GUIDO AUGUSTO FARIA PEREIRA

Considerations about the design and evaluation of immersive exergames for virtual rehabilitation of elderly fallers

São Paulo

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Corrected Version

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Dedicated to my beloved parents and family.

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“I have no special talent. I am only passionately curious”

- Albert Einstein

RESUMO

PEREIRA, G.A.F. Considerations about the design and evaluation of immersive exergames for virtual rehabilitation of elderly fallers. 2020. 199 p. Thesis (Mater of Science). Escola Politécnica, Universidade de São Paulo, São Paulo.

O aumento da expectativa de vida tem sido observado em todo o mundo e gerado a inversão das pirâmides populacionais de vários países. O processo de envelhecimento causa alterações fisiológicas que podem ter consequências importantes para a saúde, como as associadas ao controle postural e à manutenção do equilíbrio, além de déficits cognitivos. A fisioterapia convencional tem tratamentos e exercícios destinados a prevenir quedas de idosos, mas ainda enfrenta vários desafios. Estudos recentes indicam que a inclusão, no tratamento fisioterapêutico convencional, do uso de videogames com foco no exercício pode contribuir para a reabilitação do equilíbrio e redução do risco e da incidência de quedas. Esta pesquisa investigou os principais aspectos relacionados ao desenvolvimento e à avaliação, por especialistas da área de fisioterapia, de videogames imersivos para o exercício físico combinado com atividades cognitivo-motoras com foco em idosos caidores. Para isso, além de pesquisar e analisar a literatura da área, foi desenvolvido um videogame chamado BALLOONS, implementado em quatro sistemas imersivos diferentes, três em realidade virtual e um em realidade aumentada. Três implementações foram testadas com onze fisioterapeutas em duas sessões de coleta de dados. Na primeira sessão, os dois sistemas foram testados em realidade virtual por seis participantes. Na segunda sessão, os três sistemas foram testados, dois em realidade virtual e um em realidade aumentada, com oito participantes, três dos participantes da primeira sessão. Posteriormente, uma quarta versão em realidade virtual foi implementada, mas não testada. Os resultados apontam para uma avaliação positiva por especialistas em termos de segurança, tolerabilidade e aceitabilidade, mas também apontam para a necessidade de mais ajustes em relação à intensidade do exercício físico e à complexidade e diversidade das atividades cognitivas.

Palavras-chave: Idoso caidor. Reabilitação virtual. Exergame. Tecnologias imersivas. Tecnologia assistiva.

ABSTRACT

PEREIRA, G.A.F. Considerations about the design and evaluation of immersive exergames for virtual rehabilitation of elderly fallers. 2020. 199 p. Thesis (Mater of Science). Escola Politécnica, Universidade de São Paulo, São Paulo.

The increase in life expectancy has been observed worldwide and led to the inversion of the population pyramids of various countries. The aging process causes physiological changes that can have important health consequences, such as those associated with postural control and balance maintenance, as well as cognitive deficits. Conventional physical therapy has treatments and exercises designed to prevent falls from the elderly, but still faces several challenges. Recent studies indicate that the inclusion, in conventional physical therapy treatment, of exercise-focused video games may contribute to balance rehabilitation and reduction of risk and incidence of falls. This research investigated the main aspects related to the development and evaluation, by physiotherapy specialists, of immersive videogames for physical exercise combined with cognitive-motor activities focused on elderly fallers. For this, besides surveying and analyzing the literature of the area, a video game called BALLOONS was developed, which was implemented in four different immersive systems, three of them in virtual reality and one in augmented reality. Three implementations were tested with eleven physiotherapists in two data collection sessions. In the first session the two systems were tested in virtual reality by six participants. In the second session, the three systems were tested, two in virtual reality and one in augmented reality, with eight participants, three of the participants from the first session. Later a fourth version in virtual reality was implemented but not tested. The results point to positive assessment by experts in terms of safety, tolerability and acceptability, but also point to the need for further adjustments regarding the intensity of physical exercise and the complexity and diversity of cognitive activities.

Keywords: Elderly faller. Virtual rehabilitation. Exergame. Immersive technologies. Assistive technology.

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LIST OF ABBREVIATIONS AND ACRONYMS

6DOF Six degrees of freedom

AR Augmented reality

ARH Augmented reality headset

DDR3 Double Data Rate 3

DDR4 Double Data Rate 4

GB Gigabyte

GHZ Gigahertz

GPU Graphics processing unit

FOV Field of view

HDMI High-Definition Multimedia Interface

HMD Head-mounted display

HUD Heads-up display

IDE Integrated development environment

MR Mixed reality

ODT Omnidirectional treadmill

PTSD Post-traumatic stress syndrome

SDK Software development kit

SFPC Framework for Postural Control

SUS System Usability Scale

USB Universal Serial Bus

UWP Universal Windows Platform

VGA Video Graphics Array

VR Virtual reality

VRT Virtual reality training

WHO World Health Organization

WDDM Windows Display Driver Model

SUMMARY

1 INTRODUCTION

The increase in life expectancy is a phenomenon that has been observed and has generated the inversion of the population pyramids of several countries around the world, that is, each year the number of elderly people on the planet increases considerably. This changing profile of the population raises new needs and priorities that consequently require changes in the planning and practice of public policies in several sectors, especially regarding the provision of quality health services (WHO, 2011).

Older people tend to be less cognitively and/or physically active, which makes them prone to a gradual deterioration of their cognitive abilities and balance, which in turn increases the chances of falls in the day to day (UZOR, 2013) (GSCHWIND, 2014). Such falls may result in serious accidents, which may irreversibly undermine the elderly's ability to walk and move around without assistance (DUQUE, 2013) (NAWAZ, 2016).

Masud & Morris (2001) present an epidemiological review of falls. They state that falls in older people are a major public health concern in terms of morbidity, mortality and cost to health and social services. In their study they present different ways of defining and classifying falls and fallers. They examine and discuss the causes (risk factors) for falling, and the consequences of falls in older population. They claim that falls risk factors can be classified in several ways, one of them is classifying as intrinsic or extrinsic. The intrinsic are those where some event or condition affects postural control, and extrinsic, where an environmental factor is the main contributing reason for the fall.

Oakley et al. (1996) discusses the causes, or risk factors, for falls in older people and state that they are often multifactorial, involving causes in five main categories: (1) environmental (e.g. loose carpets, poor lighting, unsafe stairs, ill-fitting shoes), (2) medication (e.g. antidepressants, sedatives and hypnotics), (3) medical conditions and changes associated with ageing (e.g. poor vision, cognitive impairment), (4) nutritional (e.g. calcium and vitamin D deficiency) and (5) lack of exercise.

This change in the pattern of health problems requires new approaches and therapies so that these people can maintain a good quality of life.

Hamm et al. (2016) wrote a review about challenges and recommendations for different categories of preventions for elders in different stages of falls. The authors state that a few challenges must be addressed by the fall's prevention technology research area, namely: (1) "lack of research effort focused on reducing extrinsic risk factors, which are of equally major concern for patients who exhibit intrinsic risks and live independently"; (2) "lack of fall education interventions used in pre-falls prevention intervention systems to reduce fall risks"; (3) "current systems do not consider or support the delivery of environmental assessment interventions to reduce fall risks". The authors also state two recommendations: (1) "Identify new opportunities and develop new technology-based applications to support patients and practitioners in their efforts to overcome extrinsic risk factors"; (2) "develop technology-based applications which enable and support fall prevention intervention education and promotion of activity".

Assistive Technology plays an essential role in our society, contributing to individuals with physical and/or cognitive limitations regain their independence, social inclusion and, consequently, increasing their quality of life (LINDSTRÖM, 2018). Creating technologies that contribute to offer more independence and security to individuals with physical and/or cognitive limitations is a challenge. One important aspect is the need for personalization, given the specificity of each case, diagnosis, and patient's needs. In this case of loss of independence, the elderly can use Assistive Technology such as wheelchairs, scooters, walkers, walking sticks, crutches, prostheses and orthopedic devices to improve their mobility and motor activity. The individual will also need health professionals, caregivers and technologies to assist in his treatments. That is, even in rehabilitation, this elderly person will have difficulties performing his daily life and would benefit using Assistive Technology.

Recent studies indicate that the physical and cognitive capacities of the human being are interdependent since the most distant periods of man's existence, in which activities such as hunting involved both the motor capacity (walking, running) and the cognitive capacity (paying attention to the environment in order to identify the prey) (RAICHLEN, 2017). This motor cognitive interdependence in physical exercise, mainly aerobic exercises (such as walking), stimulates the release of neurogenesis-related factors and consequently stimulates neuroplasticity and stabilizes existing nervous structures, providing better brain functionality (LIN, 2018).

Physical therapy for older people has treatments and exercises aimed at preventing falls. However, exercise intervention programs that tackle the issue to prevent falls in older adults still have some challenges such as “poor program adherence” and “insufficient exercise intensity” that can compromise the intervention (SOHNG, 2003), (TIEDEMANN, 2014).

Choi et al. (2017) state that it is important that the program of fall prevention exercises should not only be safe and effective, but also enjoyable and easy to perform, indicating the need for innovation in fall prevention. The authors also identify five challenges conventional therapy faces: (1) exercise intensity; (2) attendance; (3) safety ;(4) engagement; (5) easy to do.

Other authors such as Proffitt et al. (2015), Tiedemann et al. (2014), van Diest et al. (2013) and Yardley et al. (2006) also discuss the need for innovation in fall prevention.

The term exergame, or "exercise-gaming" was created in 2006 by the English journalist Iain Mackenzie and describes the union of physical exercise and play (MACKENZIE, 2006). The use of exergames as physiotherapeutic tools for balance rehabilitation has become increasingly common (DAREKAR, 2015).

Fu et al. (2015) state that the use of this type of technology may be effective in reducing the risk and incidence of falls in conventional physiotherapeutic treatment. The authors point out that an advantage is that it offers a controlled environment in which it is possible to manipulate the stimuli and the progression of the difficulty of the proposed exercise to the patient. Thus, they state that the user's progress assessment becomes much clearer, in a way that helps the therapist to better plan his/her intervention.

Choi et al. (2017), in their systematic review, present exergames as an innovation for fall prevention, and discuss advantages exergames have over conventional exercise, such as: “Exergames can motivate people to practice through an attractive and interactive way and train both motor and cognitive skills when users perform dual tasks” (SKJÆRET, 2016), (VAN DIEST, 2013); “The players can focus their attention on the outcome of the movements in the game, not on the movements itself” (PROFFITT, 2015); “The exergame can be undertaken at home, either alone or within a small group, which may make the activity more accessible to many older adults” (YARDLEY, 2006). The authors, based on Hall et al. (2016) and Tiedemann et al. (2014), also state that “exergames are more enjoyable and engaging”, consequently

adding long-term adherence to exercise programs. In general, Choi et al. (2017) state that exergames advantages over conventional exercise are: (1) motivation; (2) engagement; (3) interaction; (4) motor-cognitive activities; (5) focus; (6) can be used at home; (7) long term practice.

1.1 Delimitation of the problem

One of the limitations of the exergames commonly used is that the equipment, and usually also the game (software implementation of the game), used to implement them are from the entertainment industry and were not designed for clinical rehabilitation. Therefore, they do not contain the degree of specificity necessary to perform the function of rehabilitating patients with cognitive-motor deficits (SKJÆRET, 2016) and frequently become unavailable on a short period of time because the entertainment industry moves fast to sell new products.

Authors discuss that older adults are not used to computers and to this type of technology, having a harder time to learn how to use new technology. So, they recommended that these types of games should be simple and accessible, and they concluded that involving seniors in the requirements and design process, on a participatory design approach, resulted on a solution easy to be used by them (Uzor, 2013).

Vries (2018) suggest that playing video games can keep motivation in intrinsic ways. The authors concluded that older adults could learn to use technology in the same ways as young, but the emphasis should be on time to familiarize and on positive feedback to avoid the fear of technology. Furthermore, they comment that an increase in enjoyment, effort, and tension was observed as age increased, whereas competence declined. Their data show that virtual reality (VR) training can lead to strong intrinsic motivation; overall, older adults showed high enjoyment. Games that provided ‘‘positive feedback’’ resulted in higher scores. The authors conclude that favorable attributes such as ‘‘speed’’ on one hand and ‘‘slow movements’’ on the other hand emphasize the importance of designing VR training that is adaptable to the skill level of the player, suggesting that when designing or selecting VR balance training games for older adults, these attributes should be considered to optimize user experience and increase intrinsic motivation.

Based on the author that were early cited, because technology is harder to use in older adults, immersive technologies can focus the older adult to engage. In addition, the interaction must be simpler to learn how to Interact with the virtual environment. Meaning that with the immersion technology and simpler interaction, can help this user specifically to focus and engage on the activities. Considering that to implement motor-cognitive actives is easier and more optimize in virtual environments. Furthermore, developing an exergame specifically for this type of rehabilitation, can increase chances of successfully building an exergame, that can be part of someone's treatment. Although that some VR HMD and other immersive technologies are consider high cost for the public. The tendency is that when presented to market the cost decreases and improve technically with new versions of theses equipment's (MUIKKU, 2017). Increasing the probability of people adopting VR or AR devices.

1.2 Research guiding question

Choi et al. (2017) discuss several aspects of exergames. They comment the disadvantages of using interactive technologies for fall prevention intervention in elderly fallers. Exergames have several limitations as a physical exercise alternative. One problem is the limited time spent being moderately active. Also, the current benefits of exergaming have only been studied with mainly short term and small sample sized studies. Most existing exergames were not designed for older people, who might not be able to use them correctly. They were mainly designed for entertainment of young people and not for balance rehabilitation purposes for the elderly, so they have few functions for balance training, which limit their clinical applicability. The authors give two examples: Wii Sports, that is unsuited to exercise the muscles of lower limbs, and *Dance Dance Revolution*, that is inappropriate for upper limb muscles exercising. The authors also list several advantages of exergames compared to conventional exercises, the main two being: exergames can motivate people to practice through an attractive and interactive way and train both motor and cognitive skills when users perform dual tasks; and players can focus their attention on the outcome of the movements in the game, not on the movements itself. The authors also point out that there is a lack of in-depth researches and discussions on the current state-of-the-art of exergame technologies, such as how to design

exergame-based intervention, how to evaluate its effectiveness and problems associated with current proposed solutions.

The main question of this study is if it is possible to use immersive technologies for the purpose of virtual rehabilitation for elderly fallers. In order to better understand the problem, three other questions arise: "What are the limitations of the elderly fallers?", "What is done to solve their limitations?" and "What immersive technology can we offer to solve the problem?“ These questions are important to direct major issues and pinpoint obstacles of the problem.

1.3 Objective

The objective of this study is to identify the main aspects related to the design and evaluation of immersive exergames as virtual rehabilitation for elderly fallers in terms of safety assessment, tolerability, acceptability and applicability potential.

1.4 Materials and methods

To reach the objective of this study, the following steps were done:

- literature review,
- design of an immersive exergame,
- implementation of four immersive exergames systems for rehabilitation of elderly fallers,
- submission and approval of research script by the research ethics committee,
- tests of the three immersive systems with specialists,
- analysis and discussion of the results.

This research was conducted as a mixed methods research, which involves both quantitative and qualitative methods (LOPES, 2016). An immersive exergame was designed, implemented and evaluated to gather, besides theoretical knowledge through literature review, practical knowledge about the development and evaluation of immersive exergames as virtual rehabilitation for elderly fallers. This research seeks to investigate the main aspects related to the design and evaluation of immersive exergames as virtual rehabilitation for elderly fallers in terms of safety assessment, tolerability, acceptability and applicability potential. The specific methods and

strategies for development are described at chapter four and specific methods and instruments used in the evaluation are described at chapter five

In the beginning of this research, the author and his advisor interacted with physical therapists at Medical School at Universidade de São Paulo (USP), for better understanding of the problem and to exchange ideas. A literature review was conducted in health sciences and rehabilitation technology for broader comprehension of concepts related to fall prevention of older adults. A deeper literature review about immersive technologies to promote virtual rehabilitation technologies was also done and this subject was selected as the main focus of this investigation.

As there is no commercial solution of this type available, in order to investigate its potentials and limitations, we decided to design, develop, implement and test an immersive exergame with the purpose of a virtual rehabilitation system to fall prevention of older adults.

Four prototypes were developed, first was develop two virtual reality prototypes and later added one augmented reality prototype all three prototypes were tested. Then a fourth prototype was added, however is still being tested. The method used is a mixed methods research that involves the use of both quantitative and qualitative methods. Through questionnaires with quantitative and qualitative data and interviews for a deeper insight. Due to the multidisciplinary nature of this study, and involvement with human beings. Besides, the elaboration of the documents for the research ethics committee, for authorization to experiment with participants ethically. The documentation is available at Attachment B and C.

Because of the use of virtual reality, security measurements needed implementation. This took us to consider other outputs of technologies related to virtual reality, such as augmented reality or safety measures (physical equipment that can hold the person in case of an accident). Considering the limit of physical space, participants would be immersive in a virtual environment, and not be able to see the physical world. Safety measurements had to be taken. Later, the first session of testing and data collection with a group of 6 physical therapists and tested with two different systems. The collected data analyzed and based on that data; we changed the game for improvements, for the second session of testing and data collecting. Then the game had changed to improve for users and added a third system. I did the testing in a group of 8 health professionals, witch 3 of than previously tested the first version of the game in the two first systems. After completion of two sessions of data collection. We’re able

to compare and analyze. Concluding the preliminary cycle of this study. The next steps are, use the analyses of the second session of data and change the game, based on the results. Then test with other groups such as healthy adults and older adults.

1.5 Dissertation organization

The text of this dissertation is organized in six chapters. The first chapter introduces the context and problem addressed in this research, states the main research question and objective, and presents an overview of the materials and methods used. Chapter two presents the literature review and main concepts about rehabilitation of elderly fallers and presents the main concepts and the state-of-the-art in the area of virtual rehabilitation through video games. As well the main concepts and state-of-the-art about immersive technologies and virtual rehabilitation through immersive technologies. Chapter three describes the materials and methods, the implementation details of the game and its requirements, design and development. This chapter also describes the three different systems that were implemented and tested with the developed exergame. Chapter four gives details about testing and evaluation of the different systems by physical therapists. Chapter five presents the results of the tests and evaluations of the exergames developed using the three different systems. Finally, chapter six presents the conclusions of the work, as well as contributions and future work.

This dissertation also includes two appendixes, mainly with questionaries' and systems detailed descriptions, and five attachments with forms and documents related to ethical appreciation and questionnaires.

2 LITERATURE REVIEW AND BASIC CONCEPTS

This chapter presents basic concepts and literature review, important for understanding the problem being addressed.

2.1 Elderly fallers

This section presents concepts related to the rehabilitation of elderly fallers, important for understanding the problem being addressed.

Older adult falls are a significant cause of mortality and can be classified as preventable lesions.

The severity of the injury is usually related to the height of the fall. The state of the ground surface on which the victim falls is also important, considering that harder surfaces cause more serious injuries.

Falls are usually caused by several factors. The elderly faller can live with a variety of fall risk factors, developing problems only when another factor comes into play. That way, it is often the factor that caused the fall, rather than all the risk factors that a patient has that lead to the fall.

Risk factors can be grouped into intrinsic factors or extrinsic factors. Intrinsic factors are body related factors, such as existence of a specific disease, diet, age, ability level, sleep, fear, poor vision, and muscle weakness; and extrinsic factors are external, are outside the body, such as incorrect equipment, obstacles, clothing, and footwear, slippery or uneven surfaces (SANDER,2016). Falls can be avoided by ensuring that carpets are nailed, objects such as power cords are not in the way, that hearing and vision are optimized, that dizziness is minimized, that alcohol intake is moderate and that shoes are jumped low or rubber soles (CHANG, 2010). Factors such as lighting, personal assistance equipment, and soil traction are also important in the prevention of falls (SHAW, 2003).

In summary, the cause of older adult falls is often multifactorial and may require a multidisciplinary approach to treat injuries and prevent future falls (SAROFIM, 2012).

2.1.1 Conventional rehabilitation

Conventional physiotherapeutic rehabilitation of elderly fallers focuses on the improvement of balance, gait and strength through exercise (depending on the patient's evaluation) for a gain of strength, endurance and body mechanics, combining with environmental assessment and modification such as lighting, bathroom grab rails, secure stairway, etc. (RUBENSTEIN, 2006).

The impact of conventional rehabilitation for fall risk prevention that reduces the risk of falls (MACRAE, 1994; GROSSMAN, 2018).

Possible interventions to prevent falls include:

- Regular exercise - lower limb strengthening exercise to increase muscle strength (ISHIGAKI, 2014).
- Other forms of exercise, such as gait, balance, coordination, and functional tasks, may also help to improve balance in older adults (HOWE, 2011).
- Review of evidence from clinical trials conducted by the European Food Safety Authority has led to the recommendation that people over 60 years old supplement the vitamin D diet to reduce the risk of falls and bone fractures (EFSA, 2011).
- Hip protectors - may decrease the chance of hip fracture, although they may increase the small chance of pelvic fracture in the elderly living in nursing care units. Little or no effect reported on other fractures or falls (SANTESSO, 2014)
- Treatment for osteoporosis (MACRAE, 1994).

Kendrick et al. (2014) concluded that exercise interventions may reduce the fear of falling in community-dwelling older adults immediately after the intervention, with no evidence of long-term effects.

