK. The SDK contains various important assets, like OVRCamera, which is a head-tracked stereoscopic VR camera rig; controllers and hand models (with skeletons and different meshes); sample scenes for discovering its capabilities; and scripts for handling objects and interacting with UIs, as well as other useful features for quick prototyping. Figure 19 shows the structure of the SDK and some examples of prefabs.

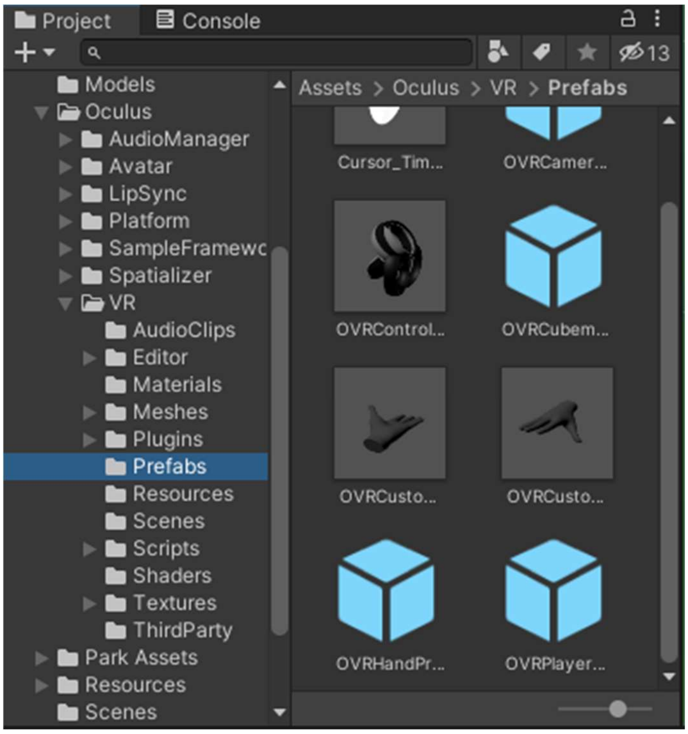

Figure 19: Oculus SDK folder, with controllers and hands prefabs presented on the right side.

4.2 Project Design

A first game was developed to study and understand the Game Engine and learn the development cycle of a game. By following tutorials and Unity's documentation, prototypes of 3D scenes were made to get familiarized with the most important concepts of the Game Engine, as well as applying ideas that were thought of in brainstorming sessions with other students and professors. All assets were obtained from the Unity Asset Store[33], cgtrader[34], Skillshare[35], and (Ortiz et al., 2020).

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[33] https://assetstore.unity.com/packages/3d/environments/low-poly-park-154815. Accessed on: 27/10/2021.

[34] https://www.cgtrader.com/free-3d-models/various/various-models/hammer-88c51d61-c7ed-491e-a4a5-18cf37a3893c. Accessed on: 27/10/2021.

[35] https://www.skillshare.com/classes/Unity-Game-Tutorial-Whack-A-Mole-3D/1969555912. Accessed on: 27/10/2021.

From these came the idea of a game that could be played with Hand Tracking as well as a game controller, to give an option to players who wanted to have contact with a tangible object (an object that could be held in the real world and mapped into the virtual world). Some initial game ideas examples were discussed with the professors and the physician cooperating with the study. Two discarded game ideas are presented as commercial games in figures 20 and 21. The idea of the game in figure 20 was to utilize farming or gardening as a simulation game. For the idea on figure 21, the full range of movements possible in this type of game could have been used for rehabilitation. Both ideas were discarded for the first game because of their restrict appeal. In a brainstorming session, it was decided that a game with broad appeal would be better.

Figure 20: Harvest Simulator VR[36], a game about farming.

Figure 21: Catch & Release[37], a fishing game.

One of the main concerns with the game ideas was to follow the Enjalbert Test (Enjalbert et al., 1988). It evaluates the motor skills of the stroke patient in a scale from 0 to 6, 0 being the absence of movement, and 6 the complete range of movements. The author decided to focus on

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[36] https://connect.unity.com/p/games-harvest-simulator-vr. Accessed on: 16/10/2021

[37] https://vrgamecritic.com/article/best-vr-fishing-games-vive-rift-psvr. Accessed on: 16/10/2021

the levels 1 through 4, as guided by the physician who was consulted for this project, as the scales 5 and 6 are too rare. From 1 through 4, the movements are:

1. Extension of the arm and movement of the hand to the mouth with synkinesis (spasms or involuntary movements).
2. Extension of the arm and movement of the hand to the mouth without synkinesis.
3. Capability of closing hand and fingers.
4. Capability of opening hand and fingers.

The game idea that was selected for development is the popular arcade game Whac-A-Mole, a game where the player uses a hammer to hit the heads of moles coming out of holes in a machine. The main reason was to achieve 1 through 3 of the Enjalbert Test with the affected hand. Another reason was the simplicity for a first game to be developed. At the same time, the movements necessary for this game are akin to games like Wii Sports on the Nintendo Wii console. Tilting the wrist, closing and opening hand, and arm extension and translation are the movements considered in this case.

During the development of the game, the initial idea suffered modifications. After the main gameplay component was developed, it was decided to give players the ability to customize the difficulty of the game by selecting one of three options, and a new mode (Mirror Mode, as seen in Figure 3) was added for a different way to engage with the rehabilitation, allowing personalization of the game.

This new mode was brought up in brainstorming sessions with consultant physician, as well as seen firsthand by the professors when visiting the Rehabilitation Center Rovisco-Pais. The Mirror Mode was introduced as an idea based on the Mirror Therapy, as previously mentioned in Chapter 2. This way, the patients can visualize their affected limb doing the movements, and by consequence they stimulate the corresponding area of the brain that was affected. A storyboard was designed (figure 22) to represent the selection of the mode, playing the game, and hitting a target.

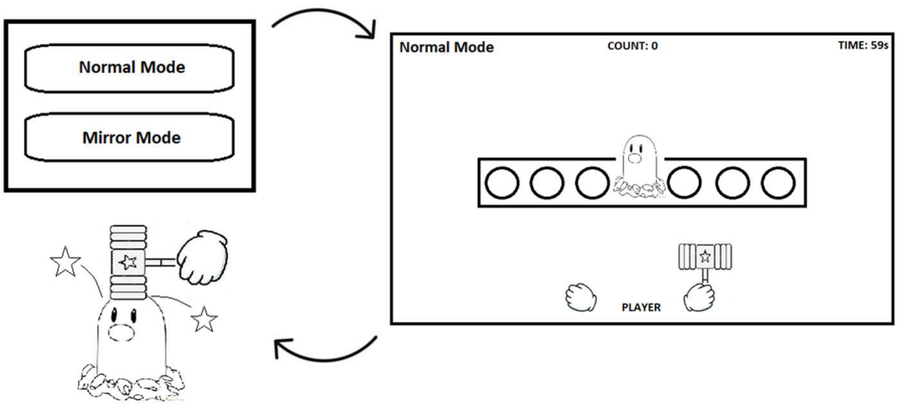

Figure 22: Early storyboard of the Whac-A-Mole game following the order: Mode Selection -> Normal Game View -> Target Hit.

Mirror Mode was implemented in a way that the player can only mirror one of their hands in the real world. The idea is that one hand in the real world is selected to make the movements, while their opposite, in the virtual world, moves the same way, like in a mirror. The example goes as follows:

- The player's right hand is impaired. Because of that, they decide to control their virtual right hand by using their left hand in Mirror Mode.
- In this mode, the Oculus Virtual Reality Camera Rig detects only the left hand. Their left hand then becomes the "Tracked Hand".
- When the player moves their "Tracked Hand", their "Opposite Virtual Hand" moves imitating the "Tracked Hand" movement. In this case, the "Opposite Virtual Hand" is the right hand, holding the hammer.
- The player can choose to show their "Tracked Hand" being moved in the Virtual World or hide it completely. When hidden, the player can only see their "Opposite Virtual Hand".
- The movement of their "Opposite Virtual Hand" can be represented in two ways (videos demonstrating this can be found on the footnote[38]):
    - Symmetrically, as if the person is looking into a real mirror, when their "Tracked Hand" moves to the left, their "Opposite Virtual Hand" (in the mirror) moves to the right. Figure 23 represents the symmetrical movement (with the option of "Hide Tracked Hand" disabled).
    - Non-symmetrically, as if the person is using their "Tracked Hand" to control the cursor of a mouse on a computer. When their "Tracked Hand" moves to the left, their "Opposite Virtual Hand" also moves to the left. Figure 24 represents this type of movement (with the option of "Hide Tracked Hand" enabled).

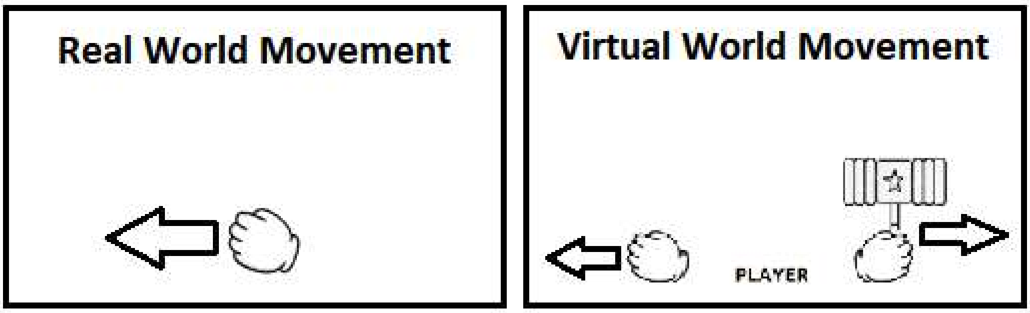

Figure 23: Symmetrical movement of the Mirror Mode, with "Hide Tracked Hand" disabled.

[38] https://uapt33090-my.sharepoint.com/:f:/g/personal/helder_paraense_ua_pt/EII4yPDO5MdJmu3cvEvHn1MByKszyGLNt7ZXUY9NA6ezkg?e=R4Nx5b

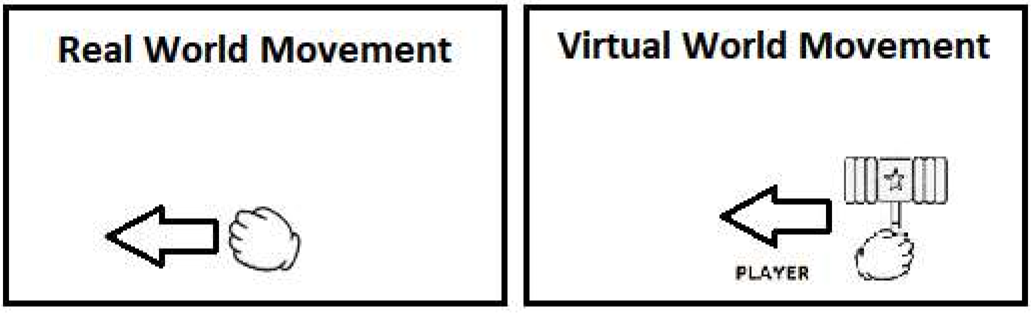

Figure 24: Non-symmetrical movement of the Mirror Mode, with “Hide Tracked Hand” enabled.

4.3 Whac-A-Mole prototype

The “Whac-A-Mole” game developed can be considered as an Action game, as previously defined in the Questionnaire section in Chapter 3 implementing several ideas that raised during the questionnaires and focus group, like difficulty settings and the possibility to perform certain actions with a little leeway (requiring very precise actions can be stressful for the patients). At the same time, there are no real penalties for failing, so *fail states* are not possible, even when the player fails to hit a target in the allocated time: no points are lost, and the player still has opportunities to succeed.

The initial configuration module of the game at first had an UI that used Unity’s Raycast, i.e., the player’s hand cast a ray that traveled to the Settings Menu. Then, the player had to pinch their index finger and thumb to select an option that the ray hit. This proved fallible, as the detection of the pinch combined with the ray could suddenly give mishits or have no effect at all. As an alternative, the UI interaction was redesigned to be closer to how a person can interact with a panel of buttons, by simply pressing them with their hands and fingers. Figure 25 shows the UI of the Settings Menu, where the player can choose the difficulty and what hand to mirror (if at all). Figure 26 shows the Game View, where the player can play the game. Figure 27 shows a user playing a prototype of the game.

When the player presses the “Jogar” button, the scene transitions to the park and the game begins. Moles will rise from a box with the score shown behind them. The moles rise in random speeds within a range, and what moles of the group will rise is also random. Depending on the difficulty, they can stay at the top position waiting to be hit, or they can recede into the box if the player takes too long to hit them (they change color temporarily from black to red to signify the “failure”).

If the player hits the moles, they recede into the box (they change color to green, temporarily, to signify the “success”). The time the moles spend at the top, waiting to be hit, is also a random number within a range. In higher difficulty modes, the number of moles increase, they are faster and more of them can rise at the same time. After 15 points are scored, the player is congratulated, and the game finishes.

Figure 25: Settings Menu. The player can interact by pressing the buttons with their hands.

Figure 26: Game View. The player can hit the moles in the head with the hammer. The environment is a park.

4.4 Apples prototype

Another game was developed after the conclusion of Whac-A-Mole, the Apples game prototype. It presents three apples in a tree, and the main objective of the player is to grab one apple, check if it is a bad one (a bad apple contains a worm), and if it is, throw it out. If it is a good apple, the player needs to bring it close to their mouth to eat it. This game was made following 4 levels of the Enjalbert Scale, instead of 3 like Whac-a-Mole. In this one, as well as closing the hand to grab an apple, the survivor needs to open it to throw away the bad apples.

Figure 27: A user playing a prototype of “Whac-A-Mole”.

It is a simple game of picking apples, based on the game prototypes of (Ortiz et al., 2020; Silva, 2017). The worm was added as a gamification idea, so users need to rotate their arms to check the apples from all sides to see if they have a worm or not. Success is only counted when the user “eats” good apples. No score is counted or decreased if they accidentally eat a bad one. Figure 28 shows the game. Instructions on how to play the game are shown in the game scene.

Figure 28: Apples game prototype.

4.5 Conclusions

This chapter discussed the tools utilized in development of the Whac-A-Mole and Apples games, like the Oculus Quest 2, the Unity Game Engine, and the C# scripting. The design of the games and their main objectives were presented afterwards followed by the definition of the Mirror Mode the application contains. The gameplay was explained in the end after showing the three main scenes present in the application. In the next chapter, tests with users will be presented, with a discussion of the results.

5 Results and Analysis

This chapter discusses, after the development of the application, the tests performed with volunteers. It begins by presenting the preparation for the tests, the script, and what findings were expected. This is a preliminary work to evaluate the usability of the prototypes and learn what needs to be improved before a formal study with stroke survivors is done. The global pandemic, unfortunately, proved to be an obstacle for performing tests with real patients, but testing with students allowed the author to perceive some shortcomings of the prototypes and helped inform further development. This chapter also presents a discussion on these findings and on the students' opinions, ending with a plan for future testing with survivors of Portugal AVC.

5.1 Test Preparation

Tests were done with students to assess the general usability of the prototypes, as well as find any issues with design to fix them before testing with the target audience. The System Usability Scale (SUS) (Brooke, 1996) was selected for this. It is a scale based on ten questions about the system's usability. The questions are all answered in a 5-point Likert scale, from "Strongly Disagree" (1) to "Strongly Agree" (5). The score ranges from 0 to 100, but it is not supposed to be a percentage. At the same time, it is not a definitive answer about the usability of the system, considering all answers are subjective. Alongside SUS, two other questions were made, regarding the participant's preference of the games played and any suggestions or opinions they thought necessary.

The script for the test goes as followed:

1. Present the project's motivation and information about the technology used.
2. Present volunteers the term of consent for them to sign (Appendix C).
3. Instruct them on how to put the hygienic protections on the Oculus Quest 2 and how to adjust the equipment on their faces.
4. Instruct them on what choices to make on the UI game menu.
5. Let them play the "Apples" game.
6. Let them play the "Whac-A-Mole" game on medium difficulty.
7. Let them play the "Whac-A-Mole" game with mirror mode (symmetrical) on hard difficulty.

8. Ask the participant to answer the survey.

The decision of having them play the "Apples" game first was made so the participants could understand the technology with a simpler game, to let them familiarize themselves with the camera movement and the detection of their hands. Secondly, having the "Whac-A-Mole" at medium difficulty was done so they could feel challenged to make the decision to hit the targets and, at the same time, engage them as the easy setting was configured thinking of the limitations of the survivors' movements. To end the experiment, the author decided to have the "Whac-A-Mole" game with mirror mode, with only the "hand in the mirror" present virtually, so they could understand the capabilities of the technology. The hard difficulty mode was chosen because it was expected that the participants already had experience after playing on medium difficulty.