Although the balance rehabilitation protocols are proven effective, they have limitations, since the major focus is motor rehabilitation. Montero-Odasso et al. (2012) states that the cognitive deficit is also related to the increased risk of falls. They mention that a practical example is that a simple walk requires not only purely motor skills, but also involves the attention that the individual must spend in the environment to avoid obstacles or even to recover from postural disturbances. The authors say that older people have greater difficulty in dividing and keeping divided attention in situations of double task, which make up the most common situations in everyday life

(e.g. walking and talking), mainly because the dual-task involves the sum of one motor activity (maintenance of balance) and another cognitive. They say that dual task, therefore, is quite challenging because it induces the individual to prioritize the postural demand to avoid a fall. The authors conclude that there is evidence that physiotherapeutic interventions that approximate the maximum of real equilibrium demand situations may promote improvement in motor and cognitive aspects related to postural control. For this, they say that it is interesting to use the dual task as a means of sharing attention resources to favor the automation of postural control and, consequently, to reduce the risk of falls.

Herold et al. (2018) categorize the cognitive-motor training in sequential training and simultaneous training. In sequential training, cognitive and motor tasks are applied at different times (on the same day or every other day). One advantage of sequential training is the fact that one of the tasks can be prioritized (cognitive or motor) depending on the deficit presented by the patient, but an important disadvantage is the fact that it is still unclear how much time interval and which order between the training of the two capacities is the most indicated. In simultaneous training, cognitive and motor tasks are performed at the same time. The cognitive task can be applied as a non-decisive factor for the execution of the motor task or as an essential factor for the fulfillment of the motor task. One of its advantages is that it optimizes therapy time by acting on the two abilities in question at once.

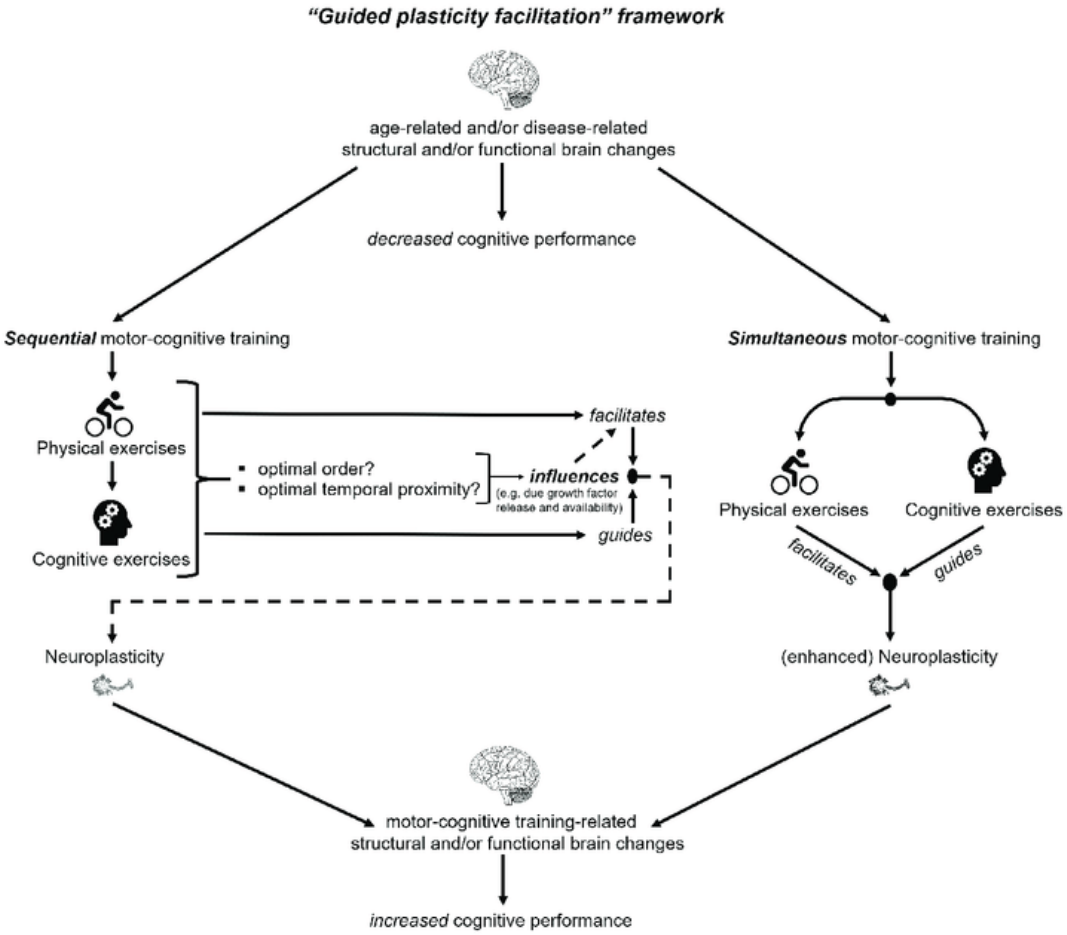


Figure 1: "Guided plasticity facilitation" Framework (HEROLD. F, 2018).

Source: HEROLD. F, 2018

Figure 1 shows the guided plasticity facilitation framework, where it displays the difference between sequential motor-cognitive training and simultaneous motor-cognitive training, and when and how the motor-cognitive activity is considered.

2.2 Virtual reality and the reality–virtuality continuum

Virtual reality (VR), is referred to as an interactive virtual setting that simulates a real-life experience (SUH, 2018). VR applications may include entertainment such as gaming and instructional purposes such as medical training or military training (BROOKS, 1999).

Presently standard VR systems are used to create graphics, images, sounds and other sensations that mimic a user's physical existence in a virtual setting through

virtual reality headset or multi-projected environment. An individual who uses virtual reality devices can look around, move in and communicate with the virtual environment (TORI; KIERNER, 2006).

The effect is commonly created by VR headsets consisting of a head-mounted display (HMD) with a considerably small screen in front of the eyes with lenses. The HMD tries to mimic binocular overlapping images to create the illusion of a three-dimensional physical world by fusing different images. To access the virtual environment, a 6-degree freedom tracking device is usually mounted on the HMD (MON-WILLIAMS, 1993).

Presence is the user's subjective experience and depends on the virtual reality system's features, virtual tasks, and user's features. People are seen when they report the sensation that they are in the virtual world (SCHUEMIE, 2001). Presence is seen as essential in order to have respondents react in VR in the same manner that they do in fact (WILSON, 2015). The level of immersion, which the sensory fidelity provided by the VR system is one of the determinants of existence. It has many parts such as views, fields of perspective and screen size and although many of them interchangeably use the presence and immersion of the term (WILSON, 2015). Presence and user experience are linked to perception, cognition, and emotion (LORENZ, 2018). Since to VR achieve this the users need to view the virtual world created by the computer through their perception. This artificial sensory input must be processed by the brain cognitively. The user will achieve a weaker or stronger sense of “being there” in the VR depending on the quality of the sensory input and its behavioral processing. This leads to a degree of perceived presence. Involvement of the user in VR can cause any emotion, such as fear, as in applications for the treatment of phobias (LORENZ, 2018).

Milgram & Kishino (1994) proposed a taxonomy for what they named mixed reality (MR), that are a subset or virtual reality (VR) technologies that involve the merging of real and virtual worlds. They proposed the concept of virtuality continuum to understand the influence of information on the physical world and the digital information. In this approach, there are different levels from virtual reality to the physical world in a continuum line.

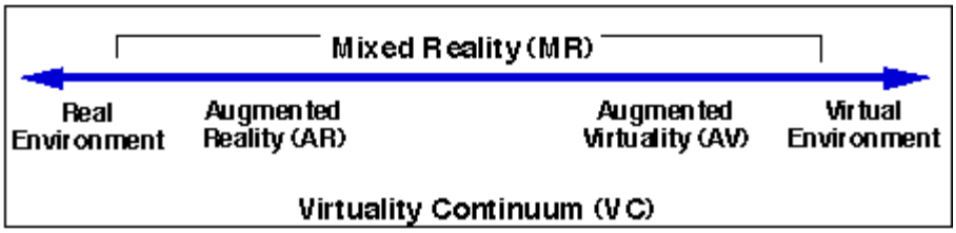


Figure 2: “Continuity of Virtuality”.

Source: MILGRAM, 1994

This taxonomy is important because it helps researches to define immersive experiences in this continuum. As presented in Figure 2, at the far left is the “real environment”, at center-left “augmented reality” (AR), at center-right is “augmented virtuality” and at the far right is “virtual environment” or “virtual reality” (VR).

2.2.1 Augmented Reality

Augmented reality (AR) is referred to as a technology that allows users to access virtual, physical data overlaid. This mediated dive positions digital assets around the physical world, increasing user interactions and experiences (SUH, 2018). Azuma (1997) defines three characteristics to be considered as AR that is, “combines real and virtual”, “Is interactive in real time” and “Is registered in three dimensions”.

AR has increased its popularity, as a result of mobile platforms, such as Apple and Google with its software development kits (SDK) such as ARKit and ARCore. That allows smartphones to use AR in diverse applications. Besides this technological switch, Azuma (1997) states many applications and how to enhance people’s daily activities such as Medical Doctors for visualization and training aid for surgery; manufacturing and for the assembly, maintenance, and repair of complex machinery; visualization, in general, could be used to annotate objects and environments with public or private information; entertainment in general. The author also suggests that AR is about enhancing user visual, aural and tactile senses by using digital information onto the physical world.

2.2.2 Mixed reality

Mixed reality is referred to as located in an area in which the physical and virtual worlds exist together. MR environment is an area for presenting real and virtual objects on a single display together (SUH, 2018) (MILGRAM, 1994). In this work, we will focus on VR and some aspects of AR.

2.2.3 Virtual rehabilitation

According to De Bruin (2010), since the late 1990s, studies have suggested the potential of virtual reality tools to enhance and encourage rehabilitation participation and as a successful tool for treatment and evaluation in a wide range of applications, particularly in the fields of motor and cognitive rehabilitation.

Laver (2017) defines virtual rehabilitation as a form of rehabilitation intervention using interactive technologies, for clinical purposes. In such systems, the virtual environments can provide visual feedback to the user via a head-mounted device, a projection system or a flat screen. Other types of feedback can be used, hearing, touch, motion, equilibrium, and smell can also provide feedback through the senses (WEISS, 2006). The amount of physical activity of the user may, therefore, depending on the intervention, vary from comparatively inactive like sitting on a laptop using a joystick, to very active difficult motions of the whole body (LAVER, 2017).

Burdea (2003) states advantages in adopting virtual rehabilitation, such as using the same VR equipment in different kinds of patients and for different kinds of exercises on these patients. He states that in patients who have post-traumatic stress syndrome (PTSD) or for kids with attention deficits and after-stroke patients, for instance, the same HMD can be used. Burdea as well states other advantages. The main advantages listed by Burdea are:

- it is fun, thus motivating the patient.
- provides objective result measurements of treatment effectiveness (limb speed, range of motion, error rates, match scores, etc.).
- collected information is stored transparently by the simulation operating computer and can be made accessible on the Internet.

- enables the patient to engage more in virtual rehabilitation.
- the patient can practice and can be monitored at distance (telerehabilitation).

Burdea (2003) also describes challenges to use virtual rehabilitation such as professional acceptance to use the technology. Some are afraid that it will replace health professionals, others complain that it is not designed for medical purposes, some complain about the cost and about accessibility to this type of technology.

Keshner (2004) emphasizes several advantages for virtual rehabilitation solutions, for example, their ecological validity, control and consistency of stimuli, real-time performance feedback, independent practice, stimulus and response modifications that depend on the user's physical abilities, the environment test and training insurance, graduated exposure to stimuli, the ability to distract or increase the user's attention, and perhaps most importantly to the therapeutic intervention, the motivation to perform these activities, so necessary for the full realization of the benefits. But the author also states that the use of VR devices is not enough, it is also necessary to develop VR content that engages and gives a sense of immersion for the user in an activity and that is useful for rehabilitation.

2.2.4 Immersive technologies to promote rehabilitation

This chapter presents the main concepts related to immersive technologies, including immersive virtual reality (VR) systems and immersive augmented reality (AR) systems, and the state-of-the-art about applications to promote rehabilitation of old adults, which is named virtual rehabilitation by several authors.

Immersive technologies include physical environment / immersive space with surrounding digital projections and sound such as the CAVE - cave automatic virtual environment (CRUZ-NEIRA, 1992), and the use of virtual reality headsets or head mounted displays – HMDs, with head-tracking and computer control of the image presented, so that the viewer appears to be inside the scene. Sutherland (1968) proposed and implemented the first head-mounted three-dimensional display and Cruz-Neira et al. (1992) proposed and implemented the first CAVE.

Although the concepts and first technological solutions are not recent, these technologies have evolved a lot and their prices have decreased significantly, making their use possible in many different areas of application.

In this research, the interest is concentrated in HMD solutions for their advantage of greater mobility and lower costs, compared to CAVE solutions. Companies such as Facebook, HTC, Microsoft and Google. Offer products and solutions to have these “immersive experiences” such products are Oculus Rift, HTC Vive, Windows Mixed Reality, and Google Daydream (MUIKKU, 2017).

2.3 Video games to promote rehabilitation

This section presents the main concepts about and related to video games and their use and potential to promote rehabilitation of elderly fallers.

2.3.1 Video Games

The expression video game has evolved from a purely technical definition to a notion of interactive entertainment. While still somewhat undefined, the term "video game", also known as “electronic games” or “computer games”, now generally encompasses any game played on hardware built with electronic logic circuits that incorporates an element of interactivity and displays the results of the player's actions (WOLF, 2007).

Video games go beyond entertainment. Many of them are categorized as serious games, which are games that have an application that goes beyond fun, also having functions returns to education, sports, and science, among other areas of knowledge (SUSI, 2007).

2.3.2 Flow and game flow

As video games usually relate to fun and entertainment, researches have explored to understand why games are fun and why they engage us. In the early 1980s, Malone (1980, 1982) performed a number of psychological researches concentrated on what makes computer games “fun” and he acknowledged three

qualitative factors that influence the entertainment level of computer games: challenge, curiosity, and fantasy. Yannakakis et al. (2006) used these variables to examine distinct variants of their matches and concluded that the ideal equilibrium between challenge and curiosity, however, depended on the individual player.

This concept that a game's attractiveness depends on how it matches the player already appeared in the "flow" structure created by Csikszentmihalyi & Csikszentmihalyi (1975). Flow is the state of complete involvement in an activity. The flow state is the mental state of operation in which a person performing an activity is fully immersed in the activity (not necessary for virtual immersion) in feeling focus, full involvement, and enjoyment in the activity. According to Jackson & Csikszentmihalyi (1999), the core element of flow is that abilities must match difficulties to preserve the participant's interest, the so-called "the golden rule of flow".

Sweetser (2005) presented a flow version, specific for video games, called "game flow", with the following eight elements:

1. Concentration – “games should require concentration, and the player should be able to concentrate on the game”.
2. Challenge – “games should be sufficiently challenging and match the player’s level of skill”.
3. Player skills – “games must support player skill development and mastery”.
4. Control – “players should feel a sense of control over their actions in the game”.
5. Clear goals – “games should provide the player with clear goals at appropriate times”.
6. Feedback – “players must receive appropriate feedback at appropriate times”.
7. Immersion – “players should experience deep but effortless involvement in the game”.
8. Social interaction – “games should support and create opportunities for social interaction”.

Sinclair et al. (2010) defined the nine elements of the "flow" experience:

1. Clear goals, the balance between perceived abilities and perceived challenge (neither too simple nor too hard).
2. The combination of action and consciousness (understand how well you are doing).
3. Clear objectives (feels committed but not overwhelmed by the challenge.).
4. Unambiguous feedback (activity achievements and failures are evident so conduct can be adapted as required, focused on what you're doing).
5. Focusing and no distractions (individual involved in the activity will concentrate and focused).
6. There is no concern about failure (feeling of individual control over the situation or activity).
7. Self-awareness is gone (no feelings of self-concern or self-interest).
8. Time becomes relative (a subjective time experience is changed).
9.“Autotelic” experience (done for itself, activities are carried out for their own sake, an experience to enjoy).

According to Sinclair et al. (2010), the flow concept has been implemented in a number of distinct areas, including several related to exergaming: sports, education and video games.

2.3.3 Exergames for rehabilitation

Games related to fitness, are known as exergames or exercise-gaming (an "exercise" and "game" junction) (MACKENZIE, 2006). Such a term is used for video games that also fulfill the form of exercise. Sinclair et al. (2007, 2010) have conducted studies on exergames applied to the treatment of obesity in children. Exergames rely on technologies that track movement or body reaction.

Papastergiou et al. (2009) said that exergames are the evolution and the consequence of technological changes designed to make videogames more fun and healthier. According to Darekar et al. (2015), the use of exergames as a

physiotherapeutic tool for the rehabilitation of balance has become increasingly common.

Researchers have been investigating technological alternatives as rehabilitation platforms", such as the use of video games, especially on the Nintendo Wii and Microsoft Kinect platforms (CHAO, 2014; ZENG, 2017; CHOI, 2017).

According to Fu et al. (2015), studies show that the use of this technology may be effective in reducing the risk and incidence of elderly fallers in conventional physiotherapeutic treatment. Furthermore, exergames offer a controlled environment in which it is possible to manipulate the stimuli and the progression of the difficulty of the proposed exercise to the patient. As a result, the user's progress assessment becomes much clearer, which in a way helps the therapist to better plan his or her behavior.

Nevertheless, according to Skjæret et al. (2016), commonly available exergames were not designed for clinical rehabilitation and therefore they do not contain specificity necessary to perform the function of rehabilitating patients with cognitive-motor deficits.

2.3.4 Immersive exergame

The term "immersive exergame" is used by Shaw (2015) to describe the type of game that uses immersive technologies, in his case the technology used was the Oculus Rift HMD. The author investigated requirements for designing an exergame, such as patient parameters, different health outcomes and patient motivation. He also evaluated the effectiveness of different levels of immersion in different conditions and concluded that an immersive exergame, is a game specifically designed for exercise that uses immersive technology for patient interaction.

2.4 Considerations

This chapter presented an overview of literature review and basic concepts of, the aging process and its consequences, described the intrinsic and extrinsic risk factors for elderly fallers and discussed the main aspects about conventional rehabilitation in this context. As well concepts related to video games and exergames, especially those

related to virtual rehabilitation purposes. Additionally, the area of research in the main concepts and technologies related to immersive technologies, both VR and AR, and their applications as virtual rehabilitation solutions.

3 THE PROPOSED IMMERSIVE EXERGAME

The rehabilitation of elderly fallers usually includes activities designed to promote better postural control and to improve marching capacity. These two functions can be exercised with a game that also promotes cognitive thinking, such as gathering objects that are presented around the patient. This was the main idea that oriented the development and tests of the immersive, cognitive-motor exergame. This chapter describes the requirements, the concept and the development of this exergame, which was named BALLOONS.

3.1 Requirements for the exergame

There are five requirements that should guide the design and development of an exergame for balance, as stated by Choi (2017):

- Exercise intensity
- Attendance
- Safety
- Engagement
- Easy to do

It is important to keep these requirements in mind when mapping the problems and difficulties while developing and testing technological solutions for rehabilitation. All of them hamper the development of an effective rehabilitation treatment: the exercises must engage the patient from beginning to the end, while promoting repetitive, safe and efficient motor-cognitive activities, respecting the specificities of each patient.

Besides these five main requirements, it is important to remember that “one solution fits all” is certainly not true in rehabilitation processes. There is a wide range of incapacities that may affect different patients. Thus, one must understand the specific limitations that can affect different elderly fallers and how they affect their daily life in order to overcome such issues. Particularly, it is necessary to use, and design targeted and specific tools for the functional clinical rehabilitation of certain patients

with specific conditions, such as individuals with neurological diseases associated with balance deficits and postural control, who may present cognitive and motor changes.

3.2 Concept of the exergame

BALLOONS v1.0 is a game for cognitive-motor training that invites the user to play in a virtual world filled with colored balloons. Using two manual controls (one for each hand), the user can interact with the presented balloons, popping them and gathering the points. The challenge is to interact with enough balloons until you gather a specific cumulative sum. When the correct sum is achieved, the game score is updated and a new round of gathering starts. This game mechanic adds a layer of cognitive activity to the exergame.

In the virtual reality version of the game, the player is stimulated to interact with the virtual environment, which is a park, when started. When a game session is started, balloons will appear randomly in the space around the user, in different directions and heights, starting under the player and going up. Balloons with the same number have the same color, and each number will have a different color.

3.2.1 Rules

In BALLOONS, the player must make the highest game score possible by popping balloons in a specified time (for example, for 5 minutes). To score game points, the players must gather balloons in order to accumulate its points, which will be computed in the gathering score (or counter). The objective is to make cumulative sums exactly equal to the amount required by the challenge (for example, sums of 10). Completing the sum exactly equal to the required amount will provide the same amount of game points to the player (and one correct mark will be computed). On the other hand, if the player gathers more points than required – for instance, by popping a balloon with value 2 when the current gathering score is 9 and the required score is 10 – no game point will be scored (and 1 incorrect mark will be computed). The gathering score will go back to zero after any of the two events happen. All scores from participants can be access at Appendix B section B.5.

3.3 Development of the exergame

The exergame was developed using Unity 3D 2018® and Microsoft Visual Studio 2017®. Some assets from Microsoft's tutorial asset for beginners' windows mixed reality were used. An asset player controller from Cyberith for the omnidirectional treadmill (ODT). The 3D assets of the park scenario were purchased on the Unity asset store, while the balloon model was purchased in the 3D warehouse website. The theme song was downloaded from YouTube's video creator and the sound effects were obtained at https://freesound.org.

3.3.1 The development processes

Because of the multidisciplinary nature of this research, the feedback of physical therapists is important and should guide the improvements and functionalities of the application. Therefore, it was decided that the development of the game would include formal test phases between versions. Figure 3 illustrates this iterative development process, where physical therapists test a build version of the software, their feedback data is collected and analyzed and adjustments in the software are then made to generate a better version of the exergame.