For hygiene purpose, two pieces of equipment were used: a silicone cover[39], and disposable hygiene covers[40] for the Oculus Quest 2. Figure 29 shows both. Alongside these covers for easy cleaning and disposable material, the participants were asked to clean their hands before touching the equipment, and they themselves applied the disposable covers and disposed of them at the end of the experiment.

Figure 29: VRCover Silicone Cover on the left, and Disposable Covers applied on the silicone cover and on Oculus Quest 2 on the right.

5.2 Results

This section presents the results of the survey done after the participants tested the application. Ten students participated on this test, being three women and seven men. From them, ten complete responses were obtained for the "Apples" prototype. For the "Whac-A-Mole" prototype, however, the first two participants were instructed to answer the statements regardless of the mode (Normal or Mirror). The author reconsidered this approach and changed for the next 8

[39] https://eu.vrcover.com/products/silicone-cover-grey-for-oculus%E2%84%A2-quest-2. Accessed on: 26/10/2021.

[40] https://eu.vrcover.com/products/disposable-hygiene-cover-for-oculus-quest-2. Accessed on: 26/10/2021.

participants, who were asked to answer the survey once for the Normal Mode and once for the Mirror Mode.

The results obtained from SUS are presented in Figures 30 (for odd-numbered statements) and 31 (for even-numbered). They are divided because the former are positive statements while the latter are negative. The full results can be seen in Appendix D. The statements are presented below:

- **S1**: I think that I would like to use this system frequently.
- **S2**: I found the system unnecessarily complex.
- **S3**: I thought the system was easy to use.
- **S4**: I think that I would need the support of a technical person to be able to use this system.
- **S5**: I found the various functions in this system were well integrated.
- **S6**: I thought there was too much inconsistency in this system.
- **S7**: I would imagine that most people would learn to use this system very quickly.
- **S8**: I found the system very cumbersome to use.
- **S9**: I felt very confident using the system.
- **S10**: I needed to learn a lot of things before I could get going with this system.

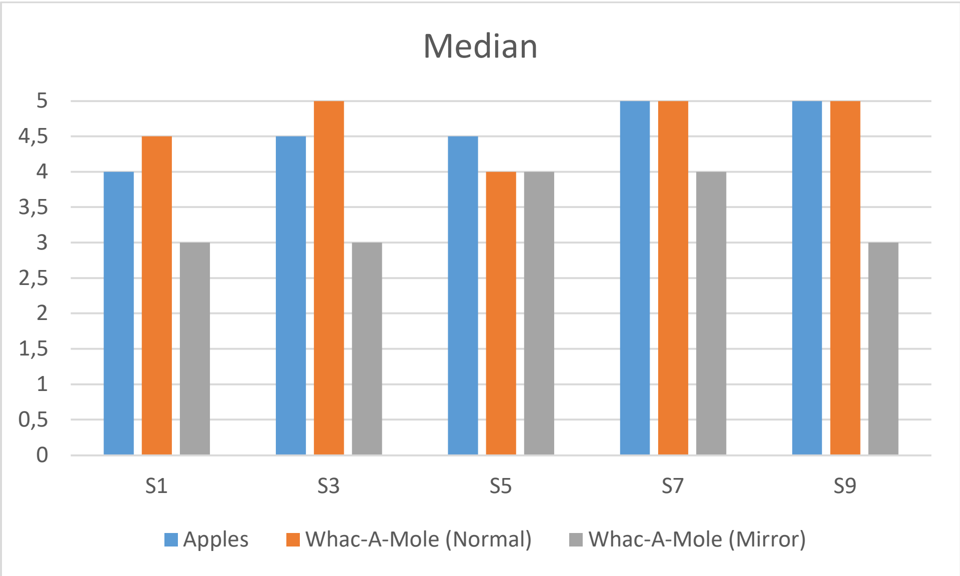

Figure 30: Median for the odd-numbered statements across the three modes tested. Higher is better.

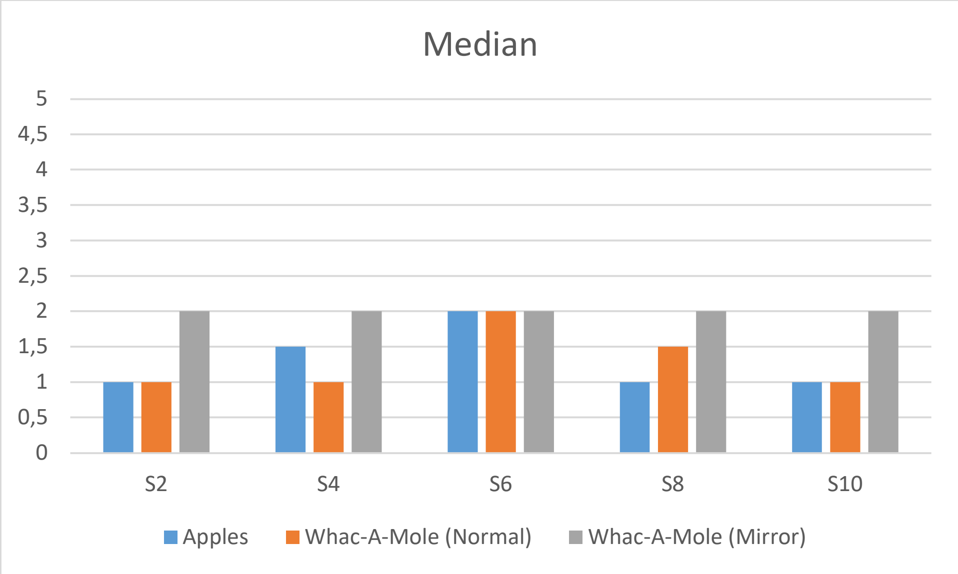

Figure 31: Median for the even-numbered statements across the three modes tested. Lower is better.

5.2.1 Apples Prototype

This was a simpler game prototype with straightforward movements (reach the apple, grab it, turn it to check for worm, then discard it by letting it go or eat it by bringing it closer to the mouth). Because of that, many participants found it easy to use. All but participant number 9 answered that they would imagine most people would quickly learn how to use this prototype, and they felt very confident using it, as seen by their responses to S7 and S9 in Figure 30. The participants also mostly disagreed that the prototype is unnecessarily complex and found it intuitive considering their responses to S8 and S10, as can be seen in Figure 31.

Regarding the participants' opinions on the prototype, one of them considered that the apples and the apple tree were not proportional in size to the other objects in the scenario. They also suggested to increase the game complexity, with options to move around the scenario between apple trees and throwing the bad apples out on a trash can. Another participant contributed with a game design idea, suggesting that apples fall off the trees and the player could catch them. These are good suggestions to improve the prototype for a future test with stroke survivors, as they would make the game more entertaining and engaging.

Two participants and the author detected issues, however, with how the game performed. The participants would bring the apples close enough to the invisible collider representing the mouth, and the game would detect them as "eating" the apples even when they were still checking if the apples were good or bad. This was an issue the author observed as well, as decreasing the size of the collider could bring other issues: for example, when using a small collider, sometimes the hand would be so close to the player's face that the Oculus Quest 2 could not detect the hand, which makes the hand disappear (and, consequently, the apple to be dropped before reaching the mouth collider). Fine tuning the size of the mouth collider is an important next step for this prototype.

5.2.2 Whac-A-Mole Prototype (Normal Mode)

This is a more complex game than the one before when considering the logic necessary for the game to work. However, the interaction with the virtual environment is as simple as the “Apples” prototype because it only asks the player to grab an object (a toy hammer, in this case), and hit the targets. Because of that, many participants found it easy to use as well (S3), as shown in Figure 30. In fact, easier than the “Apples” prototype based on their responses. At the same time, they felt other people would find it easy to use (S7), and they felt confident in engaging with the prototype (S9). The participant number 9, however, had issues with controlling the game, and their assessment was of a lower score for this one compared to “Apples”.

The participants gave their opinions on the game mostly based on how engaging it was. They described the prototype with “fun” and “active”. One of the participants enjoyed that when a mole was hit, they would turn green, easily conveying the information that the player was successful. One of the participants said they imagine this could be an effective game for rehabilitation. One participant gave ideas on how to improve the game: they suggested putting an option to play based on a time-limit. The prototype only had an option to play until 15 targets are successfully hit. The participant suggested putting options of 2, 5 or 10 minutes so players could try to get higher scores, which is a welcome suggestion that was not implemented due to time constraints. They also suggested using more rows of moles, like in the original game this prototype is based on.

Almost all participants experienced an issue in which the software would not correctly detect their grabbing gestures. The author observed this would happen because sometimes they would raise their hands too far high, away from the equipment’s sensors. Sometimes, however, the shape of their closed hands would not be detected because each person closes their hands in a different way. The author, therefore, needs to adjust the parameters of the gesture detection.

5.2.3 Whac-A-Mole Prototype (Mirror Mode)

As expected, this test proved to be more difficult for the participants. Their responses were closer to the middle values in the scale. They still did not find this mode unnecessarily complex (S2) or inconsistent (S6), but their responses were more spread out between the options this time around. Because of that, the median was closer to 3 in Figure 30, and equal to 2 in all the negative statements. It is clear the symmetrical movement that represents the mirror was disorienting, and they were mostly neutral about its usability. The SUS score, presented further on, reflects their difficulty with this type of interaction.

One of the participants suggested that the direction of the movement in the virtual environment could match the direction of their hand in the real world, just like the non-symmetrical option. However, this type of movement was not presented to the participants due to limited time for testing and answering the survey as well as an issue with the movement detection that was present with this type of movement and not fixed by the time of the tests. In further opportunities, the author would like to compare the mirror mode specifically in these two types of movement. One great suggestion from one of the participants was a presentation of an image or short video in-game to explain how the movement is done, to better contextualize the users on how and why they should engage with the Mirror Mode.

The author observed the participants improved after initial disorientation with the symmetrical movement and ponders if survivors already familiar with Mirror Therapy would have a better performance in this mode. Furthermore, a more medicine-oriented study would need to be done to investigate which mode best stimulates the survivors' brains and would be more helpful in rehabilitation.

5.2.4 SUS Scores

To obtain the SUS scores, first the odd-numbered answers (1 to 5) need to be subtracted by 1, and the even-numbered answers (1 to 5) need to be subtracted from 5. This way, all answers range from 0 to 4. After summing all the answers for each user, a score between 0 and 40 is obtained. By multiplying this result by 2.5, there is a score from 0 to 100. It is important to note that these scores cannot be analyzed in isolation (Brooke, 1996). Usability cannot be measure objectively, therefore these are used only to identify ease-of-use based on the group that tested it. This means survivors can have a very different result compared to young students familiar with the technology. Still, this research serves as guidance to improve the software and have better odds of success when testing with the target audience.

Figure 32 compares the SUS scores between the three scenarios tested at this time. The graph shows that "Whac-A-Mole" in Normal Mode slightly edges out the "Apples" prototype, though it is not a reliable difference. Although "Apples" had a lesser maximum score between the users, there is a large advantage on the minimum score between it and "Whac-A-Mole" in Normal Mode. This can be explained because one of the participants had more trouble than the rest when engaging with this game. The author believes it was a combination of problems in gesture detection and the broad movements the participant did that Oculus Quest 2 was incapable of tracking reliably.

"Whac-A-Mole" in Mirror Mode, on the other hand, had considerably lower scores compared to the others. This was explained because of the disorientation the participants felt when engaging with the prototype. Another issue here considered, the author believes that when participants needed to hit targets on a far side, they would instinctively turn their heads in the direction of the target. Due to the symmetry applied, their real hand would need to reach the opposite far side to hit the target, away from the Oculus Quest 2 cameras responsible for tracking, and this led to situations where the hand disappeared, and the toy hammer would reset to its original position.

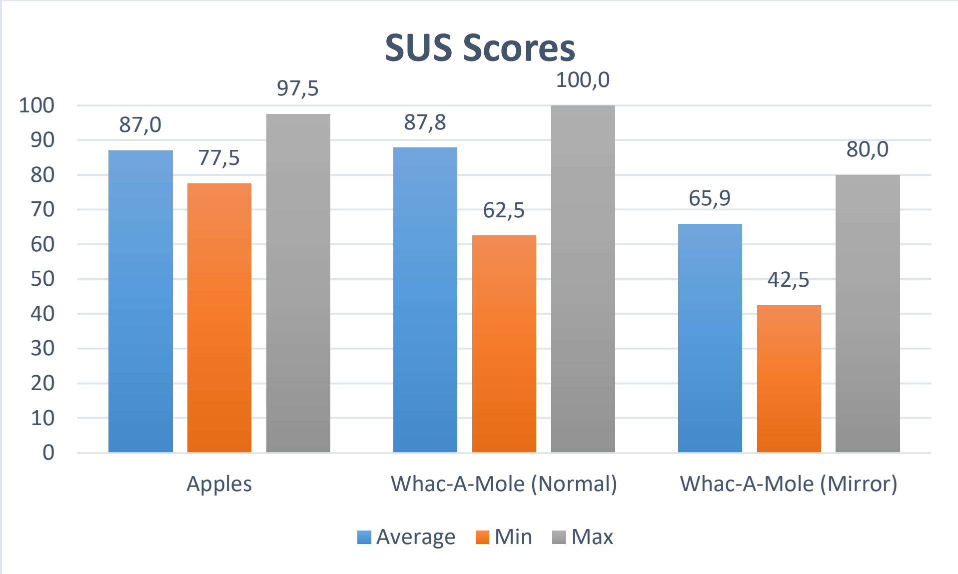

Figure 32: SUS Scores comparison between the three scenarios tested, showing the Average, the Minimum and the Maximum.

5.3 Discussion

There are positives and negatives to take from these tests. Firstly, the prototypes were considered easy to use, and the "Whac-A-Mole" in Normal Mode game was selected by six participants as their preferred experience. One person chose "Apples", and another one chose "Whac-A-Mole" in Mirror Mode. Two people could not decide on what prototype they preferred. As "Whac-A-Mole" is the more gamified experience, this was an expected result. "Apples" was considered by the author as an introduction to the technology, and an improvement of (Silva, 2017) previous work of the "Apple Eater" mini-game. Considering Statements 4 and 10 from SUS, that are more directed to the learnability of the system, it is also expected that most users would not have much difficulty learning how to use the software. It is a good result that users can learn how to perform their tasks in the games without further explanation from technical persons.

There were no complaints about the quality of the assets selected to help immerse the participants on the prototypes. Participants also seemed excited to try the technology, just as the survivors who participated on the Focus Group mentioned in Chapter 3. The author expects that, when all improvements are made, tests can be done with survivors and that they can give their feedback on the potential efficacy of the games being used on their rehabilitation. Some of these improvements are more pertinent than others: improving the gesture detector to be more accepting of different types of grip and finger positions, for instance; fixing the non-symmetrical Mirror Mode; giving more personalization options in both games, like time-limits and high-scores persistence; and gamifying even more the "Apples" game to make it more engaging.

5.4 Conclusions

This chapter discussed the preparation and realization of the tests with ten students to assess the general usability of the application and its two game prototypes: “Apples” and “Whac-A-Mole”. The results seem promising when considering the perceived ease of use and learnability. There are also some issues that need to be resolved, but the results indicate that most of them are not too much of a detriment to the user experience. Further study with survivors was not possible, unfortunately, due to the current global pandemic and survivors being considered a group of risk, and the members of Portugal AVC are still not meeting in person regularly, but the author expects that in the future, these prototypes can be tested with the intended audience.

6 Conclusions and future work

This dissertation proposed a thorough user study of stroke survivors by using quantitative research in the form of a Questionnaire, and qualitative research in the form of a Focus Group, as well as the user-centered development of game prototypes that could help the rehabilitation of said survivors as a Virtual Reality-based approach. These studies provided diverse findings about the types of experiences the target audience are interested in, the challenges that they go through in order to receive proper rehabilitation care, the differences between the needs of patients in the acute, subacute and chronic stages of the stroke, and how to best design games focused on increasing their motivation while meeting their needs.

This research found that *failstates* are not ideal for an audience that might suffer mental disorders caused by the stroke. It also found accessibility goes far beyond their physical limitations, and that in the chronic stage of stroke, survivors are more willing to engage with experiences they can easily relate to real-world activities, like walking, jogging, traveling, or swimming. Some challenges are present in the form of survivors who are not enthusiastic about games, but willing if they know before-hand the benefits a VR-based rehabilitation can provide.

It was learned how difficult game design is, and how the first-person interaction in a 3D environment is complex and not easily translated from the real world to the virtual environment. Even consolidated forms of interaction, like pinching to select an object far away, as is the norm in the Oculus Quest 2 environment, are difficult to learn and yet imprecise, and the UI of the application developed needed to be redesigned to provide a better user experience.