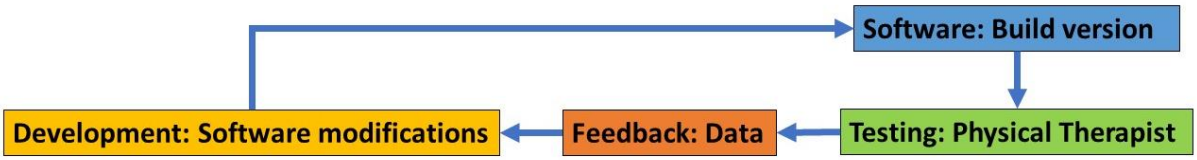


Figure 3: The development process included physical therapists.

Source: Author

Two versions of the game were developed in the time of this research (v1.0 and v1.1.). Two test sessions were conducted to evaluate each of them, and they will be described in the next chapter.

3.3.2 Development of the first version

The development of the first version of the game BALLOONS, was design and thought for VR, and was develop for the first two systems that are VR. The two first system were the same game, the difference is that the first system, was focus on postural training and limit to the real physical space. The Second System was focus on gait and had no limit of walking in the virtual space, because we used a treadmill.

3.3.2.1 Supported systems

The supported systems used in this work, where in total 3 Systems. These systems are two virtual reality systems and one AR system. The first two systems, System 1 and System 2 are based on HMD VR and where used for the first version of the game. System 1 is based on using only the HMD, this was considered as postural training due to its limit space for walking, as well the use of a harness to hold the participant not to fall, because players would not see the physical world and be immersive in the virtual environment through the HMD. Despite these details it was still important to have a focus on using the HMD and postural training. Because in another hand, System 2, despite utilizing the same game, it was focus on gait training due to the use of an ODT that allowed to walk longer distance in the virtual space. In addition, player would be hold by three pillars that hold the ring were the player is. This was important, because in the context of HMD VR, we can compare how these technologies impact different types of training such as postural and gait. Later in other sessions of this chapter, it will be discussing the development of System 3 in AR on the second version of the game.

3.3.2.2 System 1

The system was the first system to be develop due to use less equipment's, consequently being simpler to elaborate and implement. The equipment used Samsung HMD Odyssey, from the Windows Mixed Reality platform. This HMD is necessary to connect with a computer with the minimal requirements recommend ended. As well for security reasons it was used a harness to hold the person that would

be playing the game. This System was design for postural training, because of the limitation of the walking are of the physical space and that participants where be limited by the used of the harness.

3.3.2.2.1 Equipment

The Samsung® HMD Odyssey Windows Mixed Reality Headset from the windows mixed reality platform (Figure 4) is an HMD for VR, and it's from the Windows Mixed Reality platform. The kit comes bundle with 2 six degrees of freedom (6DOF) controllers, that connect though Bluetooth, the controllers when on have many small led in top of the controller illustrated in Figure 4. In System1 the participant uses a vest attached to an overhead harness (Figure 5).

Figure 4: Samsung HMD Odyssey with controllers.

Source: available at (https://www.samsung.com/br/hmd/hmd-odyssey-xe800zaa-hc1br/)

The minimal requirements to use this device in a computer (Samsung, 2018):

- Operating System: Windows 10.
- Processor: Intel®Core™ i5 7200U (7th generation mobile), dual core with Intel® Hyper-Threading Technology enabled or better. AMD Ryzen 5 1400 3.4 GHz (Gigahertz) desktop, quad core or better.
- RAM (Random Access Memory): 8 GB (Gigabyte) DDR3(Double Data Rate 3) dual channel.
- Disk Space: 10 GB.

Graphic Card: Integrated Intel HD Graphics 620 or greater DX12-capable integrated GPU (graphics processing unit), Nvidia MX150 discrete GPU, Nvidia GeForce GTX 1050 discrete GPU, Nvidia 965M discrete GPU, AMD Radeon RX 460/560.

- Graphics Driver: Windows Display Driver Model (WDDM) 2.2.
- Graphics Display Port: HDMI 1.4 or DisplayPort 1.2.
- Monitor: External or integrated Video Graphics Array (VGA) 800x600 monitor.
- USB Type: USB 3.0 Type-A or Type-C.
- Controllers Bluetooth Type: Bluetooth 4.0.

As early describe, the player would be hold by a harness, using the HMD and playing the game as illustrated in Figure 5.

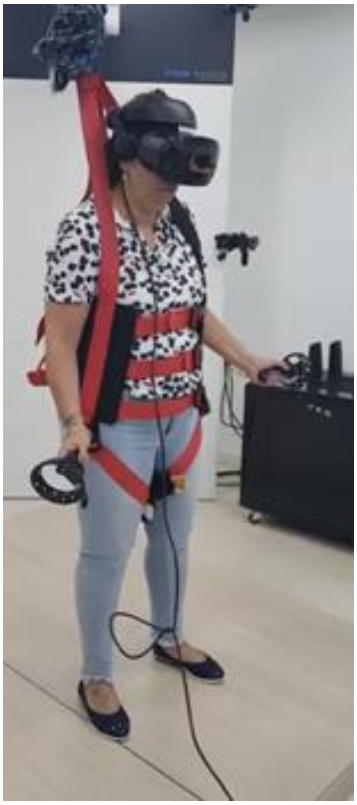


Figure 5: Participant using System 1.

Source:Author

3.3.2.2.2 Inputs and Outputs

System 1 is VR with the headset and controllers, the main processor of the information is the computer, meaning that these peripherals, besides of having a sensor, are not responsible for the main processing of data information of output-input information. Figure 6 shows a map connection, of which it connects the device transmit and receive data in System 1.

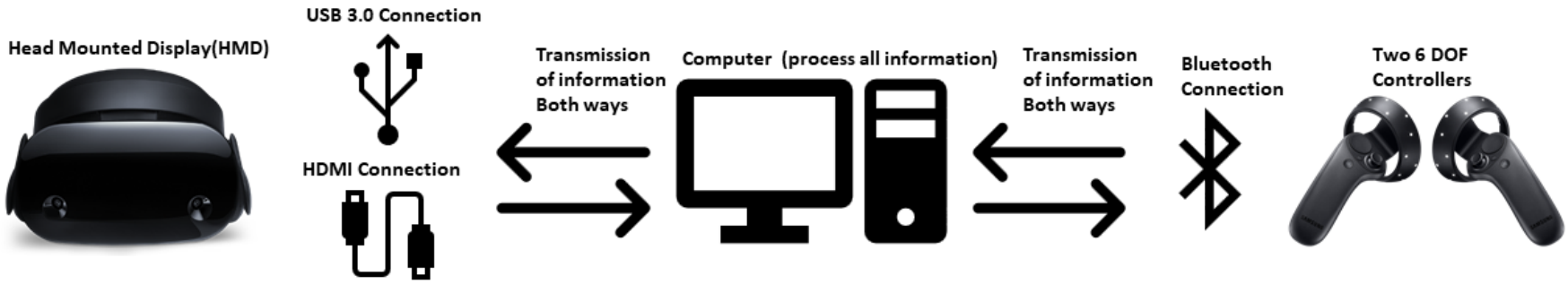


Figure 6: Map System (System 1).

Source: Author

The Unity game engine brings together all component's information into the game to run. All three systems used the Unity game engine. Other components guarantee that Unity can access libraries and Integrated Development Environment (IDE), to integrated with the Windows Mixed Reality Platform. As illustrated Unity is responsibly integrating and managing the input and output of information. Figure 7 shows the connection of the operating system with the Game engine, IDE and UWP. And the output and input information that the Game engine process of System 1 software map.

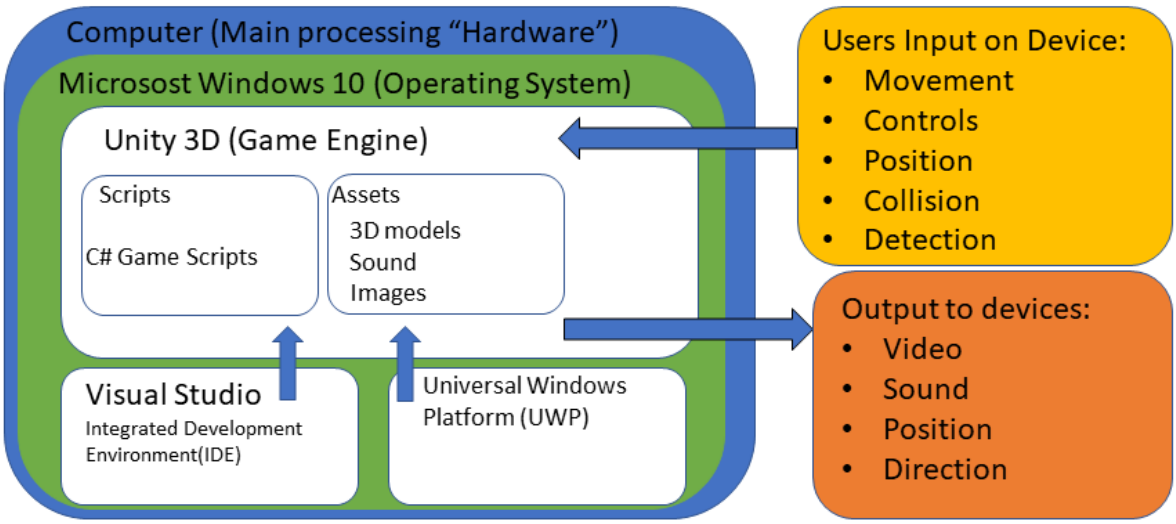


Figure 7: Software map (System 1).

Source: Author

3.3.2.3 System 2

System 2 used the same HMD as the System 1 to have the same VR experience between the systems. However, integrating another peripheral for walking for gait training, using an ODT from Cyberith. Considering that the game is the same for both systems, they would have different experiences. Because of the feature of walking in the virtual environment and focusing on gait training. Security wise, the ODT holds the participant in a three pillar of a ring in the middle where the person can walk in expected walking direction. This System is design for gait training, besides the limitation of the walking are of the physical space, an ODT can be a solution for this type of problem and test in another type of training with the same game and HMD. An ODT is a mechanical device, that allows a person to perform locomotive motion in any direction. The ability to move in any direction. Omnidirectional treadmills are used in immersive virtual environment implementations to allow movement within the virtual space. (DARKEN, 1997)

3.3.2.3.1 Equipment

The Cyberith® Virtualizer Elite, developers' version (Figure 8). is an ODT for VR and comes with SDK that work with game engines such as Unity 3D for development. The treadmill is a three pillar in the middle is a ring connect to the pillars that go up and down as illustrated in Figure 8. The ring as well inside can change direction, and users slide their foot forward in any direction to simulate a walk. The equipment must be connected to the same computer, as the used VR headset. This ODT is designed specifically working together with VR headsets, and it has a flat and slippery surface where users are holding on a ring supported by 3 pillars (Figure 8), allowing the user to enjoy walking to any direction, but, limited inside the ring. They assisted all participants to get in and out safely.

Figure 8: Cyberith virtualizer.

Source: available at (https://pikabu.ru/story/platformyi_virtualnoy_realnosti_budushchee_nastupilo_vstat_izza_kompyutera_3918038)

The minimal requirements to use this device in a computer, was not found by the author. Hypothesizing that the minimal are similar for VR HMD to run in a computer.

As early describe, the player would inside the ring, using the HMD and playing the game as illustrated in Figure 9.

Figure 9: Participant using System 2.

Source: Author

3.3.2.3.2 Inputs and Outputs

The second still in VR, with the ODT, the main processor of the information is the computer. Adding another peripheral, however maintaining the computer as the main unit of processing information. The ODT send information to the ring direction, movement speed, and movement direction. In the contact of the virtual space. Figure 10 shows a map connection, of which it connects the device transmit and receive data in System 2.

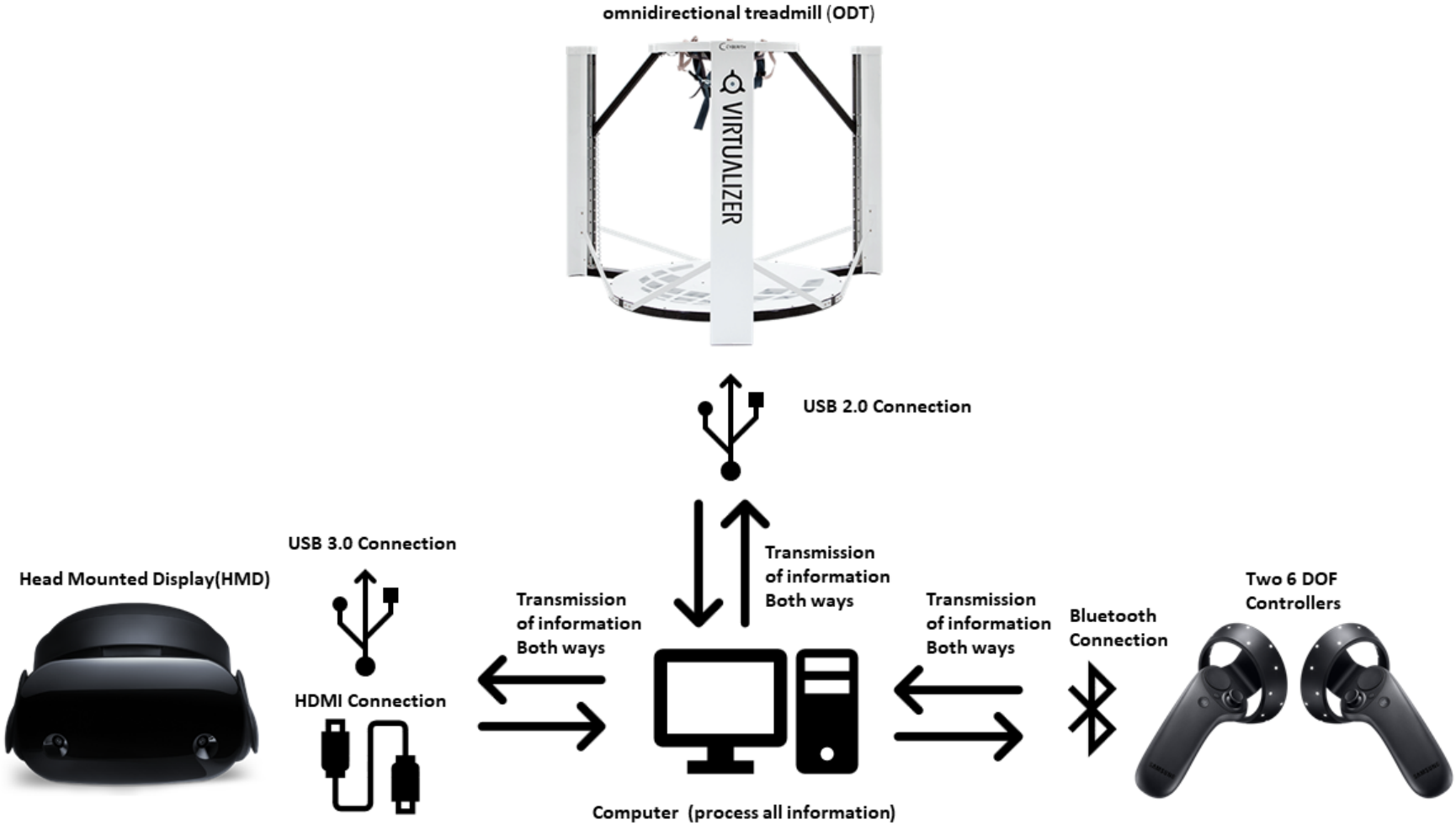


Figure 10: Map System (System 2).

Source: Author

The Unity game engine brings together as well all components information of the game to run. Other components guarantee that unity can access libraries and IDE, to integrated with the Windows Mixed Reality Platform with the addition of the Software Development Kit (SDK) from Cyberith that allows this connection to use the ODT. As illustrated Unity is responsibly integrating and managing the input and output of information. Figure 11 shows the connection of the operating system with the Game engine, IDE and UWP. And the output and input information that the game engine process of System 2 software map.

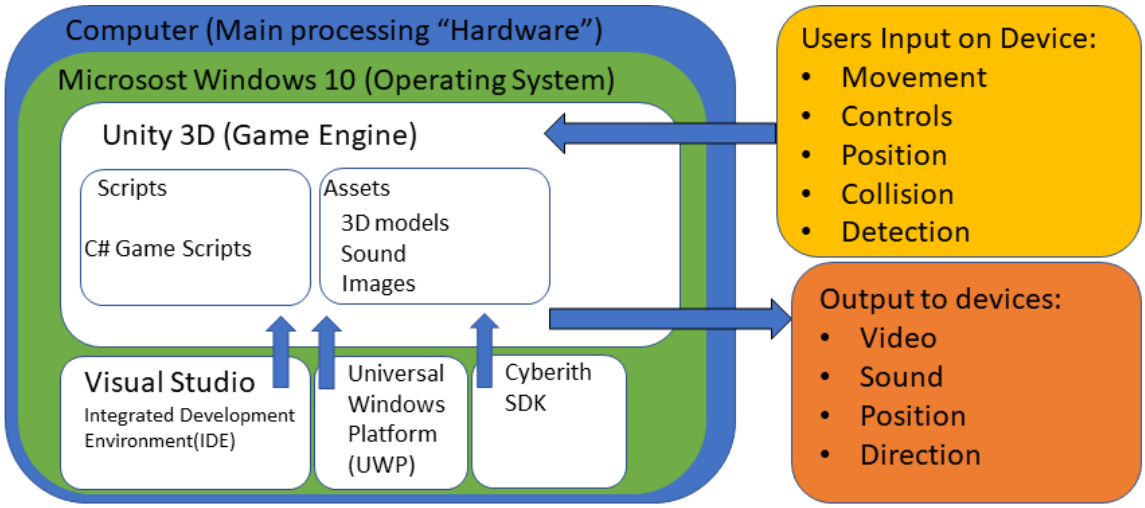


Figure 11: Software map (System 2).

Source: Author

3.3.2.4 Gameplay

Before starting a game session (triggering the game chronometer), the player can explore the environment to become familiar with the scenario and understand how to interact in the game. Once the player is ready to start the game session, he/she must touch a white cube, which will disappear. After 3 seconds, the game starts: balloons will appear randomly, moving from bottom to up, just like a balloon with helium in real life. The player needs to think and respond, moving around the scene to reach the balloons with the controllers in his hands, popping balloons until the required sum is reached to score game points.

3.3.2.5 Scene

The scene of the first version of the game is set in a park. The 3D models are low poly and are texture a simple and vibrant colors. The only object that presents movement are the balloons and the visual feedback of the heads-up display (HUD).

3.3.2.6 Heads-up display

The Figure 12 illustrates the information displayed as HUD. This information will follow the user camera, being static in relation to the user's eyes. The information presented in Figure 12 is in Portuguese because the research was done in Brazil and tested with Brazilian users. The presented information is:

1. Amount of game points the player made (denoted by "Pontos");
2. Gathering sum that the player is collecting in the game (denoted by "Contagem");
3. Time since the game started (represented by "479");
4. The required gathering sum to score game points (represented by "10");
5. A visual feedback informing if the achieved sum was correct or incorrect (represented by "Errou").

Figure 12: Heads-up display (HUD) Game scene BALLOONS v1.1 (Virtual Reality).

Source: Author

3.3.3 Development of the second version

The development of the second of the game BALLOONS, was based on the data collected from the first group. The data and the analyses are discussing in more detailed in chapter 5. Consequently, the second version of the game was developed for, System 1, System 2 and the AR version that is System 3.

3.3.4.1 Supported systems

The supported System 1 and System 2 continued for further testing, considering the feedback that was giving from specialists, System 3 was added. However, System 3 is not a VR system, but an AR system. The implementation of System 3 used an Augmented Reality Headset (ARH).

3.3.4.2 System 3

The specialists group point about the lack of visual information of the balloons, the controller's appearance, the complexity of the game and the exercise intensity. In addition, some concerns where address such as players not seeing the real physical world even with security measures, and last if AR is more suitable for the intended group. Because of this feedback, we develop System 3, that is similar to system 1 the difference is that we use an ARH. Meaning that System 3 is postural training just like System 1.

3.3.4.2.1 Equipment

The Meta 2 headset is an ARH for AR illustrated in Figure 13. The headset is not an independent device but a peripheral that needs to be connect to a computer following the minimal requirements. There are no controllers the headset detects hand gestures, meaning that the controllers are your hands. This is possible because of the front cameras and sensors on the headset. The information is display in front of a transparent glass that is front of the user's eyes. that could user see their reality mixed

with virtual objects, so that users could interact and play, with their real-world reference, for security reason and health issues.

Figure 13: Meta 2 Headset.

Source: available at (https://bestware.com/en/meta-2-augmented-reality-development-kit.html)

As early describe, the player would be hold by a harness, using the ARH and playing the game using their hands as controllers illustrated in Figure 14.

The minimal requirements to use this device in a computer (engineering.com, 2018):

- Windows 10 (64-bit) operating system.
- Intel Core i7 6700 or AMD FX 9590 processor.
- 16 GB RAM DDR4 (Double Data Rate 4) memory.
- NVIDIA GeForce GTX 970 or AMD Radeon R9 390X graphics card.
- 10 GB of hard drive space.
- HDMI 1.4b video output port.
- USB 3.0 or higher port.

Figure 14: Participant using System 3.

Source: Author

3.3.4.2.2 Inputs and Outputs

System 3 is AR; the main processor of the information is the computer. However, ARH besides capturing information of the environment to place objects, it detects hand movement and gestures. Simplifying the framework of passing information. However, information flow is higher compared to its VR counterparts. As a result of the ARH recognizing space and gesture movements that are capture by the headset cameras. Figure 15 shows a map connection, of which it connects the device transmit and receive data in System 3.

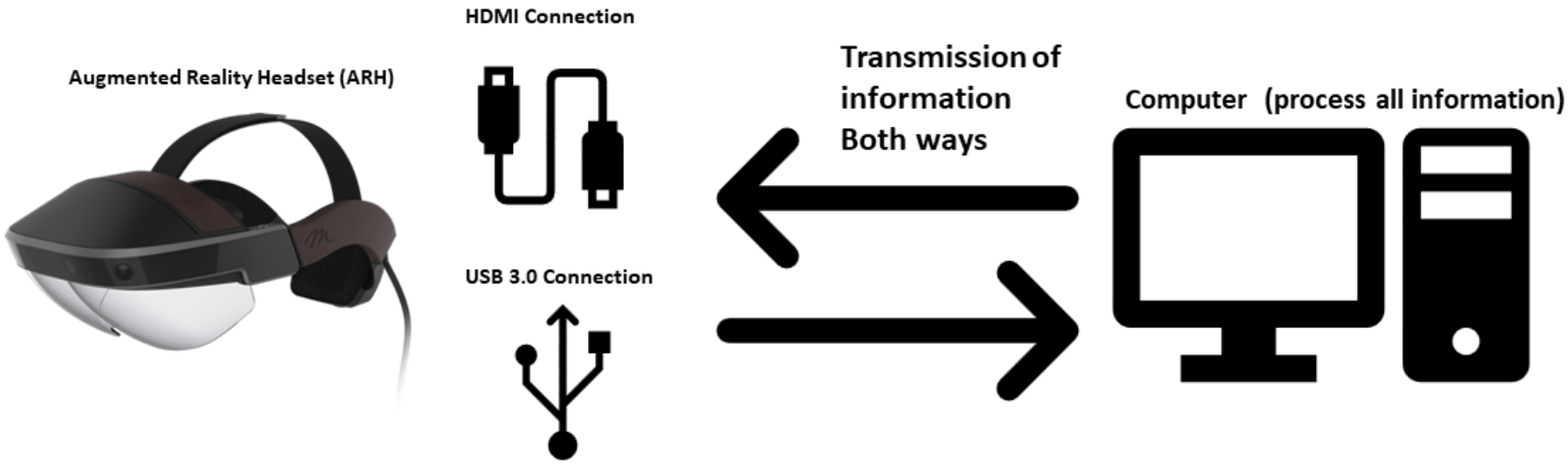


Figure 15: Map System (System 3).

Source: Author

The Unity game engine is responsible to brings all information of the components to run the game. A key component is the meta SDK that connects with a Unity game engine. As illustrated Unity is responsibly integrating and managing the input and output of information. Figure 15 shows the connection of the operating system with the Game engine, IDE and UWP. And the output and input information that the Game engine process of System 2 software map.

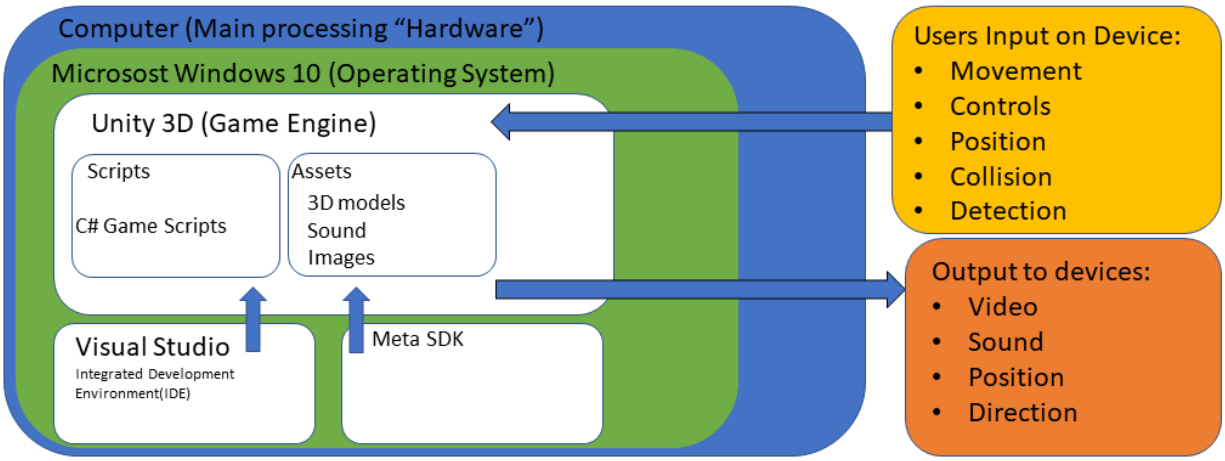


Figure 15: Software map (System 3).

Source: Author

3.3.4.3 Gameplay

The gameplay is the same compare to the first version of the game the difference is that there are more different value balloons and time to complete tasks. This was changed to see if the intensity of physical exercise would increase.

3.3.4.4 Scene

The scene is similar to the first version however, there are less objects in scene and further from the player. In System 3 despite being the same game from its counterparts, there is no scenario, only the balloons and HUD.

3.3.4 Scene development

For the Virtual Reality version of the game, the environment is set in a park with low poly 3D models and with bright and simple colors, as illustrated in Figure 16 (scenario for v1.0). The scenario gives enough visual clues to allow for spatial localization in the virtual world. Based on the feedback received for the first version of the game, the scenario was changed in order to create the impression of more available space, as illustrated in Figure 17 (scenario for v1.1).

Figure 16: Game scene BALLOONS v1.0 (Virtual Reality).

Source: Author

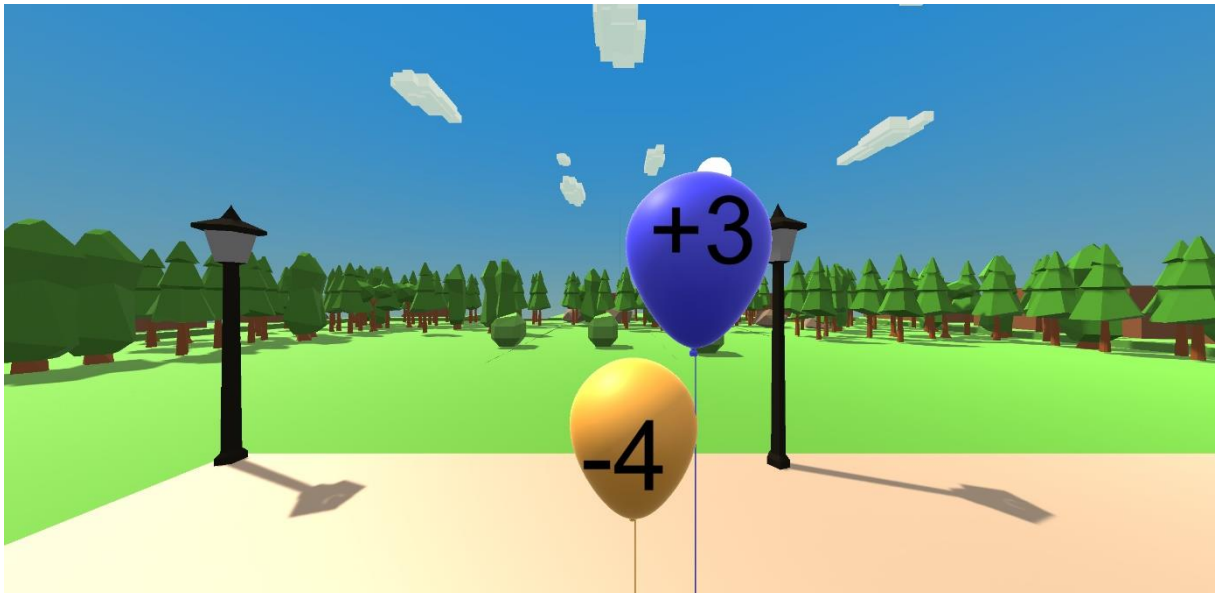


Figure 17: Game scene BALLOONS v1.1 (Virtual Reality).

Source: Author

In the Augmented Reality Headset (ARH) version, there is no scenario, just the balloons and the HMD of the information of the game. As we can see in Figure 18 virtual balloons spread in the physical world and a hand trying to reach then to pop the balloons.

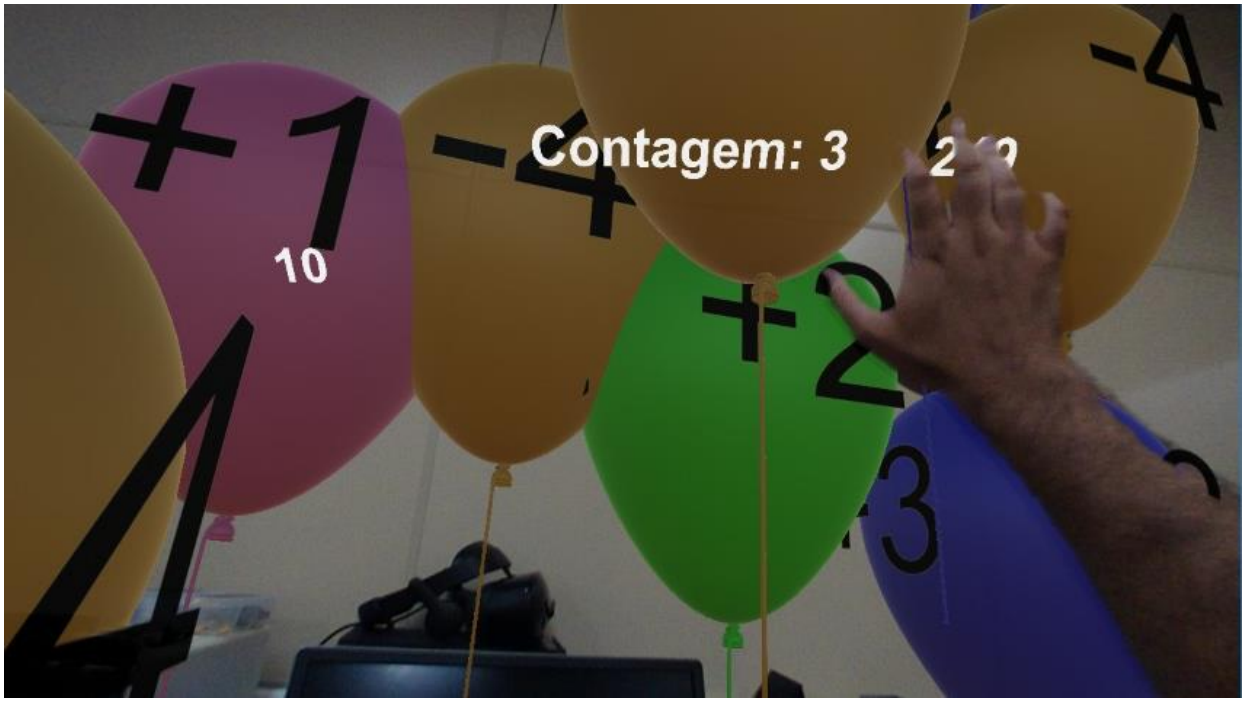


Figure 18: Game scene BALLOONS v1.1 (Augmented Reality).

Source: Author

3.4 Security and cybersickness

As a result, using HMD for VR, players are unable to see the physical word, putting the user in the risk of falling. Measures had to be part of the procedure, for safety reasons. System 1 and 3 uses a vest attached to an overhead harness, in case the person would fall they would not fall to the ground and the vest would hold the person. They used the vest when playing the game with only the HMD. When playing the game on System 2 with the ODT the Virtualizer equipment, the equipment holds the person by the thighs, through a ring that is being hold by three pillars. Although you need to set up every time somebody's use it and assist the person to get out, so they don't slip on the floor, due to the slippery floor of the ODT.

3.5 Versions of the game (visual comparison)

The game had 2 different versions. However, the second version has modification based on the feedback of the collection from the first group referred as Group 1. That will be discussed in further chapters. Visual changes in the environment, game assets, game rules, and assets.

- Further virtual controllers from the player's original position. (avoid accidental balloon popping). Figure 19 shows the hands are closer to the user with a simple geometric representation. While Figure 20 shows white humanoid, hands are far from the players perspective.

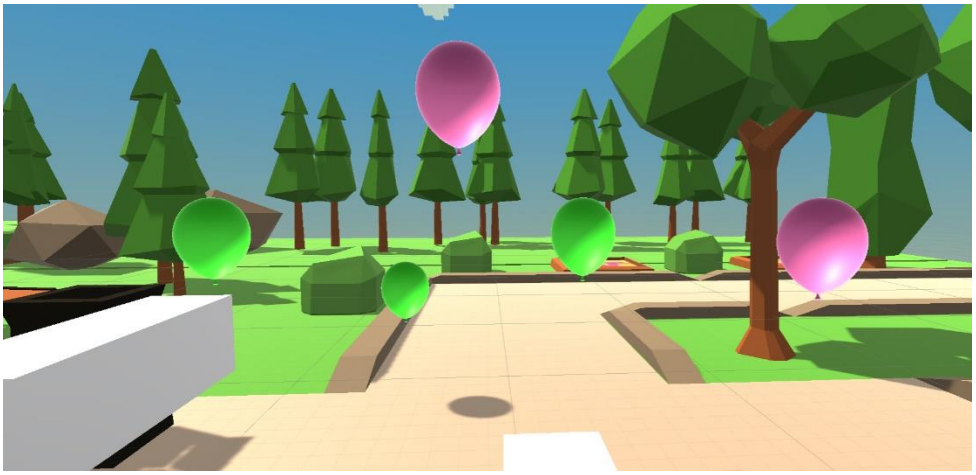


Figure 19: Game scene BALLOONS v1.0 square hands (controller position).

Source: Author

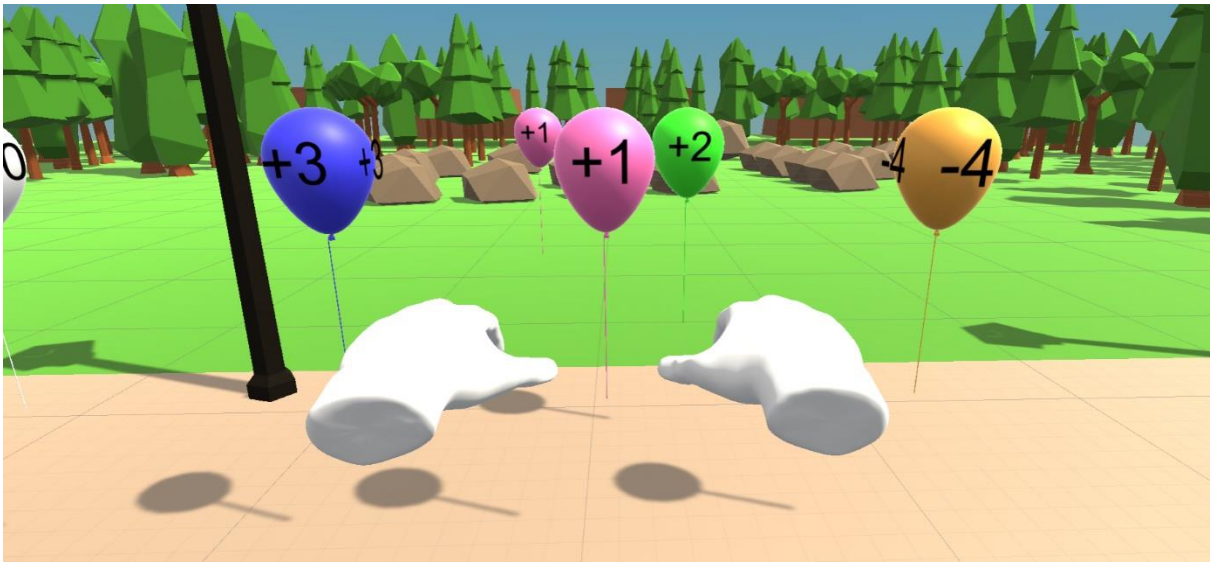


Figure 20: Game scene BALLOONS v1.1 version white hand (controller position).

Source: Author

- Replacing the controllers where cubes into 3D white hand models. Figure 21 illustrates the square shape hands of the player of BALLOONS v1.0 of the game. Figure 22 shows the replacement of the square hands to more humanoid hands that are white color.

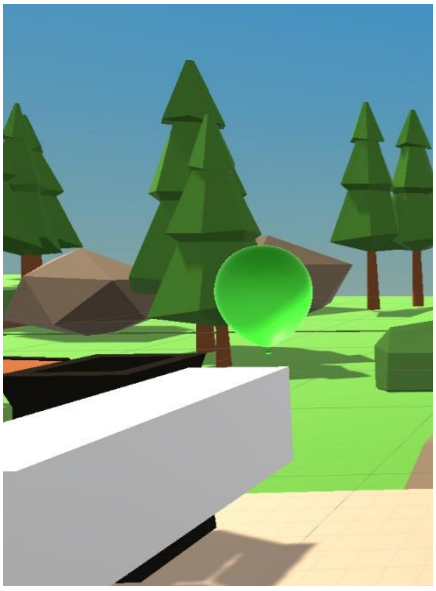


Figure 21: Game scene BALLOONS v1.0 version square hands.

Source: Author

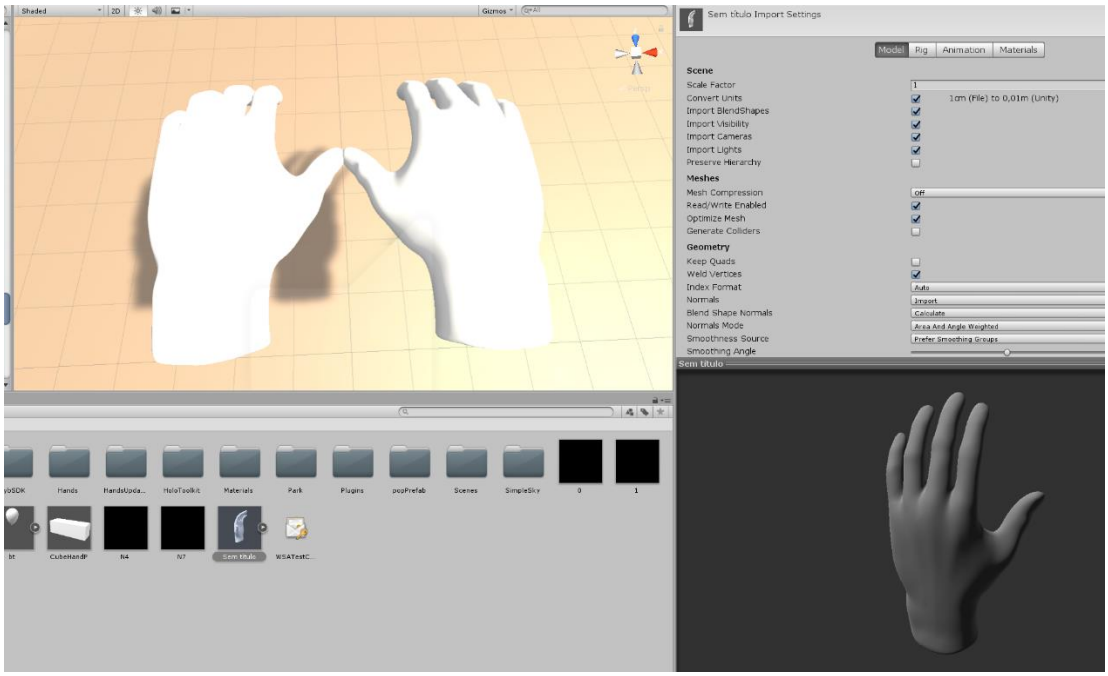


Figure 22: Game scene BALLOONS v1.1 version human hands in the Unity game engine.

Source: Author

- Adding more balloons with different values such as 0, +3, -4 and with a numeric indication for each color of every different balloon. Figure 23 presents BALLOONS v1.0 of the game with pink and green balloons with no numeric value. Figure 24 presented BALLOONS v1.1 of the game with over five balloons

with the visual representation their score value. That is white is 0, pink is +1, green is +2, blue is +4 and orange is -4. Increasing 3 more balloons and visual written numeric values.

Figure 23: Game scene BALLOONS v1.0 version of the balloons.

Source: Author

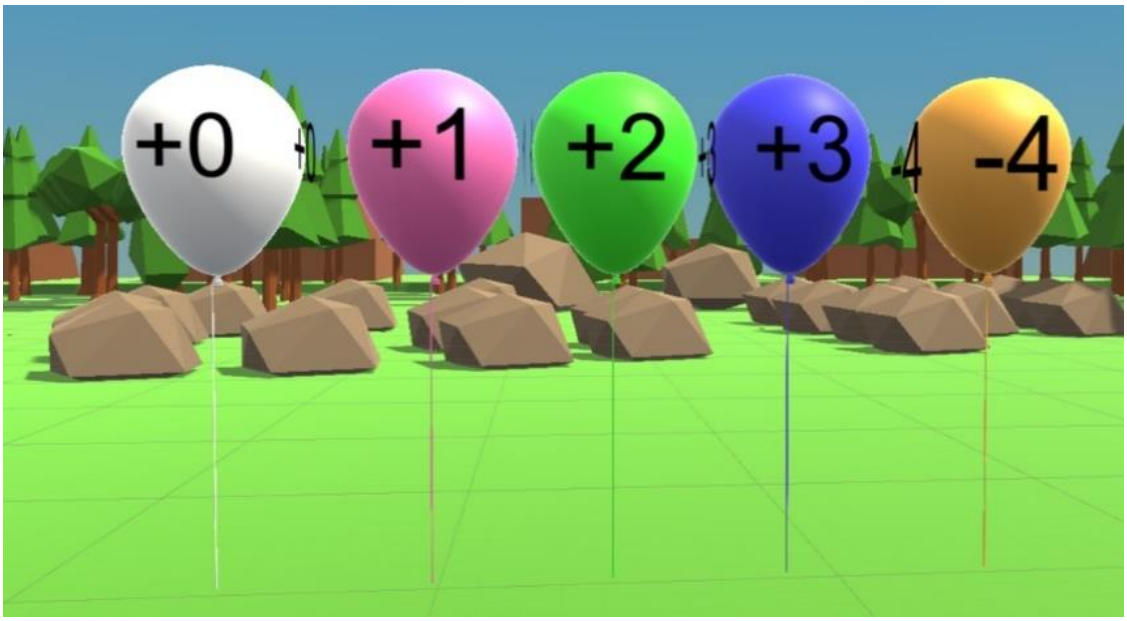


Figure 24: Game scene BALLOONS v1.1 version of the balloons and their change aesthetic.