The two VR-based game prototypes developed were tested with students and performed well in terms of ease of use and learnability, at least from the point of view of young adults familiar with the technology, although there are shortcomings yet to be resolved. And while the two game prototypes consider four levels of the Enjalbert Test, no conclusions about their efficacy in rehabilitation can be made at this time, mainly due to the global pandemic that, at the same time as it shows the need of VR technology for rehabilitation at home, it also impedes further testing with people that can be considered at risk.

Subsequently, there are issues that need to be solved before further tests can be done with survivors. First and foremost, the gesture detection needs to be reworked. As of now, the detection of a closed hand is done by comparing the positions of the bones to a closed fist. It needs to be able to detect different positions for detection of a closed hand and be more forgiving with how close the fingers are to the palm of the hand, especially considering the limitations of the survivors.

The “Apples” prototype can be improved, having models with better proportions, and more gamification added, like the ability of traveling around the environment, points for correctly disposing of bad apples in trash cans, and even time-limits. It can also be improved with the addition of better visual feedback when an apple is grabbed. “Whac-A-Mole” needs the possibility of tracking high-scores and have time-limits as well. At the same time, the difficulty options could be more personalized, maybe with more granularity in the choices (like being able to choose the number of moles, set maximum number of points, adding more rows, etc). Both games can also be improved with audio feedback when performing actions, and they need something crucial for rehabilitation: progress tracking, so users can see while they engage with the application how they are performing and if they are getting better scores.

As mentioned before, tests with survivors are paramount for these prototypes to become tools in their rehabilitation. After the COVID-19 pandemic is finished, tests can be arranged with Portugal AVC and studies in game development and medical research can help advance innovation in stroke rehabilitation.

Other opportunities might arise in the future with new VR devices and better Hand Tracking technology. Comparisons can be done with Oculus Quest 2’s new update that duplicates the frequency the Hand Tracking is performed. Devices with better field-of-view can also solve some of the issues with Hand Tracking as well.

And finally, more game ideas can be implemented. Ideas like the farming and fishing games that were discarded before can be revisited, and it can even be possible to simulate navigating through an environment while walking in the same place, by utilizing the full power of the motion detection of the HMDs and their inside-out tracking.

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Appendices

A Questionnaire

Características de sobreviventes do AVC para investigação em Realidade Virtual

Questionário sobre características de público-alvo para desenvolvimento de jogo de Realidade Virtual focado em reabilitação de sobreviventes do Acidente Vascular Cerebral (AVC), no âmbito do Mestrado em Engenharia Informática da Universidade de Aveiro, do aluno Helder Paraense Serra.

Este questionário tem como objetivo obter informações necessárias para o desenvolvimento de uma solução em Realidade Virtual para reabilitação, permitindo que sobreviventes do AVC na fase crónica possam continuar a exercitar os membros superiores afetados, providenciando uma melhor qualidade de vida e permitindo realizar, da melhor maneira possível, suas tarefas diárias. É importante que a aplicação em Realidade Virtual seja uma ferramenta motivadora, e por isto é necessário avaliar se combinar passatempos e desportos favoritos com Realidade Virtual traz benefícios em termos de motivação na reabilitação.

Pretende-se também obter informações demográficas sobre sobreviventes de AVC, buscando conhecer melhor este público em termos de suas capacidades, passatempos e desportos preferidos, familiaridade com jogos, e conhecimento sobre realidade virtual.

Favor contactar o autor, Helder Paraense Serra, no e-mail helder.paraense@ua.pt em caso de dúvidas ou problemas ao responder este inquérito.

Este questionário possui até 25 questões e pode levar, em média, 15 minutos.

Este inquérito é anónimo.

O registo das respostas ao inquérito não contém qualquer informação sobre a sua identidade, excepto se alguma pergunta do inquérito solicitar alguma identificação e a fornecer.

Se usou um código para aceder a este inquérito este código não será guardado junto com as suas respostas. O código é gerido numa base de dados separada e apenas é utilizado pelo programa para registar que concluiu o inquérito. Não há forma de relacionar os códigos dos convidados a participar no inquérito com as respostas dadas.

Seguinte

Participantes

Informações demográficas sobre os participantes.

*Género

Escolher uma das seguintes respostas

- Feminino
- Masculino
- Outro:

*Idade

Escolher uma das seguintes respostas

- Até 34 anos
- Entre 35 e 44 anos
- Entre 45 e 54 anos
- Entre 55 e 64 anos
- Entre 65 e 74 anos
- 75 anos ou mais

*Lado do corpo com menos força (hemiparesia)

Escolher uma das seguintes respostas

- Esquerdo
- Direito

*Profissão antes do AVC

*Profissão atual

Anterior

Seguinte

Passatempos

Informações sobre atividades de lazer e desportos ou exercícios físicos que os sobreviventes possuem interesse.

*Atividades de lazer preferidas

Selecione todas as opções que se apliquem
Por favor, selecionar pelo menos uma resposta

- Ver televisão
- Jogar jogos de mesa / tabuleiro
- Ouvir música
- Ler livros / revistas / jornais
- Pintar
- Crochê / Bordar / Tricot / Costura
- Cozinhar
- Fotografia
- Jardinagem
- Artesanato
- Tocar instrumento musical
- Outro:

*Qual(is) instrumento(s) musical(is)?

*Quanto tempo gasta em média com atividades de lazer?

Escolher uma das seguintes respostas

- Menos de 1 hora por semana
- Entre 1 e 3 horas por semana
- Entre 3 e 6 horas por semana
- Mais de 6 horas por semana

*Que exercícios físicos praticava antes do AVC?

Selecione todas as opções que se apliquem

Por favor, selecionar pelo menos uma resposta

- Jogos com bola em equipa (futebol, andebol...)
- Jogos com bola individuais (ténis, ténis de mesa, golfe...)
- Ciclismo
- Dança
- Caminhada / Corrida
- Pilates / Yoga / Tai chi
- Ginásio
- Natação
- Outro:

***Se não tivesse limitações físicas**, que exercícios físicos gostaria de praticar?

Selecione todas as opções que se apliquem

Por favor, selecionar pelo menos uma resposta

- Jogos com bola em equipa (futebol, andebol...)
- Jogos com bola individuais (ténis, ténis de mesa, golfe...)
- Ciclismo
- Dança
- Caminhada / Corrida
- Pilates / Yoga / Tai chi
- Ginásio
- Natação
- Outro:

*Possui alguma experiência com videojogos?

Sim | Não

*Em que tipo de dispositivo(s) teve experiência com videojogos?

Selecione todas as opções que se apliquem

- [ ] Telemóveis
- [ ] Tablets
- [ ] Consolas (Nintendo, PlayStation, Xbox, Sega, Atari...)
- [ ] Computador

*Joga videojogos atualmente?

Sim | Não

*Quanto tempo gasta em média com videojogos?

Escolher uma das seguintes respostas

- Menos de 1 hora por semana
- Entre 1 e 3 horas por semana
- Entre 3 e 6 horas por semana
- Mais de 6 horas por semana

*Como costuma jogar videojogos?

Selecione todas as opções que se apliquem

- [ ] Sozinho(a)
- [ ] Acompanhado(a)

*Possui experiência com **Realidade Virtual**?

Sim | Não

Realidade Virtual - É um ambiente digital gerado por computador com o qual o utilizador pode interagir e sentir a experiência como se fosse real. Esta interação pode ocorrer em tempo real por diversos meios sensoriais (visão, audição, olfato, tato, e paladar).*

No contexto deste projeto, a interação envolve visão, audição e tato por meio de um dispositivo com ecrãs como exibido na imagem abaixo, capaz de detetar o ambiente em que o utilizador se encontra e também o movimento de suas mãos com o auxílio de câmaras.