Source: Author

- Adding balloons with negative values to increase players attention. Figure 25 presents the orange balloon that scores value is negative four.

Figure 25: Orange Balloons, value at -4 of the BALLOONS v1.1.

Source: Author

- The environment had to be changed, placing objects further for players that they could focus on collecting balloons and have the impression to move more and explore the space of the virtual environment. Figure 26 and Figure 29 illustrates the top view of the scenario of the BALLOONS v1.0 and BALLOONS v1.1 of the game. Figure 27 and Figure 30 shows an angle view of the scenario of the BALLOONS v1.0 and BALLOONS v1.1 of the game. Figure 28 and Figure 31 presents a front view of the scenario of the BALLOONS v1.0 and BALLOONS v1.1 game.

Figure 26: Game scene BALLOONS v1.0, top view of the design environment.

Source: Author

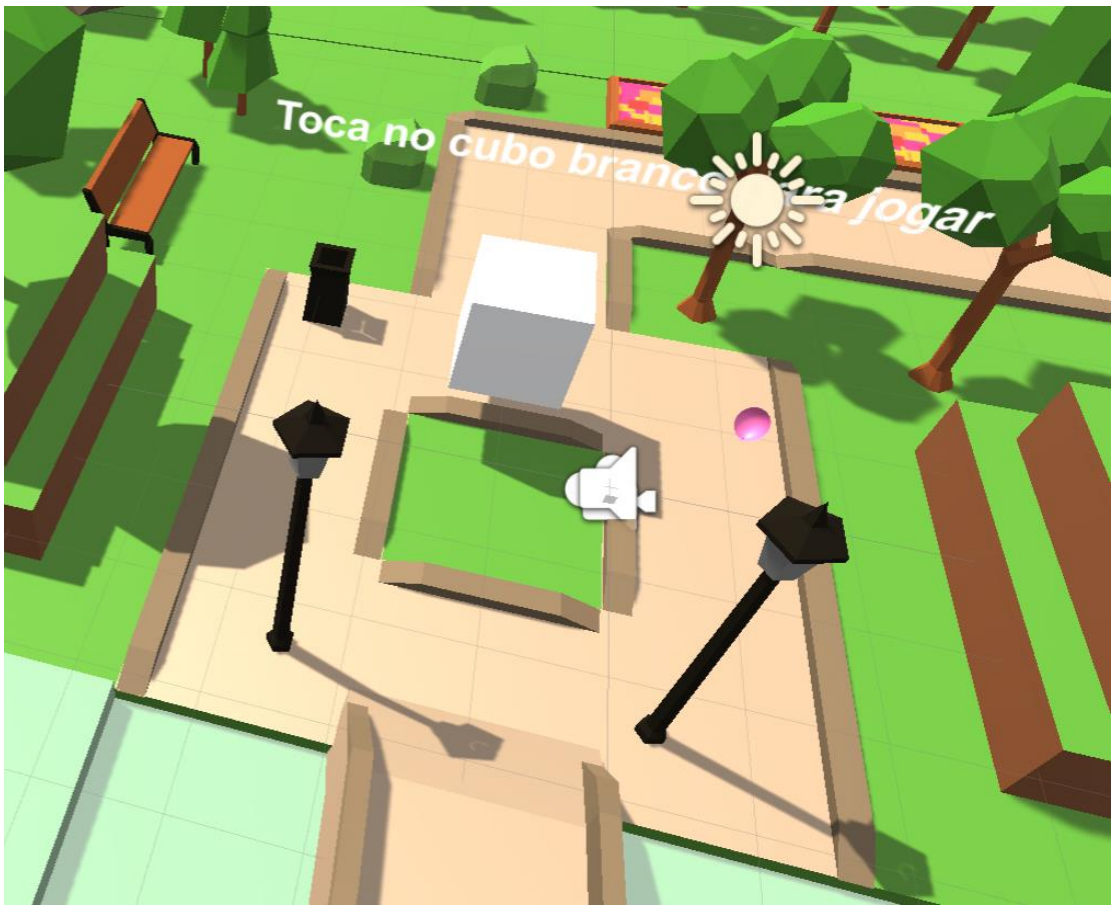


Figure 27: Game scene BALLOONS v1.0, top angle view of the design environment.

Source: Author

Figure 28: Game scene BALLOONS v1.0, front view of the design environment.

Source: Author

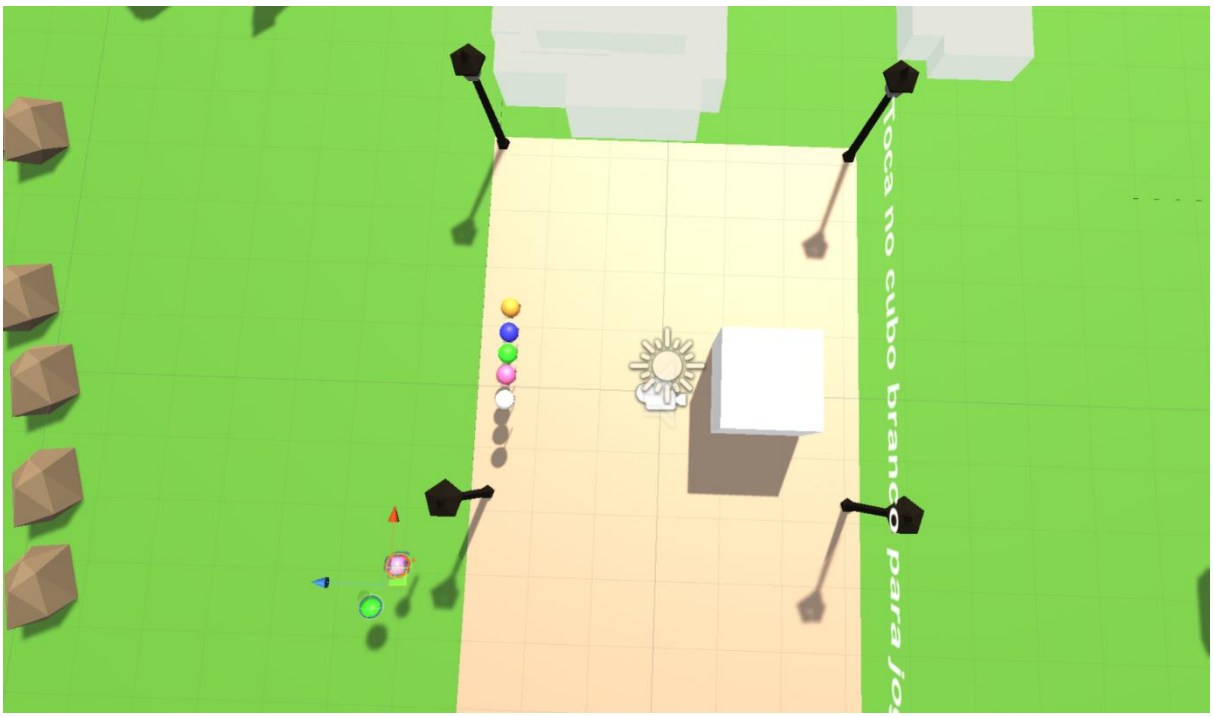


Figure 29: Game scene BALLOONS v1.1 version, top view of the design environment.

Source: Author

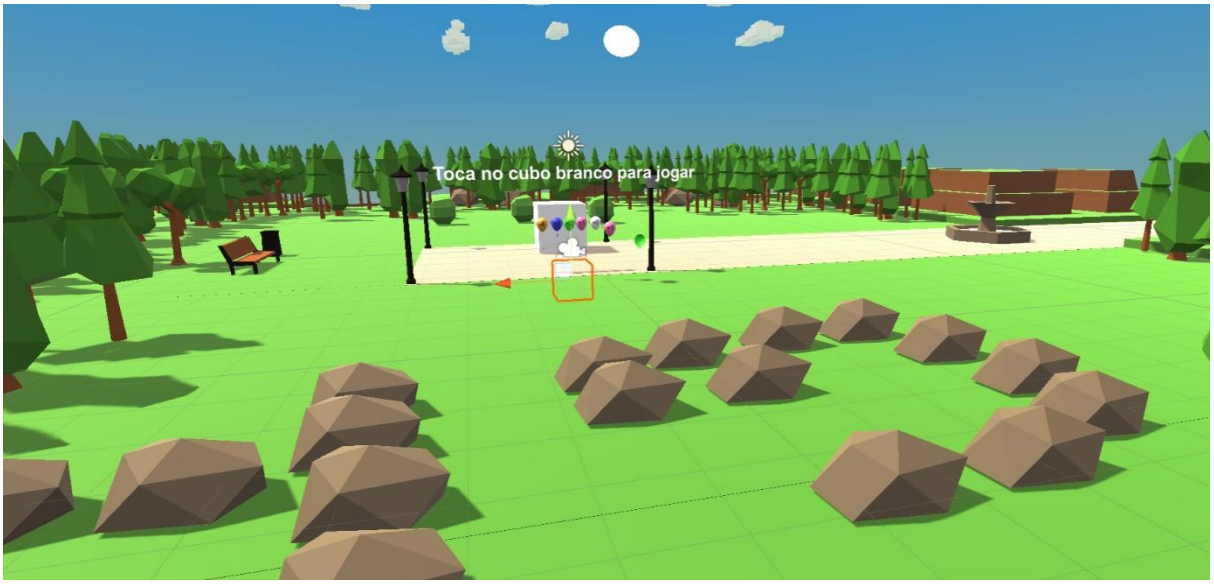


Figure 30: Game scene BALLOONS v1.1, further angle view of the design environment.

Source: Author

Figure 31: Game scene BALLOONS v1.1, front view of the design environment.

Source: Author

- Game Session 5 to 10 minutes,
- Scoring was changed, when players summed of 10, 3 times the sum would change to 20. And players would receive 20 points for the right sum.
- Invisible game object was added as an Invisible collider underneath the player to avoid surprised random balloon colliding player's virtual hand controlled by accident and frustrating players.

3.6 System 4

Because of the results, that are discuss in further detailed in chapter 5 of this study. System 1 had the most positive feedback, even being the simplest of the 3 systems, it succeeded in qualitative and quantitative results. Other research using version 4 is being initiated by researchers from the Motor Behavior Lab (Lacom). However, because of software compatibility, the Windows Mixed Reality platform had to change for another platform with fewer compatibility issues. That platform is OpenVR an SDK and application programming interface developed by Valve for supporting the SteamVR (HTC Vive).

Consequently, we used the HTC Vive device as the VR HMD for System 4. In addition, based on the data of Group 2 and analyzed, that is discuss in chapter 5, we made some changes to the version of BALLOONS v1.2. for the updated version of System1, discussing the changes in this version of the game in the next section.

Because, the data is being collected and the research is specifically for clinical research, we will be brief in this section and focus more in game modifications for this specific version. The questionnaires of this specific research were elaborated by Prof. José Eduardo Pompeu and Jéssica Maria Ribeiro Bacha from Department of Physical Therapy, Speech Therapy and Occupational Therapy. School of Medicine, Universidade de São Paulo. The questionnaires can be access at Attachment D.

Figure 32: HTC Vive Kit.

Source: available at (https://www.vive.com/media/filer_public/b1/5f/b15f1847-5e1a-4b35-8afe-dca0aa08f35a/vive-pdp-ce-ksp-family-2.png)

Figure 33: Person testing System 4-SteamVR update.

Source: Author

3.7 BALLOONS v1.2

Based on the collect data of Group 2, modifications where made for this specific version. This version of the game is not the focus of this work, we will focus on BALLOONS v1.0 and v1.1 for having 2 sessions of collected data and analyses, later discuss in further chapters. The modifications made for BALLOONS v1.2 are:

- Added sound feedback. Such as correct and incorrect answers, and when the game is over.
- Change human hands for the model game controllers for more accurate position of the controllers to catch balloons.

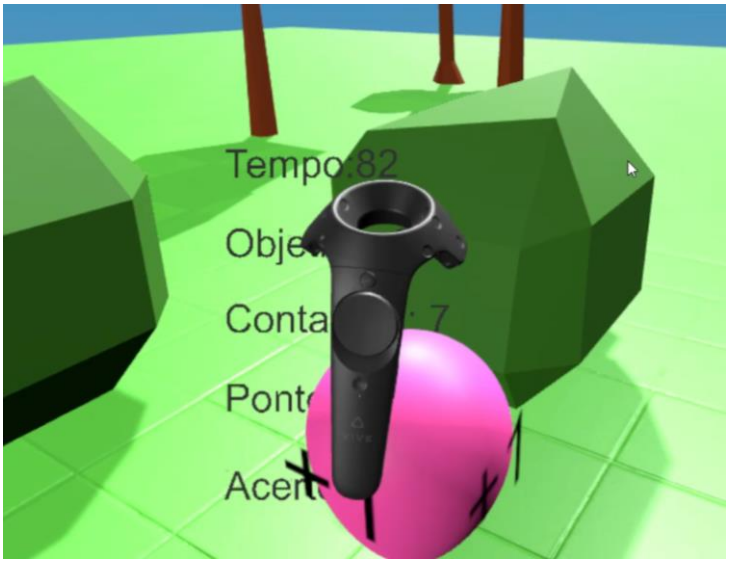


Figure 34: Game scene BALLOONS v1.2 version controller (controller position).

Source: Author

- HUD closer and to the left size, with a bigger font size. The Figure 35 illustrates the information displayed as HUD. This information will follow the user camera, being static in relation to the user's eyes. The information presented in Figure 35 is in Portuguese because the research was done in Brazil. The presented information is:
    1. Time since the game started (represented by "Tempo:50");
    2. The required gathering sum to score game points (represented by "Objetivo:20");
    3. Gathering sum that the player is collecting in the game (denoted by "Contagem: 17");
    4. Amount of game points the player made (denoted by "Pontos: 310");
    5. A visual feedback informing if the achieved sum was correct or incorrect (represented by "Acertou!").

Figure 35: Heads-up display (HUD) Game scene BALLOONS v1.2 (Virtual Reality).

Source: Author

- Added a 3D low poly bushes around to give indication of space limit.

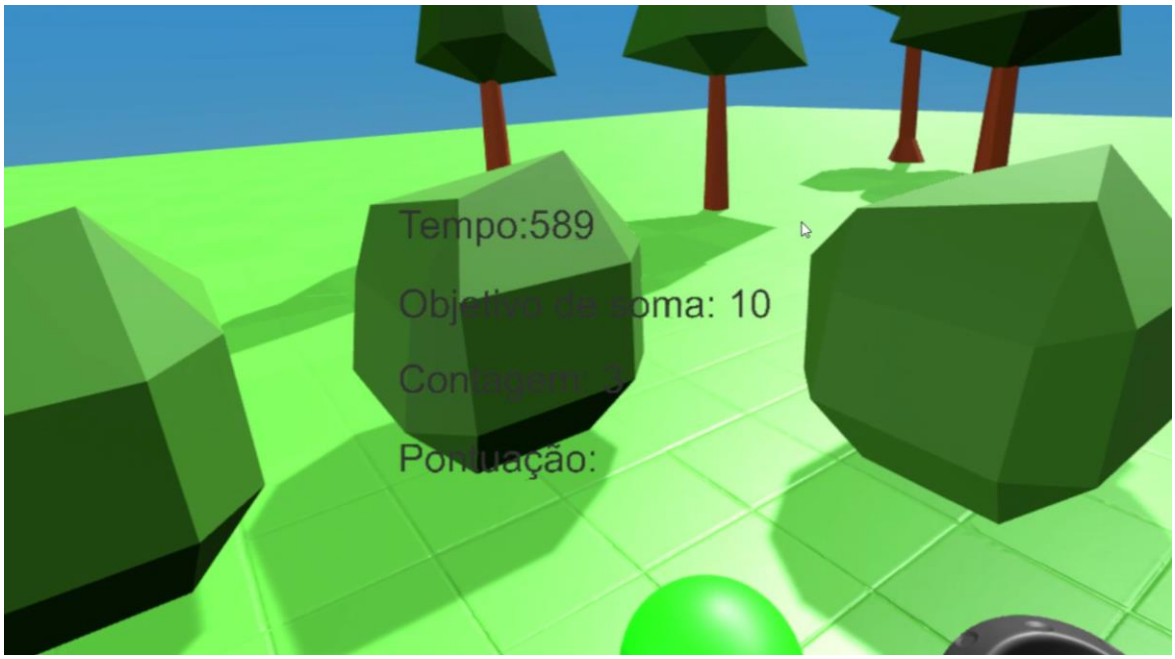


Figure 36: Game scene BALLOONS v1.2 Bush position.

Source: Author

3.8 Considerations

This chapter presented the proposal of the cognitive-motor game BALLOONS v1.0 and BALLOONS v1.1 and the systems that were implemented for virtual rehabilitation testing with specialists. In addition, giving details of each electronic system of the 3 implemented systems. The description and comparisons of the two versions of the game. Last, a briefly BALLOONS v1.2 on System 4. The following chapter presents the details of testing and data collection of the game.

4 TESTING AND EVALUATION WITH SPECIALISTS

This research applied a mixed-methods survey-based study. The data collected included interviews and questionnaires, in order to acquire both qualitative and quantitative data. This chapter presents the details of testing and evaluation, with physical therapists, of the two developed versions (BALLOONS v1.0 and v1.1) of the proposed exergame. This study had two data collection sessions: the first one with a group of 6 physical therapists tested on BALLOONS v1.0. The second session, with 8 new physical therapists and 3 from the previous session, a total of 11 in the second session, tested on BALLOONS v1.1.

4.1 Instruments for data collection

The following instruments of data collection were used:

- interviews,
- Questionnaires,
- observations and notes by the researcher and collaborators,
- video recording of participants.

Our questionnaires were used in this research.

1. Pre-virtual reality discomfort questionnaire (Q1).

- This questionnaire can be access at Appendix A section A.1.
- The objective was to map his/her susceptibility to nausea and motion sickness.
- The questionnaire was based on the “Questions of the Motion Sickness Screening Questionnaire” and extracted from Costa et al (2018).

2. Technology use questionnaire (Q2).

- This questionnaire is presented at Appendix A Section A.2.
- The objective was to examine familiarity with video game and VR headsets or discomfort with VR.
- The questionnaire was based on the “Questions of the Technology Use Profile Questionnaire” and extracted from Costa et al (2018).

3. Post-test questionnaires (Q3).

- This questionnaire can be access at Appendix A section A.3.
- This questionnaire is answering each time that a participant plays one of the systems.
- This questionnaire is separate in part A (Q3-A), B (Q3-B) and C (Q3-C).
- Part A - Discomfort questionnaire after virtual reality (safety and tolerability) (Q3-A).
    - Q3-A is to collect levels of any health side effects or any physical discomforts.
    - The questionnaire “Cybersickness Questionnaire” related to health side effects and technology use was based on Costa et al (2018). their questionnaire was adapted from the validated brazilian portuguese version of the Simulator Sickness Questionnaire (KENNEDY,1993) (CARVALHO, 2011), which uses a 5 Likert scale of intensity.
- Part B - Satisfaction questionnaire (acceptability) (Q3-B)
    - Q3-B is a 5 Likert scale, to evaluate if the game is acceptable to users.
    - The Post-test questionnaire, Part B - Satisfaction questionnaire (acceptability) is based on the System Usability Scale (SUS), a 10-item questionnaire with five response options for respondents; from Strongly agree to Strongly disagree (BROOKE, 1996).
- Part C - Satisfaction Interview (Acceptability) (Q3-C)
    - This interview was done each time a system was tested.
    - The interview questions were based on Costa et al (2018).
    - The questions where design to see if their a possibility of using the game in clinics, home as part of their patient treatment. As well if they like or dislike any thing about the game.
    - Question 15 was not asked for being redundant to question 12 and 13 of Q3-C.
    - Question were asked to be written, interviewed participants could speak their mind if they feel necessary.

4. Questionnaire and evaluation interview of physiotherapists (applicability)(Q4).

- This questionnaire can be access at Appendix A section A.4.
- This questionnaire is answer when all systems are tested.
- This questionnaire is separate in part A (Q4-A) and B (Q4-B).
- Part A – Questionnaire (Q4-A).
    - This questionnaire is based on Systems Framework for Postural Control (SFPC). Based on Sibley 2015.
    - This questionnaire was not modified.
    - The questionnaire was use based on Tahmosybayat (2018) that made a literally review in exergame intervention in older adults that used the SFPC.
- Part B – Interview (Q4-B)
    - Answers were asked to be written, interviewed participants could speak their mind if they feel necessary.
    - The questions are focus on applicability to patient treatment.
    - Questions Elaborated by Prof. José Eduardo Pompeu and adapted by the Author of this work.

4.2 First test session: BALLOONS v1.0

An experiment was designed to collect the subjective impressions of specialists in order to evaluate the effectiveness of the first version of the exergame BALLOONS v1.0, as a tool for rehabilitation process of postural and gait problems and to identify what next steps should be taken to continue its development.

4.2.1 Participants

Six physical therapists participated in this first test session. All of them had previous experience with commercial virtual reality technology. They have used virtual reality HMD, for pleasure or research. Meaning this would not be the participants first time using VR in an HMD.

4.2.2 Study design

This experiment was fully within-subject, were all participants were required to test and evaluate both Systems 1 and 2. All participants realized all the tests in one continuous session.

In order to reduce bias due to the order of testing, two subgroups were created, as shown in Table 1. Half of the participants started with System 1 and the other half started with System 2.

Table 1. Group1, number of participants and testing order.

Test Session	Participants	order	1st test	2nd test	3rd test
(Group 1) BALLOONS v1.0	(3) P1, P2, P3	1	(VR) System 1	(VR ODT) System 2	X
(Group 1) BALLOONS v1.0	(3) P4, P5, P6	2	(VR ODT) System 2	(VR) System 1	X
(Group 2) BALLOONS v1.1	(2) P7, P8	3	(VR) System 1	(AR) System 3	X
(Group 2) BALLOONS v1.1	(2) P3, P6	4	(AR) System 3	(VR) System 1	X
(Group 2) BALLOONS v1.1	(3) P9, P10, P11	5	(VR) System 1	(AR) System 3	(VR ODT) System 2
(Group 2) BALLOONS v1.1	(1) P4	6	(AR) System 3	(VR) System 1	(VR ODT) System 2

Source: Author

4.2.3 Procedure

Before beginning the tests, each participant was weighted, submitted to blood limit of the ODT equipment. and to an adapted version of the Ishihara test for color blindness (BIRCH, 1997) available at Attachment A.

The two pre-test questionnaires (Q1 and Q2) were then applied. Next, the rules of the exergame were presented and an explanation of how to use the equipment was given.

The test phase followed. The participants played one of the two systems for 5 minutes without breaks. Participants who had difficulties to play the game due to calibration issues were allowed another attempt after a recalibration process.

At the end of the game session, the participants were asked to answer the questionnaires Q3-A, Q3-B, Q3-C and Q4-A. A small break of 10 minutes was allowed for recovery.

The participants were then conducted to the second System of their group. Another game session of 5 minutes occurred and the post-test questionnaires (Q3-A, Q3-B, Q3-C and Q4-A) were applied for this second system.

At the end of the experiment, each participant had given his/her impressions and thoughts about the two implementations of the exergame.

4.3 Second test session: BALLOONS v1.1

The analysis of results of the first test session, which are described in detail in Chapter 5, guided the improvements to reach version 1.1. This new developed version was then evaluated. Implemented in System 1, and System 2. System 3, using – Augmented Reality – was also implemented and analyzed.

4.3.1 Participants

Eight physical therapists participated in this second session. Three of them have already tested the first version of the exergame. The other five were new participants who had no previous experience with virtual reality technology.

4.3.2 Study Design

This experiment was designed to be fully within-subject, were all participants were required to test and evaluate both Systems 1, 2 and 3. All participants realized all the tests in one continuous session.

In order to reduce bias due to the order of testing, four groups were created, and the participants were attributed to them as demonstrated in Table 1. Due to setup difficulties specific to the ODT (such as entering in the equipment and getting out), it was decided that the System 2 should be tested last in all groups. This decision might result in a biased evaluation because the test order affects the level of tiredness of a participant. However, this bias was accepted, because more than one system would be tested from each participant.

The same procedures for the first test session were conducted, but the game session lasted 10 minutes instead of 5 minutes. In order to measure the perceived intensity of the physical activity, we added a yes or no answer to question 11 “did physical exercise to be able to perform the tasks of the game” from Q3-B and ask in sequence “How intense was the physical exercise” in a Borg CR10 Scale (BORG, 1982). The testing was done, at the Motor Behavior Lab (Lacom). School of Physical Education and Sports, University of São Paulo.

4.4 Considerations

This chapter details the procedure of testing and evaluation with specialists. Based on a mixed-methods survey-based study, giving details of the study design, participants and the procedure. The chapter as well informs the collection of data, the qualitative and quantitative data and the questionnaires used for this testing.

5 RESULTS AND ANALYSES

This chapter describes the data collected in the two sessions from the specialists.

5.1 Analyses of the data System 1

System 1 is in both test groups, the game version in the first group is different with improvement previous describe in this chapter and more in detail in chapter 3. As presented in Figure 37, Group 1 the answers of Q3-A, there is no discomfort. However, in the answers of Group 2, there is some discomfort, tiredness insight shows the biggest percentage. Which increased time and difficulty might have cause an impact on user discomfort. Despite any health aspect reaching moderate discomfort in Q3-A.

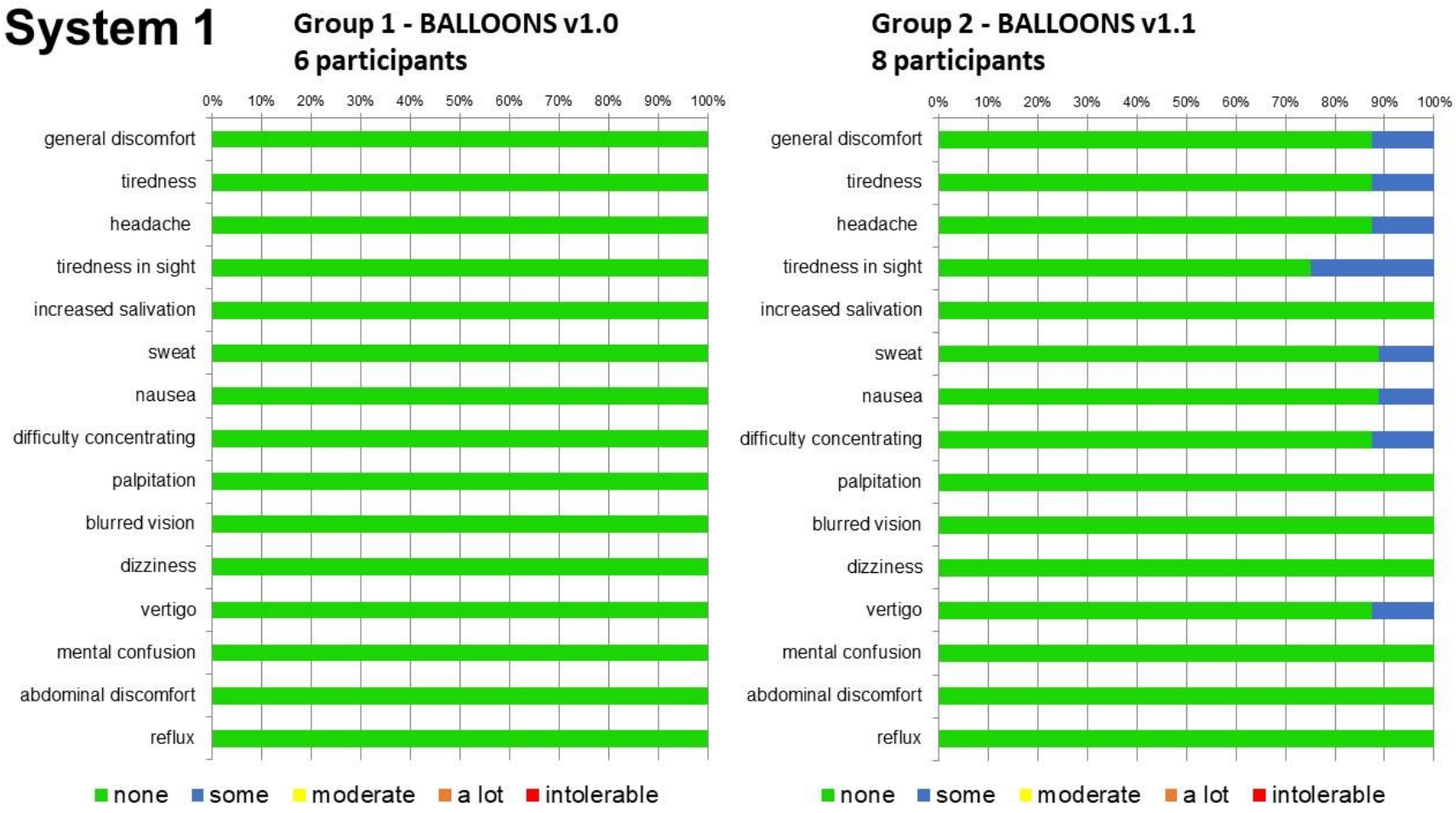


Figure 37: Part A - Questionnaire of discomfort after virtual reality (safety and tolerability) (Q3-A)– Comparison of the two Groups in System 1.

Source: Author

In the other hand, Q3-B data shows from Figure 38 to be on the contrary, question 10 and 11 in the first group are 50% in strongly in disagreeing to over 60% in Group 2. Despite of increased game enjoyment and understanding of game and easier to play in questions 1, 2 and 3 compared to Group 2. The difficulty of the game has influenced because of the increase neutral responded in questions 4 to 8. What concerns is that in question 7 in Group 2 more people feel less safe in contra part question 9 all users strongly agree that is easy to use the VR glasses. The data indicates that players submitted in more constant movement probably fells less safe, decreasing the answer “strongly agree” and “agree” to “neutral” in some responses. Based on the presented data on Q3-B on Group 2 compared to Group 1, 50% to more 60% is the increase of strongly disagree more than they did some physical activity. In the other hand, the percentage of sternly agreeing is 0% to over 20%. Designate that the individuals of the group have different opinions about what is considered physical activity.

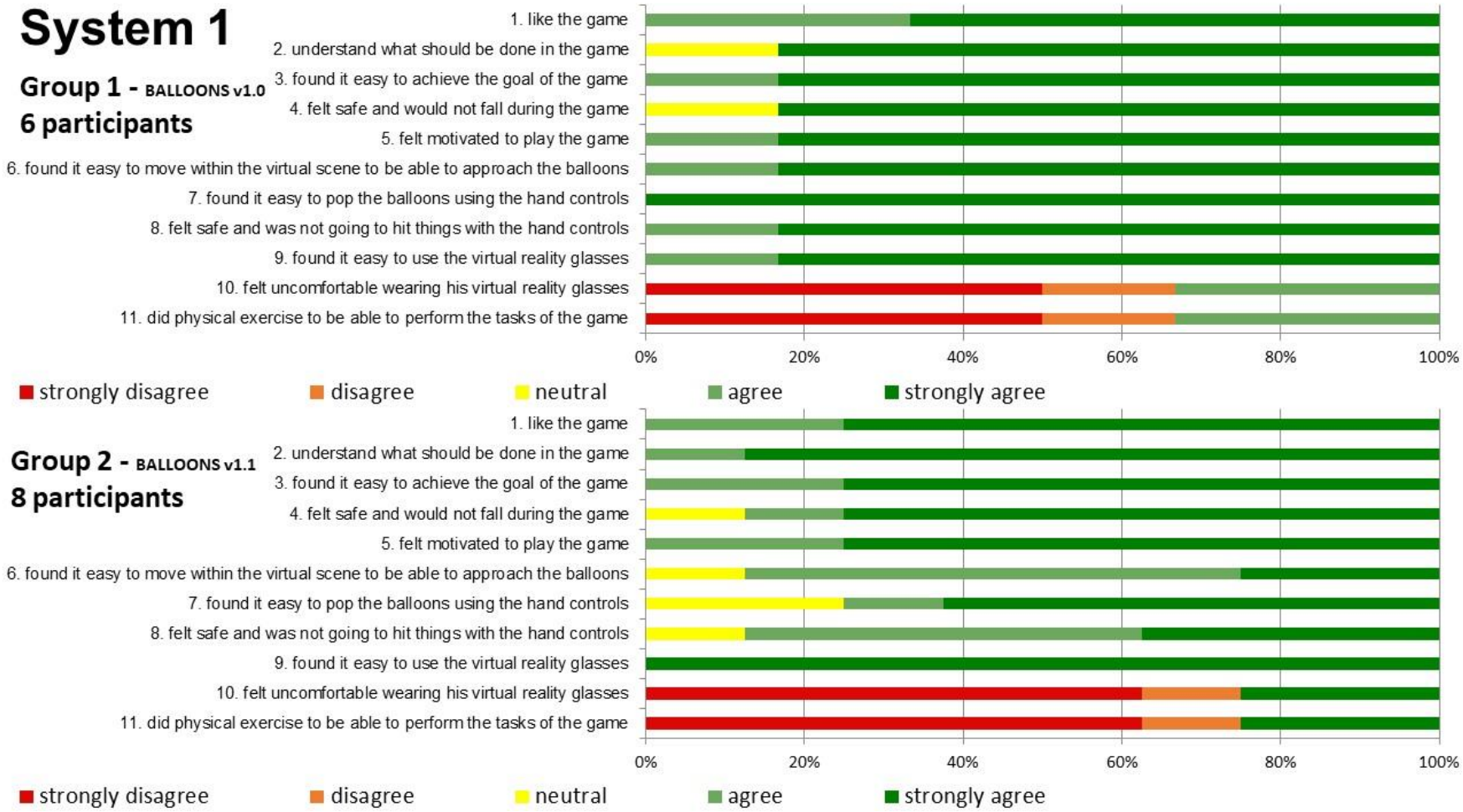


Figure 38: Part B - Satisfaction questionnaire (acceptability) (Q3-B)- Comparison of the two Groups in System 1.

Source: Author

Appendix B presents answers questions and tables, with detailed. Section B.3.2.1. is the answers and tables of Group 1. Section B.3.2.2. the answers and tables as well the added questions in Group 2. The written answers from Q3-C, point to the same issues as Q3-B. This information can be access at Appendix B section B.3.3. for answers and analyses of the data.

5.2 Indications of the data overall System 1

System 1 needs improvement such as, game content, and exercise intensity. In addition, System 1 is highly accepted by participants in both groups and presented stable performance.

5.3 Analyses of the data System 2

System 2 is in both test groups, the game version in the first group is different with improvement previous describe in this chapter. Figure 39, in Group 1 the data of Q3-A, it is noticeable that are answers such as tiredness in sight, sweat, nausea, dizziness and vertigo discomfort, are increase significantly compared to Group 2. Because of the increase time and added changes to the game causes these answers in Group 2. Explaining, that increased active physical activity, in System 2 discomfort caused the increased. Despite any health aspect reaching moderate discomfort. This indicates that the increase activities are pointing out health side effects expected when using VR.

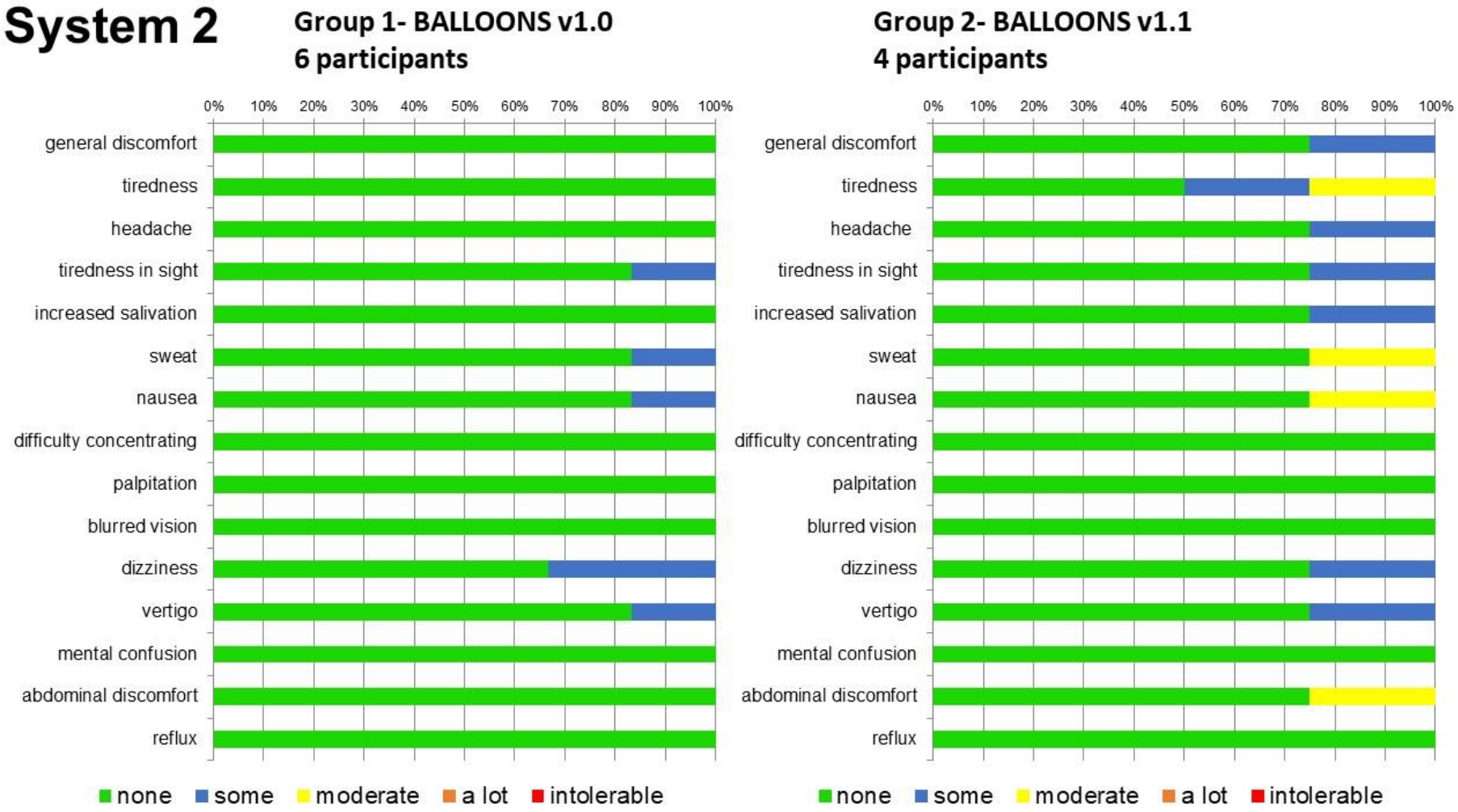


Figure 39: Part A - Questionnaire of discomfort after virtual reality (safety and tolerability) (Q3-A) – Comparison of the two Groups in System 2.

Source: Author

However, Q3-B data presented in Figure 40 shows that question 10 and 11 in the Group 1are 50% in strongly in agreeing to over 70% in Group 2, despite of players increases of game enjoyment and understanding of game and easier to play in questions 2 compared to Group 2. What brings to concern is that that there are more strongly disagree with the questions question 6. In the other hand, if we consider that participants had to use the treadmill it would justify these answers. Contrasting that the added device cause. Because, the users strongly disagree more in usability. Meaning that the impact is existent but not positive overall. A worrisome based on answers Q3-B in Group 2 compared to Group 1. Increase of strongly disagree more than they did some physical activity. Suggesting that the group have's different perspective and opinions, about what they could consider physical activity and the technical issues.

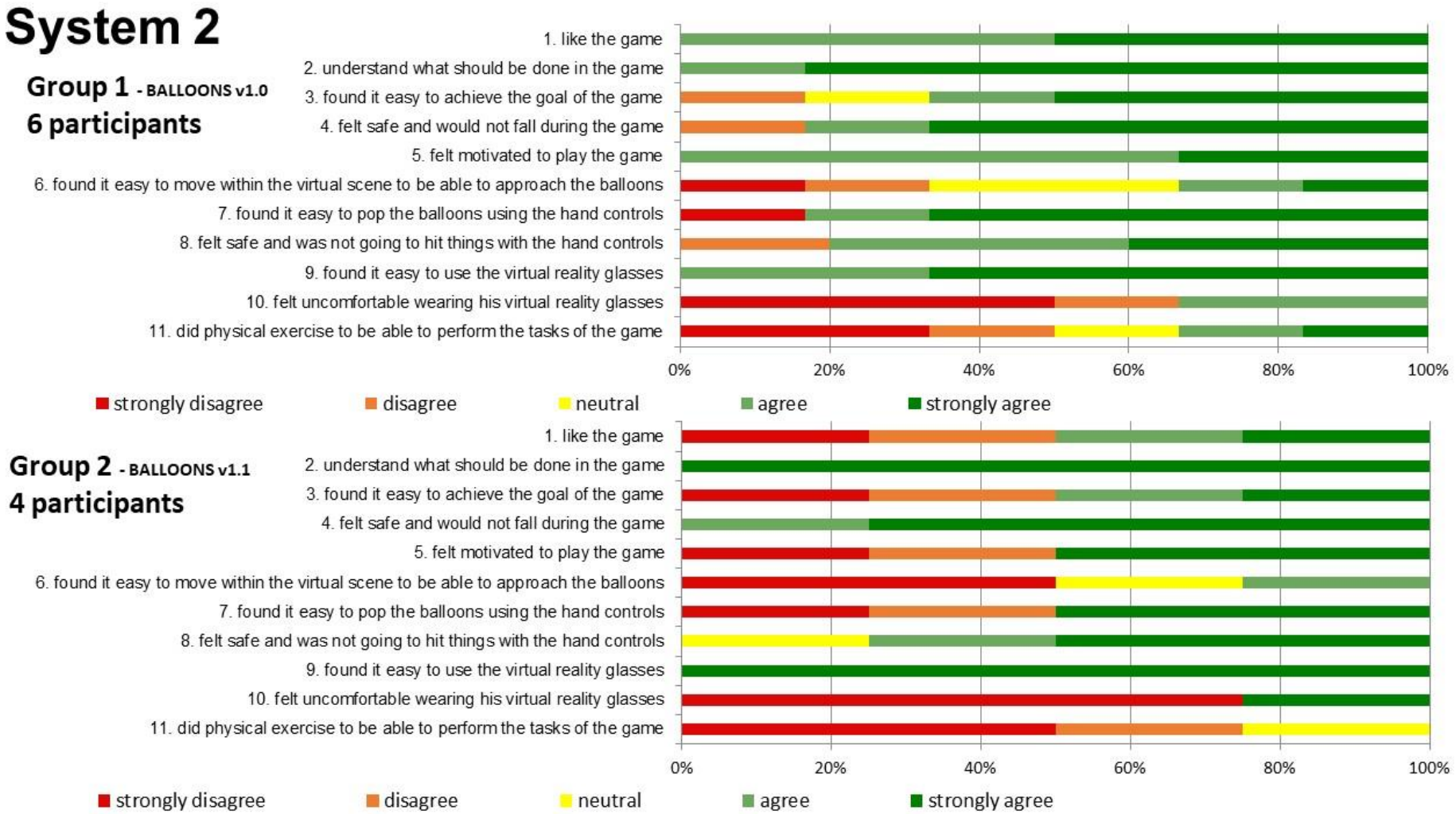


Figure 40: Part B - Satisfaction questionnaire (acceptability) (Q3-B)- Comparison of the two Groups in System 2.