*Fontes:

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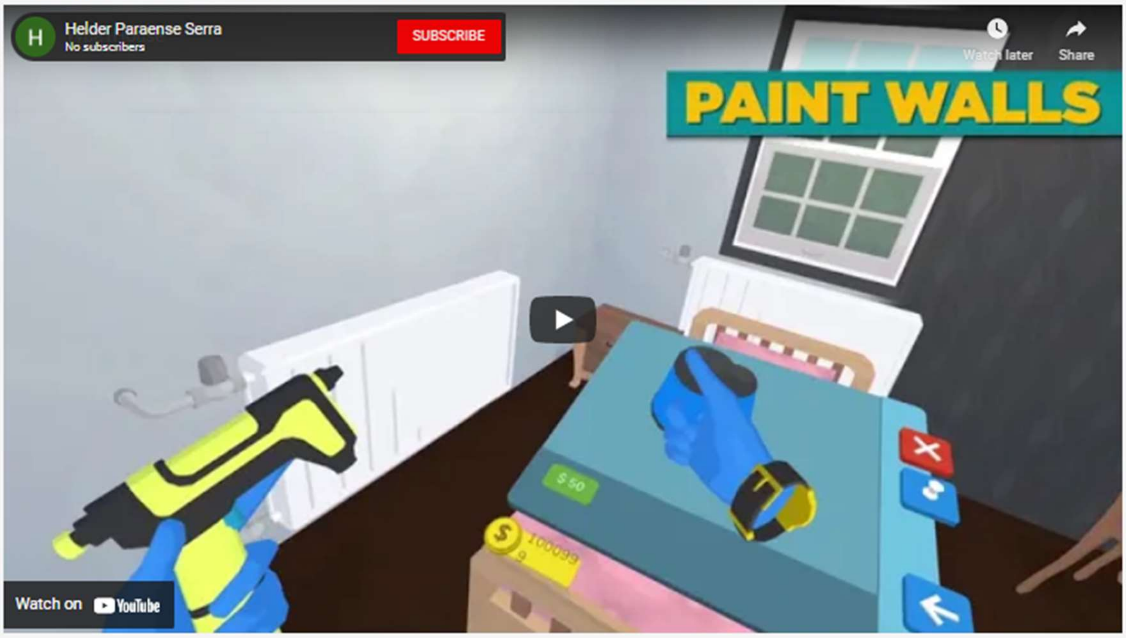
Anterior | Seguinte

The videos can be viewed in the following playlist:
https://youtube.com/playlist?list=PLYskQ5uzpdYckqW6GrYFd1dp4kK32ZyHR

Tipos de Experiência em Videojogos - Simulação

Primeiro tipo de experiência, focado em simular tarefas do quotidiano com liberdade para experimentação e diversão. Neste videojogo, o jogador pode apanhar objetos com suas mãos como faria no mundo real, trabalhando na decoração como quiser.

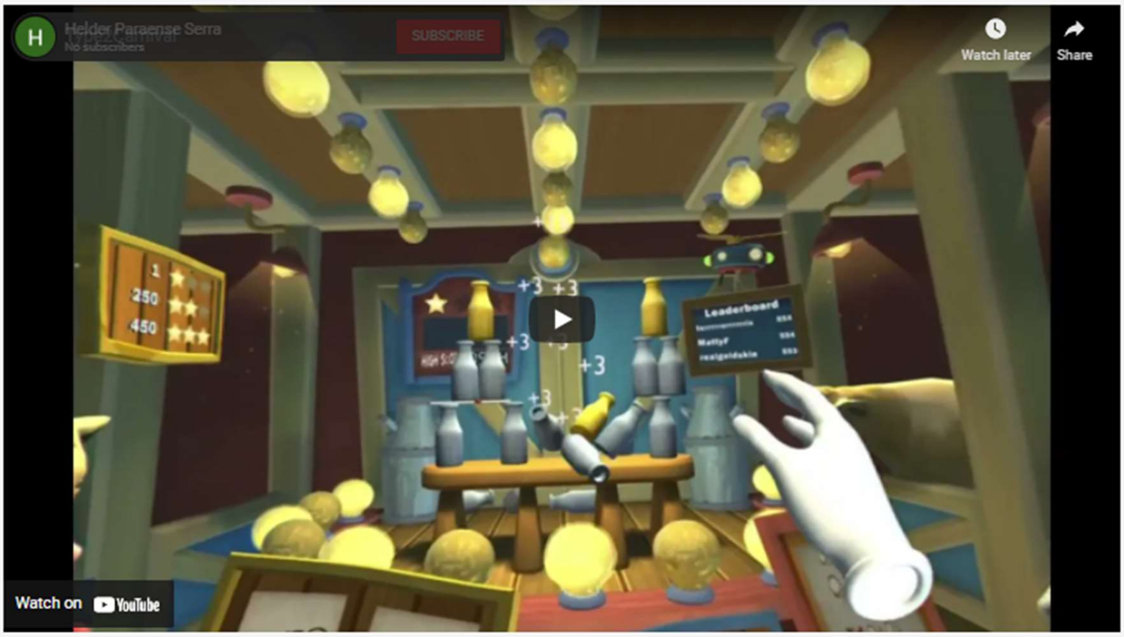


*Com base no vídeo acima, selecione a opção que melhor corresponde sua opinião acerca das seguintes afirmações.

	Discordo totalmente	Discordo parcialmente	Indiferente	Concordo parcialmente	Concorto totalmente
O cenário apresentado parece-me agradável.	○	○	○	○	○
Gostaria de experimentar videojogos como este.	○	○	○	○	○
Consigo perceber facilmente como controlar este videojogo.	○	○	○	○	○
Consigo imaginar-me a gastar muitas horas a jogar este videojogo.	○	○	○	○	○
Os objetivos deste videojogo são claros e fáceis de entender.	○	○	○	○	○

Tipos de Experiência em Videojogos - Ação

Segundo tipo de experiência, focado em simples ações e objetivos claros. Neste videojogo, o jogador interage com jogos de feira e faz movimentos semelhantes aos que faria no mundo real, como atirar bolas ou equilibrar objetos.

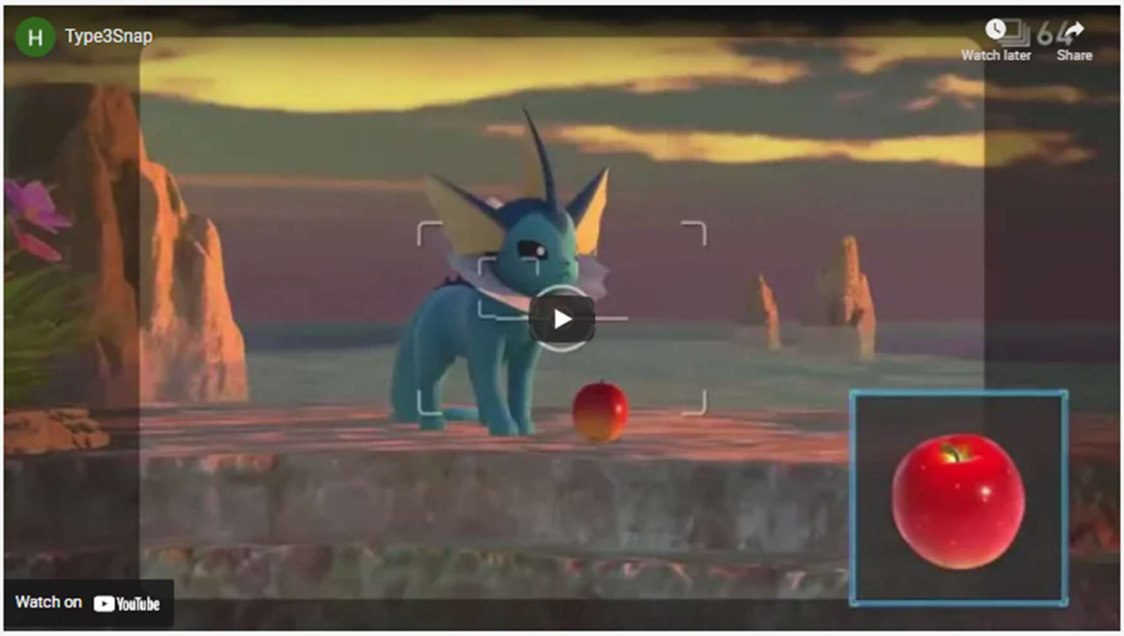


*Com base no vídeo acima, selecione a opção que melhor corresponde sua opinião acerca das seguintes afirmações.

	Discordo totalmente	Discordo parcialmente	Indiferente	Concordo parcialmente	Concorto totalmente
O cenário apresentado parece-me agradável.					
Gostaria de experimentar videojogos como este.					
Consigo perceber facilmente como controlar este videojogo.					
Consigo imaginar-me a gastar muitas horas a jogar este videojogo.					
Os objetivos deste videojogo são claros e fáceis de entender.					

Tipos de Experiência em Videojogos - Aventura

Terceiro tipo de experiência, focado na exploração de cenários e interação com os mesmos. Neste videojogo, o jogador encontra-se no papel de um fotógrafo, e pode utilizar estratégias como atirar frutas para conseguir fotografar cenários diferentes e ter suas fotografias avaliadas ao final.