Source: Author

Appendix B section B.3 presents answers and tables, with detailed information. Section B.3.2.1. is the answers and tables of Group 1. Section B.3.2.2. with the added question in Group 2. In the questionnaire's part written answers first a binary, Yes and No question and a written question. Participants could report on relevant to their experience of play in System 2. the written answers from Q3-C, indicate as well to the same issues. This information can be access on the Appendix B section B.3.3.2. and B.3.3.4. for answer and raw data.

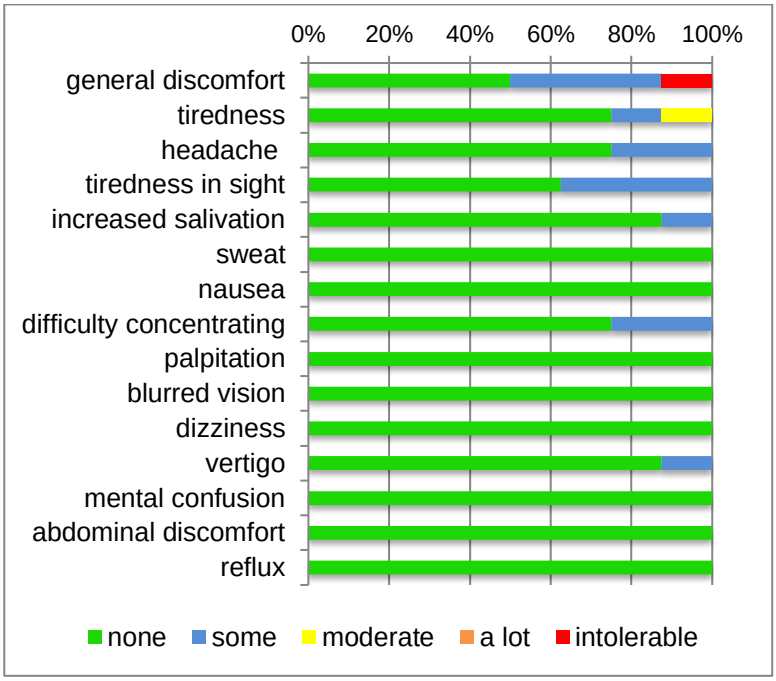
5.4 Indications of System 2

Unfortunately, the technical issues overcome the experience. Meaning that even with modification of the first game it’s not clear, the technical problems overcome the experience of the game. In addition, technological accessibility such as price and space were considered by participants. The technical issues likely to have addressed to have a clear view of the possibilities and applications for future use. However, we should not be discouraging and ignore what is achievable in System 2.

5.5 Analyses of the data System 3

System 3 was only in Group 2. None of the participants had previous experience with the system. Graph 1, data of Q3-A, points there is some discomfort, especially some discomfort. However, percentages are low or non-existing. Considering that even players using ARH had to use the vest for security issues and increased physical activity, we expect it to have some discomfort. This is plausible, because System 1 has some discomfort and System 3, have more discomfort in comparison to System 1 in Group 2.

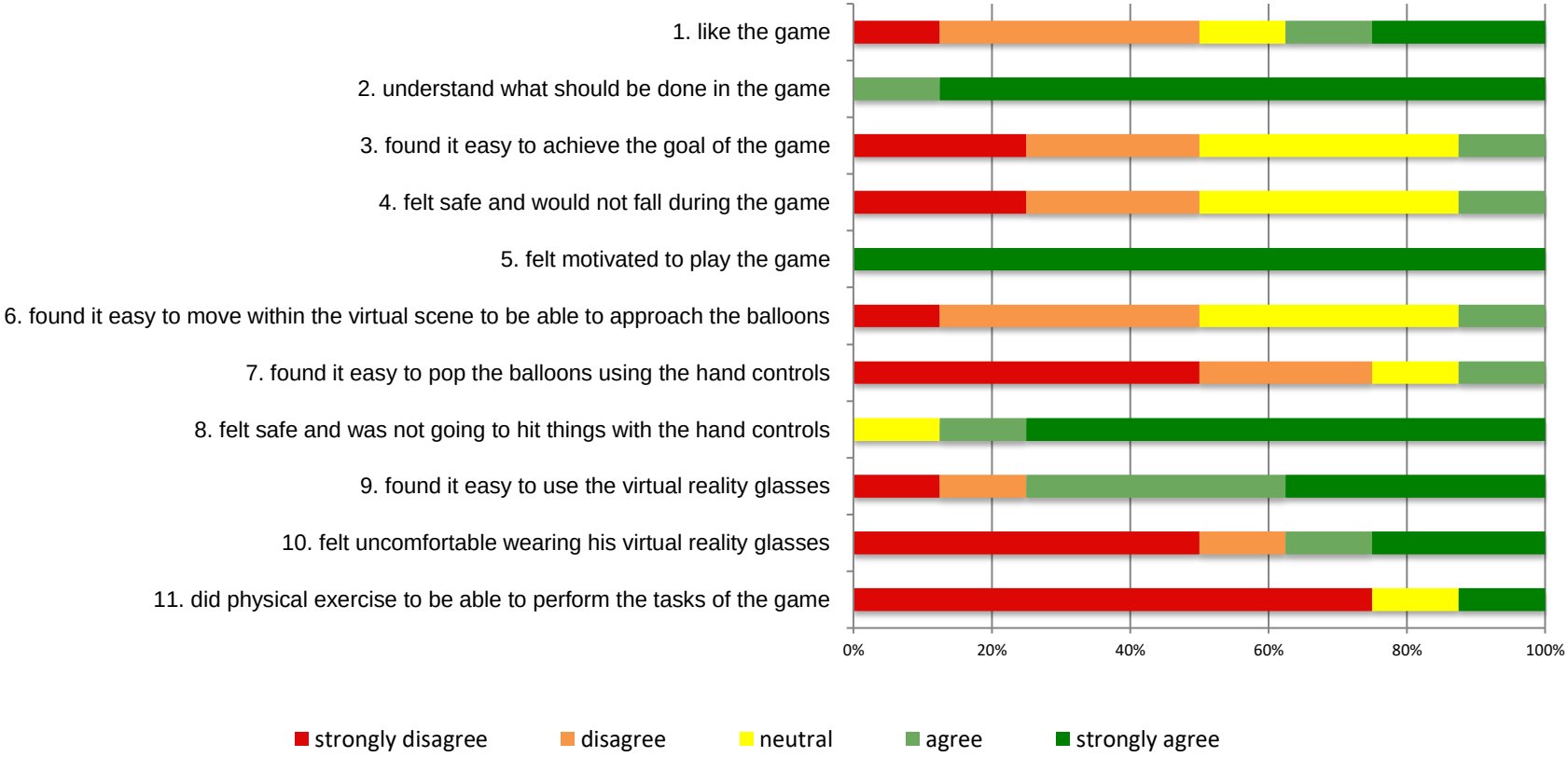
Graph 1. Part A - Questionnaire of discomfort after virtual reality (safety and tolerability) (Q3-A) – System 3.



Source: Author

However, Graph 2 from Q3-B data shows that even being an AR system does not signify necessarily that is a safer system or physically active. In the other hand, it was easy to understand what the activity was, felt motivated and safe. However, the enjoyment was low and felt hard to pop the balloons using hand gestures in this case. Most excruciating thing is that most participants did not felt that they were doing physical activity.

Graph 2. Part B - Satisfaction questionnaire (acceptability)(Q3-B) – System 3.



Source: Author

Appendix B section B.3.3.2. presents answered questions and tables, with detailed information of Q3-B. Section B.3.1.2. is the answers and tables of Group 2 in Q3-A. The written answers from Q3-C, point as well to the same issues presented in Graph 2. This information can be access on the Appendix B section B.3.3.5. for answer and analyses of the data.

5.6 Indications of System 3

Unfortunately, the technical issues overcome the experience, as well in System 3. Besides being less impactful. Another issue is interaction. Because of its different form of interaction, is necessary to learn how to use it first, impacted the experience. Besides the technical issues. System 3 is a strong candidate despite its technical limitations and issues, for alternatives of players that are more sensitive to HMD. This means that despite the technical issues, they can use as well augmented reality for this virtual rehabilitation. When the technology matures and improves it will probably be a welcome addition for virtual rehabilitation in general.

5.7 Summary of results

The initial results of this research confirmed the existence of a lack of exercise intensity and the necessity of adding more cognitive activities and challenges to the game and content in all 3 Systems. The calibration in the treadmill must improve and increase its sensitivity to make it easier to move and frustrate less and learn faster how to use the treadmill. Another technical issue is to use a lighter HMD and if possible, a wireless solution VR solution that users can't tangle with the cable while practicing their rehabilitation so that can move even more freely and move to intensify their bodies. Besides of all this for improvement, based on the professionals' interviewed reported, qualitative and quantitative results the game and the installment solutions show that can be used for rehabilitation and that it can impact. Adding software changes allows use in a clinic, accompanied with a health professional and be a supplement for treatment. Overall, the game BALLOONS and its Systems have the potential to favor virtual rehabilitation and assistive service for falling elders. In addition, System 1 in general has showed the most technically stable and more acceptable by

specialists for clinical use, consequently BALLOONS V1.2 was made, for System 1 with the HTC Vive due to better software combability. System 1 with the HTC Vive and BALLOONS v1.2. is being tested clinically by researches from Department of Physical Therapy, Speech Therapy and Occupational Therapy. School of Medicine, University of São Paulo. For this reason, it will be discussed in future works. The exploration of technologies that can be used for lower limbs, that integrate with VR and capture a more precise walk movement for virtual environments. This is important not just for physical therapy rehabilitation, but for VR in general, to integrate better the human body in immersive environments. Last, explain constantly to participants, through video or tutorials so that all participants have guarantee well explain instructions.

5.8 Considerations

This chapter presented the results of BALLOONS v1.0 and BALLOONS v1.1, applied in 3 systems and evaluated with physical therapists. Tested in two groups Group 1 and Group 2. The chapter showed the analyses of the collected data, and table and figures to illustrate the results. The results, confirms that the future steps are to increase exercise intensity, adding more cognitive activities and challenges. In addition, System 1 has presented the most favorable to be in used in rehabilitation.

6 FINAL CONSIDERATIONS

The results presented in this research indicate positive assessment by experts in elderly fallers therapy, for the two immersive VR and one immersive AR implementations of the BALLOONS game, in terms of safety, tolerability and acceptability as a virtual rehabilitation tool. The considerations about the design of an exergame for elderly fallers:

1. Must have health professionals involved in all stages of development.
2. Use strategies of rapid prototyping and successive iterations
3. Use platforms that can be used for physical activity
4. Give consistent visual feedback (users need to clearly perceive when they touch an object in the scenario)
5. Give preference to technologies that are more flexible to use and adapt and can be easily develop.
6. Develop the game as simple as possible, for flexibility to adapt in other platforms and to change the game based on feedback of the specialist.
7. Guarantee that participants will not have severe side effects.
8. Five requirements of Choi (2017): exercise intensity, attendance, safety, engagement, easy to do.

The main considerations for evaluation of an exergame for elderly fallers, by rehabilitation specialists, that should be taken to establish standardized evaluation procedures are:

1. safety assessment
2. tolerability
3. acceptability
4. applicability potential

Besides the contributions of this thesis to increase the knowledge in the virtual rehabilitation area, the BALLOONS game and its implementations developed for this research proved to be useful platforms for further investigation on virtual rehabilitation for elderly fallers.

6.1 Future work

In order to continue the investigation, there are some important improvements that should be done in the BALLOONS game and the immersive implementations developed in technical improvements:

- Better harness that could hold users and give more freedom of movement in a broader space.
- Use wireless or standalone, and lighter HMD.
- Include more activities and challenges in the game content and the possibility of level of difficulty adjustments by therapists.
- Add more positive feedback to stimulate patients and include more physically intense exergames.
- Include physiological measurements exercise intensity for a more objective way of evaluating.

After the suggested technical improvements, it is recommended a new evaluation with experts and new adjustments, if necessary. Pre-clinical and clinical testing with older adults' non-experts are recommended to calibrate a clinical test with patients to better evaluate applicability, safety, tolerability, acceptability.

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APPENDIX A – COLLECTION INSTRUMENTS

All the instruments presented in this appendix were included in the research plan submitted and approved by the Ethics Committee in Research. Table 2 presents an overview about the research instruments presented in this appendix. Following, all the questionnaires are presented in the original version, in portuguese, as they were applied in this research. For each questionnaire it is also included a translation to English for the purpose of comprehension here.

Table 2. Overview about the questionnaires for clinical research presented in appendix A

	Instrument	Title of the applied research instrument	Authorship / reference	Page
Q1	Pre-virtual reality discomfort questionnaire	Questionário de desconforto pré realidade virtual	Costa et al (2018)	108
Q2	Technology use questionnaire	Questionário de uso de tecnologia	Costa et al (2018), adapted by the author for this work.	110
Q3	Post-test questionnaire	Questionário pós-teste	Costa et al (2018), Kennedy (1993), Carvalho (2011).	115
Q3.A	Discomfort questionnaire after virtual reality (safety and tolerability)	Parte A - Questionário de desconforto pós realidade virtual (segurança e tolerabilidade)	Costa coet al (2018), Kennedy (1993), Carvalho (2011).	115
Q3.B	Satisfaction questionnaire (acceptability)	Parte B - Entrevista de satisfação (aceitabilidade)	Brooke (1996), adapted by the author for this work.	117
Q3.C	Satisfaction interview (acceptability)	Parte C - Entrevista de satisfação (aceitabilidade)	Costa et al (2018)	120
Q4	Questionnaire and evaluation interview of physiotherapists (applicability)	Questionário e entrevista de avaliação dos fisioterapeutas (aplicabilidade)	Sibley (2015),Tahmosybayat (2018)	123
Q4.A	Questionnaire	Parte A - Questionário	Sibley (2015),Tahmosybayat (2018)	123
Q4.B	Interview	Parte B - Entrevista	Elaborated by Prof. José Eduardo Pompeu and adapted for this work.	130

Source: Author

A.1. Pre-virtual reality discomfort questionnaire (Q1).

Data:

Nome: _____ Idade: ____ Sexo: M ( ) F ( )

1. O sr(a) está sentindo algum desconforto neste momento?

( ) Não ( ) Sim

Se sim, por favor, descreva: _____

2. O sr(a) teve episódios de enjôo ou vômito hoje ou recentemente?

( ) Não ( ) Sim

3. O sr(a) possui histórico de enjôo relacionado a meio de transporte?

( ) Não ( ) Sim

Se sim, por favor, descreva onde (carro, trem, avião, barco, etc) e quando (recentemente ou há muito tempo):

_____

4. O sr(a) já sentiu tontura ou náuseas enquanto assistia a um filme em uma tela grande (ex. cinema)?

( ) Não ( ) Sim

5. O sr(a) sente tontura ou enjôo quando lê em um carro ou ônibus em movimento?

( ) Não ( ) Sim

6. O sr(a) prefere ser o motorista, ao invés do passageiro, porque senão sente tontura ou náuseas?

( ) Não ( ) Sim

_____

Observação: Caso o(a) participante responda SIM para alguma das questões anteriores, excluí-lo(a) dos testes, exceto se tiver respondido SIM na questão 3, mas relatar episódio único não recente.

A.1.1. English (translation) of the Pre-virtual reality discomfort questionnaire (Q1).

Questions translated by the author.

Table 3. English (translation) of the Pre-virtual reality discomfort questionnaire (Q1).

Question/Pergunta	Translation (English)	Original (Portuguese)
Q1-1	1. Are you feeling any discomfort currently? () No () Yes If so, please describe:	1. O sr(a) está sentindo algum desconforto neste momento? () Não () Sim Se sim, por favor descreva:
Q1-2	2. Have you had episodes of motion sickness or vomiting today or recently? () No () Yes	2. O sr(a) teve episódios de enjôo ou vômito hoje ou recentemente? () Não () Sim
Q1-3	3. Do you have a history of motion sickness? () No () Yes If so, please describe where (car, train, plane, boat, etc.) and when (recently or long ago):	3. O sr(a) possui histórico de enjôo relacionado a meio de transporte? Se sim, por favor, descreva onde (carro, trem, avião, barco, etc) e quando (recentemente ou há muito tempo): () Não () Sim
Q1-4	4. Have you ever felt dizzy or nauseous while watching a movie on a large screen (e.g. cinema)? () No () Yes	4. O sr(a) já sentiu tontura ou náuseas enquanto assistia a um filme em uma tela grande (ex. cinema)? () Não () Sim
Q1-5	5. Do you feel dizzy or sick when reading from a moving car or bus? () No () Yes	5. O sr(a) sente tontura ou enjôo quando lê em um carro ou ônibus em movimento? () Não () Sim
Q1-6	6. Do you prefer to be the driver, rather than the passenger, because otherwise you feel dizzy or nauseous? () No () Yes	6. O sr(a) prefere ser o motorista, ao invés do passageiro, por que senão sente tontura ou náuseas? () Não () Sim

Source: Author

A.2. Technology use questionnaire (Q2).

Data:

Nome: _____ Idade: ____ Sexo: M ( ) F ( )

1. O(a) sr(a) possui celular?

( ) Não ( ) Sim

Se sim,

1.1 Seu celular tem acesso à internet?

( ) Não ( ) Sim

Se sim,

1.1.1 Com que frequência o sr(a) utiliza a internet do celular?

( ) Nunca ( ) Em torno de uma vez por mês

( ) Em torno de uma vez por semana ( ) Quase todos os dias

1.2 O (a) sr(a) joga algum jogo no celular?

( ) Nunca ( ) Em torno de uma vez por mês

( ) Em torno de uma vez por semana ( ) Quase todos os dias

2. Com que frequência o(a) sr(a) utiliza computador?

( ) Nunca ( ) Em torno de uma vez por mês

( ) Em torno de uma vez por semana ( ) Quase todos os dias

3. Com que frequência o(a) sr(a) joga videogame atualmente?

( ) Nunca ( ) Em torno de uma vez por mês

( ) Em torno de uma vez por semana ( ) Quase todos os dias

Se não respondeu Nunca

3.1.1. Quais plataformas utiliza para jogar ? (anotar todas)

( ) PC ( ) smartphone ( ) tablet ( ) Nintendo switch ( ) XBOX ONE

( ) wii ( ) Wii U ( ) PlayStation 4 ( ) PlayStation 3 ( ) Xbox 360

( ) DS ( ) Psvita ( ) PSP ( ) 3DS

( ) Outra(s) _____

3.1.2. Qual plataforma utiliza com maior frequência para jogar ? (anotar uma apenas)

( ) PC ( ) smartphone ( ) tablet ( ) Nintendo switch ( ) XBOX ONE

( ) wii ( ) Wii U ( ) PlayStation 4 ( ) PlayStation 3 ( ) Xbox 360

( ) DS ( ) Psvita ( ) PSP ( ) 3DS

( ) Outra _____

4. Você já usou algum aparelho de realidade virtual?

( ) Não ( ) Sim

Se sim, 4.1. Qual?

( ) HTC Vive ( ) Oculus rift ( ) Windows Mixed Reality

( ) GearVR ( ) Google cardboard

( ) Outra(s) _____

4.2. Com qual tipo de conteúdo? (anote todas que mencionar)

( ) Vídeo ( ) filme ( ) fotográfica ( ) experiência interativa ( ) jogo

( ) Outro(s) _____

4.3. Com que frequência você utiliza realidade virtual?

( ) Raramente ( ) Em torno de uma vez por mês

( ) Em torno de uma vez por semana ( ) Quase todos os dias

4.4. Em que situações usa ou usou realidade virtual? Por favor, comente. (anotar com o maior detalhamento possível)

_____
_____
_____
_____
_____
_____

5. Há algum aparelho de realidade virtual na sua residência?

( ) Não ( ) Sim

Se sim, 5.1. Qual?

( ) HTC Vive ( ) Oculus rift ( ) Windows Mixed Reality

( ) GearVR ( ) Google cardboard ( ) Outra(s) _____

5.2. Com qual tipo de conteúdo? (anote todas que mencionar)

( ) Vídeo ( ) filme ( ) fotográfica ( ) experiência interativa ( ) jogo

( ) Outro(s) _____

5.3. A quem pertence e quem utiliza? Por favor, comente. (anotar com o maior detalhamento possível)

_____
_____
_____
_____
_____
_____

6. Gostaria de acrescentar alguma informação que considere relevante sobre suas experiências anteriores relacionadas ao uso de tecnologia? (anotar com o maior detalhamento possível)

_____
_____
_____
_____
_____
_____
_____
_____
_____

A.2.1. English (translation) of the Technology use questionnaire (Q2).

The questions of Technology use questionnaire (Q2) in Portuguese (original), can be found in Appendix A.2.

Table 4. English (translation) of the Technology use questionnaire (Q2).