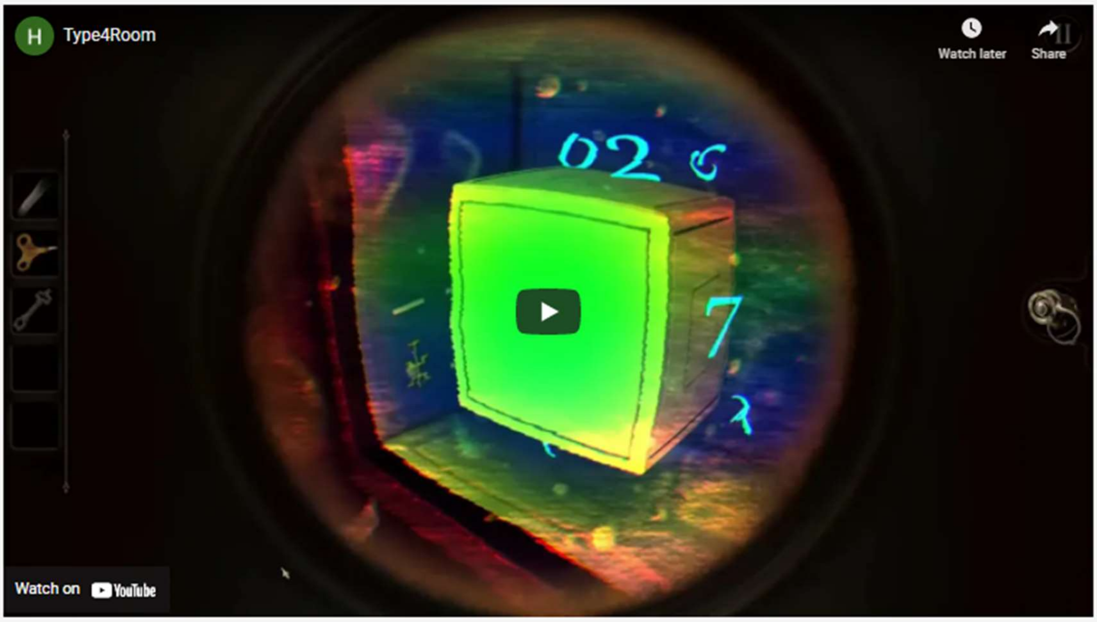


*Com base no vídeo acima, selecione a opção que melhor corresponde sua opinião acerca das seguintes afirmações.

	Discordo totalmente	Discordo parcialmente	Indiferente	Concordo parcialmente	Concorto totalmente
O cenário apresentado parece-me agradável.	○	○	○	○	○
Gostaria de experimentar videojogos como este.	○	○	○	○	○
Consigo perceber facilmente como controlar este videojogo.	○	○	○	○	○
Consigo imaginar-me a gastar muitas horas a jogar este videojogo.	○	○	○	○	○
Os objetivos deste videojogo são claros e fáceis de entender.	○	○	○	○	○

Tipos de Experiência em Videojogos - Quebra-cabeça

Quarto tipo de experiência, focado em raciocínio lógico e solução de problemas por meio de interação com um objeto ou com o mundo virtual. Neste videojogo, o jogador possui uma grande caixa de segredos com diversos desafios de raciocínio lógico para abrir a caixa e descobrir o que há dentro.



*Com base no vídeo acima, selecione a opção que melhor corresponde sua opinião acerca das seguintes afirmações.

	Discordo totalmente	Discordo parcialmente	Indiferente	Concordo parcialmente	Concorto totalmente
O cenário apresentado parece-me agradável.	○	○	○	○	○
Gostaria de experimentar videojogos como este.	○	○	○	○	○
Consigo perceber facilmente como controlar este videojogo.	○	○	○	○	○
Consigo imaginar-me a gastar muitas horas a jogar este videojogo.	○	○	○	○	○
Os objetivos deste videojogo são claros e fáceis de entender.	○	○	○	○	○

Motivação em Videojogos

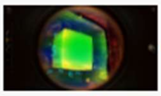
Informações sobre o que pode motivar participantes a jogar.

*Com base nos vídeos apresentados, selecione a opção que melhor corresponde sua opinião acerca das seguintes afirmações.

	Discordo totalmente	Discordo parcialmente	Indiferente	Concordo parcialmente	Concorto totalmente
Desafio e superação são importantes para tornar um videojogo interessante.					
Realizar tarefas dentro de um limite de tempo é necessário para aumentar o desafio.					
Sinto-me mais motivado(a) se sou capaz de visualizar meu progresso ao longo do tempo ao realizar uma tarefa, podendo assim perceber o quanto melhorei.					
Após ver estes diferentes tipos de experiência, sinto-me mais motivado(a) a experimentar videojogos como estes.					
Sinto-me interessado em utilizar videojogos na minha reabilitação se isto ajudar-me a obter melhores resultados.					

*Classifique os jogos por ordem de sua preferência:

Escolha 1 para o videojogo preferido, 2 para o segundo colocado, 3 para o terceiro, e 4 para o videojogo que menos gostou.

	1	2	3	4
 Primeiro jogo - Simulação				
 Segundo jogo - Ação				
 Terceiro jogo - Aventura				
 Quarto jogo - Quebra-Cabeças				

Caixa de Sugestões

Escreva aqui exemplos se possui ideias de cenários ou atividades para videojogos, ou conhece videojogos que considera interessantes.

Se possui dúvidas, sugestões ou opiniões acerca das questões e respostas deste questionário, escreve na caixa de texto abaixo.

Anterior

Submeter

B Focus Group Meeting Script

Reunião com Membros da Portugal AVC

• Iniciar agradecendo a disponibilidade e participação na reunião.

• Apresentar-me: sou Helder Paraense, aluno do Mestrado em Engenharia Informática da Universidade de Aveiro, e o tema da minha dissertação é o uso de Jogos Sérios em Realidade Virtual para a Reabilitação de Membros Superiores de Sobreviventes do AVC.

• Antes de continuar, gostaria de solicitar o vosso consentimento para que o som desta reunião seja gravado para que eu possa utilizar o conteúdo para a minha dissertação. Nenhuma pessoa será identificada e ao fim do projeto a gravação será apagada. A qualquer momento, se não tiverem mais disponibilidade ou não quiserem mais participar, podem sair desta reunião.

• Ao fim, deixar darem sugestões, e se continuarem a querer falar mesmo que a hora esteja a terminar, deixar continuarem. Lembrá-los de responder ao inquérito.

Informações

Aluno: Helder Paraense
E-mail: helder.paraense@ua.pt
Inquérito: https://forms.ua.pt/index.php?r=survey/index&sid=463644&lang=pt

Objetivos

• O objetivo principal desta reunião é obter informações sobre as características do público-alvo para ajudar a guiar o desenvolvimento de uma aplicação de jogos sérios em Realidade Virtual para reabilitação de membros superiores.

• Para tal, deseja-se descobrir quão dispostos estão a experimentar a Realidade Virtual como auxílio para o exercício do membro superior com paralisia.

• É desejável descobrir o que lhes motivariam a experimentar e quais são seus anseios sobre a tecnologia.

Público-alvo

• São sobreviventes do AVC.

• Predominantemente pessoas entre 35 e 65 anos (baseado nos respondentes atuais do inquérito enviado)

• Podem ser de qualquer género.

ROTEIRO

• Primeira Parte (10 min)

o Apresentação do projeto e objetivo da reunião

o Apresentação do Oculus Quest 2 (Reconhecimento das Mãos)

o Discussão

• Segunda parte (40 min)

o Discussão sobre as características dos participantes

o Discussão sobre videojogos

o Perguntas abertas que estimulam respostas elaboradas

o Uma ou duas perguntas baseadas em um vídeo a ser exibido durante a reunião

Parte 1 – Apresentação

1. O que pensam sobre videojogos?

    • Possuem alguma experiência com videojogos? Se sim, quais?

    • O que pensam sobre videojogos para reabilitação (como Nintendo Wii, Microsoft Kinect)?

2. O que pensam sobre a Realidade Virtual?

    • Conheciam antes desta apresentação?

    • Possuem alguma experiência com RV? Como?

Parte 2 – Sobre videojogos

3. Qual seu passatempo favorito?

    • Estariam dispostos a jogar videojogos baseados neste passatempo, se possível?

    • Estariam dispostos a jogar videojogos baseados em passatempos diferentes, se isto ajudar na reabilitação?

4. (Vídeo) O que pensam sobre este vídeo? (talvez incluir na apresentação na primeira parte?)

5. (Vídeo) O que pensam sobre este videojogo?

6. O que gostariam de ver em videojogos?

• Que tipos de experiências, cenários, desafios?

• O que pensam sobre jogos com tarefas comuns e realistas, como cozinhar ou desportos?

• O que pensam sobre jogos com possibilidades fantásticas ou abstratas, como voar ou fazer mágica?

7. O que sugerem que possa ser feito para os motivar mais a utilizar videojogos na sua reabilitação?

8. Há alguma preocupação sobre que movimentos são capazes de fazer com os braços e as mãos?

9. Há alguma sugestão que gostariam de fazer para ou sobre o projeto?

C Consent Form for the Tests

universidade de aveiro | deti departamento de electrónica, telecomunicações e informática | ieeta

Declaração de Consentimento Informado para participação em Investigação

Este estudo de investigação está a ser desenvolvido no âmbito da dissertação do Mestrado em Engenharia Informática no DETI, Universidade de Aveiro e com o apoio do IEETA, do aluno Helder Augusto Paraense de Oliveira Serra.

Objectivo do estudo:

Avaliar a usabilidade de uma aplicação de jogos sérios em Realidade Virtual para reabilitação de sobreviventes de Acidente Vascular Cerebral.

Materiais usados:

Neste estudo um participante usará um dispositivo Head-Mounted Display (HMD) para Realidade Virtual, para visualizar e interagir com um ambiente virtual utilizando suas mãos.

Procedimento:

Este estudo está divido em 4 etapas: 1) Familiarização com o equipamento utilizando um jogo; 2) Interação com um jogo utilizando movimentos das mãos de forma espelhada; 3) Realização de um questionário sobre o que foi experimentado no ambiente virtual; 4) Análise quantitativa e qualitativa dos resultados obtidos.

Os seus dados, incluindo a informação recolhida nos questionários e entrevistas, serão analisados pelos investigadores do IEETA, DETI. Todos os dados recolhidos são confidenciais. Os elementos envolvidos no estudo tomarão as medidas necessárias à salvaguarda e protecção dos dados recolhidos por forma a evitar que venham a ser acedidos por terceiros não autorizados.

Gostaríamos de contar com a sua participação. A participação não envolve qualquer prejuízo ou dano material e não haverá lugar a qualquer pagamento. O material necessário para a realização deste estudo será fornecido pelos investigadores envolvidos. A sua participação é voluntária, podendo em qualquer altura cessá-la sem qualquer tipo de consequência. Também poderá pedir a rectificação ou destruição da informação recolhida a qualquer momento. Agradecemos muito o seu contributo, fundamental para a nossa investigação.

O/A participante:

Declaro ter lido e compreendido este documento, bem como as informações verbais fornecidas e aceito participar nesta investigação. Como participante desta investigação, declaro estar consciente que a minha participação poderá ser filmada e/ou fotografada e/ou gravada. Permito a utilização dos dados que forneço de forma voluntária, confiando que apenas serão utilizados para investigação, com as garantias de confidencialidade e anonimato. Autorizo a comunicação dos dados de forma anónima a outras entidades que estabeleçam parceria de investigação científica.

Nome do participante: ______________________________

Assinatura: ______________________________ Data: ___ / ___ / ___

Helder Paraense Serra (Aluno Mestrado, DETI, Univ. Aveiro)
helder.paraense@ua.pt Assinatura: ______________________________

Paulo Dias (Professor Auxiliar, IEETA, DETI, Univ. Aveiro)
paulo.dias@ua.pt

Beatriz Sousa Santos (Professora Associada com Agregação, IEETA, DETI, Univ. Aveiro)
bss@ua.pt

D Complete Test Results

APPLES

Statements	Answers	Participants (N = 10)
S1: I think that I would like to use this system frequently.	Strongly Disagree	0
	Disagree	0
	Neutral	3
	Agree	4
	Strongly Agree	3
S2: I found the system unnecessarily complex.	Strongly Disagree	7
	Disagree	3
	Neutral	0
	Agree	0
	Strongly Agree	0
S3: I thought the system was easy to use.	Strongly Disagree	0
	Disagree	1
	Neutral	0
	Agree	4
	Strongly Agree	5
S4: I think that I would need the support of a technical person to be able to use this system.	Strongly Disagree	5
	Disagree	3
	Neutral	0
	Agree	2
	Strongly Agree	0
S5: I found the various functions in this system were well integrated.	Strongly Disagree	0
	Disagree	0
	Neutral	0
	Agree	5
	Strongly Agree	5
S6: I thought there was too much inconsistency in this system.	Strongly Disagree	3
	Disagree	7
	Neutral	0
	Agree	0
	Strongly Agree	0
S7: I would imagine that most people would learn to use this system very quickly.	Strongly Disagree	0
	Disagree	0
	Neutral	0
	Agree	1
	Strongly Agree	9
S8: I found the system very cumbersome to use.	Strongly Disagree	6
	Disagree	4
	Neutral	0
	Agree	0
	Strongly Agree	0
S9: I felt very confident using the system.	Strongly Disagree	0
	Disagree	0
	Neutral	0
	Agree	4
	Strongly Agree	6
S10: I needed to learn a lot of things before I could get going with this system.	Strongly Disagree	8
	Disagree	2
	Neutral	0
	Agree	0
	Strongly Agree	0

WHAC-A-MOLE (NORMAL)

Statements	Answers	Participants (N = 8)
S1: I think that I would like to use this system frequently.	Strongly Disagree Disagree Neutral Agree Strongly Agree	0 0 0 4 4
S2: I found the system unnecessarily complex.	Strongly Disagree Disagree Neutral Agree Strongly Agree	5 3 0 0 0
S3: I thought the system was easy to use.	Strongly Disagree Disagree Neutral Agree Strongly Agree	0 0 0 1 7
S4: I think that I would need the support of a technical person to be able to use this system.	Strongly Disagree Disagree Neutral Agree Strongly Agree	6 1 0 1 0
S5: I found the various functions in this system were well integrated.	Strongly Disagree Disagree Neutral Agree Strongly Agree	0 0 0 5 3
S6: I thought there was too much inconsistency in this system.	Strongly Disagree Disagree Neutral Agree Strongly Agree	3 5 0 0 0
S7: I would imagine that most people would learn to use this system very quickly.	Strongly Disagree Disagree Neutral Agree Strongly Agree	0 0 0 3 5
S8: I found the system very cumbersome to use.	Strongly Disagree Disagree Neutral Agree Strongly Agree	4 3 1 0 0
S9: I felt very confident using the system.	Strongly Disagree Disagree Neutral Agree Strongly Agree	0 0 1 1 6
S10: I needed to learn a lot of things before I could get going with this system.	Strongly Disagree Disagree Neutral Agree Strongly Agree	6 0 0 2 0

WHAC-A-MOLE (MIRROR)

Statements	Answers	Participants (N = 8)
S1: I think that I would like to use this system frequently.	Strongly Disagree Disagree Neutral Agree Strongly Agree	0 1 6 1 0
S2: I found the system unnecessarily complex.	Strongly Disagree Disagree Neutral Agree Strongly Agree	0 7 1 0 0
S3: I thought the system was easy to use.	Strongly Disagree Disagree Neutral Agree Strongly Agree	0 2 5 0 1
S4: I think that I would need the support of a technical person to be able to use this system.	Strongly Disagree Disagree Neutral Agree Strongly Agree	3 2 1 2 0
S5: I found the various functions in this system were well integrated.	Strongly Disagree Disagree Neutral Agree Strongly Agree	0 0 2 4 2
S6: I thought there was too much inconsistency in this system.	Strongly Disagree Disagree Neutral Agree Strongly Agree	1 5 1 1 0
S7: I would imagine that most people would learn to use this system very quickly.	Strongly Disagree Disagree Neutral Agree Strongly Agree	0 1 3 2 2
S8: I found the system very cumbersome to use.	Strongly Disagree Disagree Neutral Agree Strongly Agree	1 5 2 0 0
S9: I felt very confident using the system.	Strongly Disagree Disagree Neutral Agree Strongly Agree	0 0 5 1 2
S10: I needed to learn a lot of things before I could get going with this system.	Strongly Disagree Disagree Neutral Agree Strongly Agree	3 2 2 1 0