Question/Pergunta	Translation (English)	Original (Portuguese)
Q2-1	1. Do you have a cell phone? () No () Yes	1. O(a) sr(a) possui celular? () Sim () Não
Q2-1.1	1.1 Does your mobile phone have internet access? () No () Yes If so,	1.1 Seu celular tem acesso à internet? () Sim () Não Se sim,
Q2-1.1.1	1.1.1 How often do you use mobile internet? () Never () Around once a month () Around once a week () Almost every day	1.1.1 Com que frequência o sr(a) utiliza a internet do celular? () Nunca () Em torno de uma vez por mês () Em torno de uma vez por semana () Quase todos os dias
Q2-1.2	1.2 Do you play any games on your mobile phone? () Never () Around once a month () Around once a week () Almost every day	1.2 O (a) sr(a) joga algum jogo no celular? () Nunca () Em torno de uma vez por mês () Em torno de uma vez por semana () Quase todos os dias
Q2-2	2. How often do you use a computer? () Never () Around once a month () Around once a week () Almost every day	2. Com que frequência o(a) sr(a) utiliza computador? () Nunca () Em torno de uma vez por mês () Em torno de uma vez por semana () Quase todos os dias
Q2-3	3. How often do you currently play video games? () Never () Around once a month () Around once a week () Almost every day	3. Com que frequência o(a) sr(a) joga videogame atualmente? () Nunca () Em torno de uma vez por mês () Em torno de uma vez por semana () Quase todos os dias
Q2-3.1.1	If not answered Never 3.1.1. What platforms do you use to play? (write them all down) () PC () smartphone () tablet () Nintendo switch () XBOX ONE () Wii () Wii U () PlayStation 4 () PlayStation 3 () Xbox 360 () DS () Psvita () PSP () 3DS( ) Others()	Se não respondeu Nunca3.1.1. Quais plataformas utiliza para jogar ? (anotar todas)() PC () smartphone () tablet () Nintendo switch () XBOX ONE () Wii () Wii U () PlayStation 4 () PlayStation 3 () Xbox 360 () DS () Psvita () PSP () 3DS( ) Outros()
Q2-3.1.2	3.1.2. Which platform do you use most often to play? (write one down only) () PC () smartphone () tablet () Nintendo switch () XBOX ONE () wii () Wii U () PlayStation 4 () PlayStation 3 () Xbox 360 () DS () Psvita () PSP () 3DS () Other	3.1.2. Qual plataforma utiliza com maior frequência para jogar ? (anotar uma apenas) () PC () smartphone () tablet () Nintendo switch () XBOX ONE () wii () Wii U () PlayStation 4 () PlayStation 3 () Xbox 360 () DS () Psvita () PSP () 3DS () Outra

Q2-4	4. Have you ever used any virtual reality gadgets? () No () Yes	4. Você já usou algum aparelho de realidade virtual? () Não () Sim
Q2-4.1	If so, 4.1. Which? () HTC Vive () Oculus rift () Windows Mixed Reality () GearVR () Google cardboard ( ) Others ()	Se sim, 4.1. Qual? () HTC Vive () Oculus rift () Windows Mixed Reality () GearVR () Google cardboard ( ) Outros ()
Q2-4.2	4.2. What type of content? (write down all you mention) () Video () movie () photographic () interactive experience () game ( ) Others	4.2. Com qual tipo de conteúdo? (anote todas que mencionar) () Video () movie () photographic () interactive experience () game ( ) Outros
Q2-4.3	4.3. How often do you use virtual reality? () Rarely () Around once a month () Around once a week () Almost every day	4.3. Com que frequência você utiliza realidade virtual? () Nunca () Em torno de uma vez por mês () Em torno de uma vez por semana () Quase todos os dias
Q2-4.4	4.4. In what situations do you use, or have you used virtual reality? Please comment. (note in as much detail as possible)	4.4. Em que situações usa ou usou realidade virtual? Por favor, comente. (anotar com o maior detalhamento possível)
Q2-5	5. Are there any virtual reality devices in your home? () No () Yes	5. Há algum aparelho de realidade virtual na sua residência? () Não () Sim
Q2-5.1	If so, 5.1. Which? () HTC Vive () Oculus rift () Windows Mixed Reality () GearVR () Google cardboard () Other	Se sim, 5.1. Qual? () HTC Vive () Oculus rift () Windows Mixed Reality () GearVR () Google cardboard () Outros
Q2-5.2	5.2. What type of content? (write down all you mention) () Video () movie () photographic () interactive experience () game ( ) Others	5.2. Com qual tipo de conteúdo? (anote todas que mencionar) () Video () movie () photographic () interactive experience () game ( ) Outros
Q2-5.3	5.3. Who does it belong to and who does it use? Please comment. (note in as much detail as possible)	5.3. A quem pertence e quem utiliza? Por favor, comente. (anotar com o maior detalhamento possível)
Q2-6	6. Would you like to add any information that you consider relevant about your past experiences related to technology use? (note in as much detail as possible)	6. Gostaria de acrescentar alguma informação que considere relevante sobre suas experiências anteriores relacionadas ao uso de tecnologia? (anotar com o maior detalhamento possível)

Source: Author

A.3. Post-test questionnaire (Q3).

A.3.1. Part A - Discomfort questionnaire after virtual reality (safety and tolerability) (Q3-A).

Nome: _____ Idade: ____ Sexo: M ( ) F ( )

Data: _____ Horário: _____

Grupo de estudo: ( ) E1 ( ) E2 ( ) J1 ( ) J2 ( ) I1 ( ) I2

Sistema utilizado: ( ) COGMIS-P ( ) COGMIS-G

Parte A - Questionário de desconforto pós realidade virtual (segurança e tolerabilidade)

Por favor, assinale com um X a intensidade do desconforto que o (a) sr(a) sentiu, em relação a cada um dos aspectos listados na tabela.

Aspecto	1 nenhum	2 algum	3 moderado	4 bastante	5 intolerável
Desconforto geral					
Cansaço					
Dor de cabeça					
Cansaço na vista					
Aumento da salivação					
Suor					
Náusea					
Dificuldade de concentração					
Palpitação					
Visão borrada					
Tontura					
Vertigem					
Confusão mental					
Desconforto abdominal					
Refluxo					

A.3.1.1. English (translation) of the Part A - Discomfort questionnaire after virtual reality (safety and tolerability) (Q3-A).

Table 5. English (translation) of the Part A - Discomfort questionnaire after virtual reality (safety and tolerability) (Q3-A) and question order.

	Englsih/ Portuguese	1	2	3	4	5
	Aspect/ Aspecto	nome/ nenhum	some/ algum	moderate/ moderado	a lot/ bastante	intolerable/ intolerável
Question/ Pergunta						
Q3-A-1	General discomfort/ Desconforto geral					
Q3-A-2	Tiredness/ Cansaço					
Q3-A-3	Headache/ Dor de cabeça					
Q3-A-4	Tiredness insight/ Cansaço na vista					
Q3-A-5	Increased salivation/ Aumento da salivação					
Q3-A-6	Sweat/ Suor					
Q3-A-7	Náusea/ Náusea					
Q3-A-8	Difficulty concentrating/ Dificuldade de concentração					
Q3-A-9	Palpitation/ Palpitação					
Q3-A-10	Blurred vision/ Visão borrada					
Q3-A-11	Dizziness/ Tontura					
Q3-A-12	Vertigo/ Vertigem					
Q3-A-13	Mental confusion/ Confusão mental					
Q3-A-14	Abdominal discomfort/ Desconforto abdominal					
Q3-A-15	Reflux/Refluxo					

Source: Author

A.3.2. Part B - Satisfaction questionnaire (acceptability) (Q3-B).

Parte B - Questionário de satisfação (aceitabilidade)

Afirmação	Discordo totalmente	Discordo	neutro	Concordo	Concordo totalmente
1. O(a) Sr(a). gostou do jogo					
2. O(a) Sr(a). conseguiu entender o que deveria ser feito no jogo					
3. O(a) Sr(a). achou fácil atingir o objetivo do jogo.					
4. O(a) Sr(a). se sentiu seguro(a) e que não ia cair durante o jogo					
5. O(a) Sr(a). se sentiu motivado a jogar o jogo.					
6. O(a) Sr(a). achou fácil se deslocar dentro do cenário virtual para poder se aproximar dos balões.					
7. O(a) Sr(a). achou fácil estourar os balões usando os controles de mão.					
8. O(a) Sr(a). se sentiu seguro e que não ia bater nas coisas com os controles de mão.					
9. O(a) Sr(a). achou fácil de utilizar os óculos de realidade virtual.					
10. O(a) Sr(a). sentiu incômodo ao usar os óculos de realidade virtual.					
11. O(a) Sr(a). fez exercício físico para conseguir executar as tarefas do jogo.					

A.3.2.1. English (translation) of the Part B - Satisfaction questionnaire (acceptability) (Q3-B).

Table 6. English (translation) of the Part B - Satisfaction questionnaire (acceptability) (Q3-B).

		Affirmation/ Afirmação	Strongly Disagree/ Discordo totalmente	Disagree/ Discordo	Neutral/ Neutro	Agree/ Concordo	Strongly Agree/ Concordo Totalmente
Q3-B-1	like the game/ O(a) Sr(a). gostou do jogo						
Q3-B-2	understand what should be done in the game/ O(a) Sr(a). conseguiu entender o que deveria ser feito no jogo						
Q3-B-3	found it easy to achieve the goal of the game/ O(a) Sr(a). achou fácil atingir o objetivo do jogo.						
Q3-B-4	felt safe and would not fall during the game/ O(a) Sr(a). se sentiu seguro(a) e que não ia cair durante o jogo						
Q3-B-5	felt motivated to play the game/ O(a) Sr(a). se sentiu motivado a jogar o jogo.						
Q3-B-6	found it easy to move within the virtual scene to be able to approach the balloons/ O(a) Sr(a). achou fácil se deslocar dentro do cenário virtual para poder se aproximar dos balões.						
Q3-B-7	found it easy to pop the balloons using the hand controls/ O(a) Sr(a). achou fácil estourar os balões usando os controles de mão.						
Q3-B-8	felt safe and was not going to hit things with the hand controls/ O(a) Sr(a). se sentiu seguro e que não ia bater nas coisas com os controles de mão.						

Q3-B-9	found it easy to use the virtual reality glasses/ O(a) Sr(a). achou fácil de utilizar os óculos de realidade virtual.						
Q3-B-10	felt uncomfortable wearing his virtual reality glasses/ O(a) Sr(a). sentiu incômodo ao usar os óculos de realidade virtual.						
Q3-B-11	did physical exercise to be able to perform the tasks of the game/ O(a) Sr(a). fez exercício físico para conseguir executar as tarefas do jogo.						

Source: Author

A.3.3. Part C - Satisfaction Interview (Acceptability) (Q3-C).

Parte C - Entrevista de satisfação (aceitabilidade)

12. O(a) Sr(a). acha que seria possível alguém jogar este jogo numa clínica de reabilitação ?
( ) Sim ( ) Não
Justifique, por favor.

_____

_____

_____

_____

_____

13. O(a) Sr(a). acha que seria possível alguém jogar este jogo em casa? ( ) Sim ( ) Não
Justifique, por favor.

_____

_____

_____

_____

_____

14. O(a) Sr(a) tem alguma sugestão, elogio ou crítica? Escreva.

_____

_____

_____

_____

_____

_____

<<<< Questão válida APENAS para os Grupos I1 e I2 >>>>
15. O(a) Sr(a). continuaria utilizando este sistema para treinamento de equilíbrio após o fim desse projeto? ( ) Sim ( ) Não
Justifique, por favor.

_____

_____

_____

_____

_____

A.3.3.1. English (translation) of the Part C - Satisfaction Interview (Acceptability) (Q3-C).

Table 7. English (translation) of the Part C - Satisfaction Interview (Acceptability) (Q3-C).and question order.

	Translation (English)	Original (Portuguese)
Q3-C-12	Do you think it would be possible for someone to play this game in a rehabilitation clinic? ( )Yes ( )No	O(a) Sr(a). acha que seria possível alguém jogar este jogo numa clínica de reabilitação? ( ) Sim ( ) Não
Q3-C-13	Do you think it would be possible for someone to play this game at home? ( ) Yes ( )No	O(a) Sr(a). acha que seria possível alguém jogar este jogo em casa? ( ) Sim ( ) Não
Q3-C-14	Do you have any suggestions, compliments or criticisms? Write.	O(a) Sr(a) tem alguma sugestão, elogio ou crítica? Escreva.
Q3-C-15	Would you continue to use this system for balance training after the end of this project? ( ) Yes ( )No Justify, please.	O(a) Sr(a). continuaria utilizando este sistema para treinamento de equilíbrio após o fim desse projeto? ( ) Sim ( ) Não Justifique, por favor.

Source: Author

A.4. Questionnaire and evaluation interview of physiotherapists (applicability) (Q4).

A.4.1. Part A – Questionnaire (Q4-A).

Nome: _____ Idade: ____ Sexo: M ( ) F ( )

Data: _____ Horário: _____

Grupo de estudo: ( ) E1 ( ) E2

PARTE A - Questionário

Item avaliado		**Descrição**	0,00	0,25	0,50	0,75	1,00
1. Limitação biomecânica: graus de liberdade, força, limites de estabilidade	Estabilidade Funcional: o teste capacita o movimento	Testa a capacidade de mover o centro de massa o máximo possível nas direções AP e ML dentro da base de suporte					
	Sistema Motor Central	Testa alongamento e coordenação suficiente através da atividade física do jogo					
	Estabilidade Estática	Testa a capacidade de manter a posição do centro de massa em posição não suportada quando a base do suporte não muda (pode incluir postura larga, postura estreita de 1 perna, tandem, alguma condição permanente)					
2. Orientação espacial: percepção da gravidade e verticalidade	Verticalidade	Testa a capacidade de orientar adequadamente em relação à gravidade (por exemplo, avaliação de lean)					

3. Estratégias motoras: reativo, antecipatório, voluntário	Controle Postural Reativo	Testa a capacidade de recuperar a estabilidade após uma perturbação externa para trazer o centro de massa dentro da base de apoio através de movimentos corretivos (por exemplo, tornozelo, quadril e estratégias)					
	Controle Postural Antecipatório	Testa a capacidade de mudar o centro de massa antes de um movimento voluntário discreto (por exemplo, levantando perna, levantar o braço, virar a cabeça)					
4. Controle dinâmico: marcha, proativo	Estabilidade Dinâmica	Testa a capacidade de exercer controle contínuo do centro de massa quando a base do suporte é mudando (por exemplo, durante a marcha e transições posturais)?					
5. Estratégia sensorial: integração, reponderação	Integração Sensorial	Testa a capacidade de repor a informação sensorial (visão, vestibular, somatossensorial) quando entrada alterada					

6. Processamento cognitivo: atenção, aprendizagem	Influência cognitiva	Testa a capacidade de manter a estabilidade enquanto responde aos comandos durante a tarefa ou comparecer para tarefas adicionais (por exemplo, dupla tarefa)					

A.4.1.1. English (Original) of the Questionnaire and evaluation interview of physiotherapists (applicability) (Q4-A).

Table 8 extracted information from Tahmosybayat et al., 2018, and the author of this table the information and put on an order.

Table 8. English (Original) of Q4-A questions and question order.

	Evaluated item/ Item avaliado		Description/ Descrição	0,0	0,25	0,50	0,75	1,00
Q4-A-1	1. Biomechanical constraints: degrees of freedom,strength, limits of stability 1. Limitação biomecânica: graus de liberdade, força, limites de estabilidade.	1 Functional Stability 1 Estabilidade Funcional: o teste capacita o movimento	Test the ability to move the centre of mass as far as possible in the AP and ML directionswithin the base of support? Testa a capacidade de mover o centro de massa o máximo possível nas direções AP e ML dentro da base de suporte					
Q4-A-2		2 Underlying Motor Systems 2 Sistema Motor Central	Test strength and coordination sufficiently through the physical activity of the game? Testa alongamento e coordenação suficiente através da atividade física do jogo					

Q4-A-3		3 Static Stability 3 Estabilidade Estática	Test the ability to maintain position of the centre of mass in unsupported stance when the baseof the support does not change (May include wide stance, narrow, 1-legged stance, tandem,any standing condition)? Testa a capacidade de manter a posição do centro de massa em posição não suportada quando a base do suporte não muda (pode incluir postura larga, postura estreita de 1 perna, tandem, alguma condição permanente)				
Q4-A-4	2. Orientation in space: perception of gravity,verticality	4 Verticality 4 Verticalidade	Test the ability to orient appropriately with respect to gravity (e.g. evaluation of lean)? Testa a capacidade de orientar adequadamente em relação à gravidade (por exemplo, avaliação de lean)				

Q4-A-5	3. Movement strategies: reactive, anticipatory,voluntary 3. Estratégias motoras: reativo, antecipatório, voluntário	5 Reactive Postural control 5 Controle Postural Reativo	Test the ability to recover stability after an external perturbation to bring the centre of masswithin the base of support through corrective movements (e.g. ankle, hip, and steppingstrategies)? Testa a capacidade de recuperar a estabilidade após uma perturbação externa para trazer o centro de massa dentro da base de apoio através de movimentos corretivos (por exemplo, tornozelo, quadril e estratégias)				
Q4-A-6		6 Anticipatory PosturalControl 6 Controle Postural Antecipatório	Test the ability to shift the centre of mass before a discrete voluntary movement (e.g. stepping-lifting leg, arm raise, head turn)? Testa a capacidade de mudar o centro de massa antes de um movimento voluntário discreto (por exemplo, levantando perna, levantar o braço, virar a cabeça)				

Q4-A-7	4. Control of dynamics: gait, proactive 4. Controle dinâmico: marcha, proativo	7 Dynamic Stability 7 Estabilidade Dinâmica	Test the ability to exert ongoing control of centre of mass when the base of the support ischanging (e.g. during gait and postural transitions)? Testa a capacidade de exercer controle contínuo do centro de massa quando a base do suporte é mudando (por exemplo, durante a marcha e transições posturais)?				
Q4-A-8	5. Sensory strategies: integration, reweighting 5 Estratégia sensorial: integração, reponderação	8 Sensory Integration 8 Integração Sensorial	Test the ability to reweight sensory information (vision, vestibular, somatosensory) wheninput altered? Testa a capacidade de repor a informação sensorial (visão, vestibular, somatossensorial) quando entrada alterada				
Q4-A-9	6. Cognitive processing: attention, learning 6 Processamento cognitivo: atenção, aprendizagem	9 Cognitive influences 9 Influência cognitiva	Test the ability to maintain stability while responding to commands during the task or attendto additional tasks (e.g. dual-tasking)? Testa a capacidade de manter a estabilidade enquanto responde aos comandos durante a tarefa ou comparecer para tarefas adicionais (por exemplo, dupla tarefa)				

Source: Author

A.4.2. Part B – Interview (Q4-B).

PARTE B - Entrevista

7. O(a) Sr(a) tem alguma sugestão, elogio ou crítica? Por favor, comente.

_____
_____
_____
_____

8. Você acredita que reabilitação virtual pode ser uma alternativa aos métodos tradicionais da reabilitação ou complementar a eles?

_____
_____
_____
_____
_____

9. O que você acha que já está bom e que seria útil? Porque?

_____
_____
_____
_____
_____

10. O que você acha que precisa melhorar?

_____
_____
_____
_____
_____

11. O que você acha que seria ideal.

_____

_____

_____

_____

_____

A.4.2.1 English (translation) of the Part B – Interview (Q4-B).

Table 9. English (translation) of the Part B – Interview (Q4-B) question order.

Question/ Pergunta	Translation (English)	Original (Portuguese)
Q4-B-7	Do you have any suggestions, compliments or criticisms? Please comment.	O(a) Sr(a) tem alguma sugestão, elogio ou crítica? Por favor, comente.
Q4-B-8	Do you believe that virtual rehabilitation can be an alternative to or complementary to traditional rehabilitation methods?	Você acredita que reabilitação virtual pode ser uma alternativa aos métodos tradicionais da reabilitação ou complementar a eles?
Q4-B-9	What do you think is already good and useful? Why?	O que você acha que já está bom e que seria útil? Porque?
Q4-B-10	What do you think needs improvement?	O que você acha que precisa melhorar?
Q4-B-11	What do you think would be ideal?	O que você acha que seria ideal?

Source: Author

APPENDIX B - Data collected from participants

This Appendix presents the data that was collected in both groups. This Appendix presents the data collected in the two sessions of tests: session 1 with Group 1 and session 2 with Group 2. The participants P1, P2, P3, P4, P5 and P6, named as Group 1, participate in Session 1. The participants P3, P4 and P6, also participate in Session 2. The participants of Session 2, named as Group 2, were P3, P4, P6, P7, P8, P9, P10 and P11. Table 10 presents the age and sex of all participants, table 11 describes the different technological solutions implemented for this research and table 12 gives an overview of their participation in the test sessions and sequences of testing.

Table 10. Age and Sex of all participants from session 1 and 2

Session / Sessão	Group / Grupo	Participant/ Participante	Age/ Idade	Sex/ Sexo
1	1	P1	34	F
1	1	P2	37	F
1, 2	1, 2	P3	58	F
1, 2	1, 2	P4	27	F
1	1	P5	39	F
1, 2	1, 2	P6	34	F
2	2	P7	30	F
2	2	P8	41	F
2	2	P9	24	M
2	2	P10	31	F
2	2	P11	43	F

Source: Author

Table 11. Codes for each technology solution, combination of software and hardware, developed for this research

Code of technology solution	Software version	Hardware configuration	Time (min)
VR_1	Balloons v1.0	System 1	5
		(HMD Virtual Reality)	
VR_ODT_1	Balloons v1.0	System 2	5
		(HMD Virtual Reality + Ominidirectional treadmill)	
VR_2	Balloons v1.1	System 1	10
		(HMD Virtual Reality)	
VR_ODT_2	Balloons v1.1	System 2	10
		(HMD Virtual Reality + Ominidirectional treadmill)	
AR	Balloons v1.1	System 3	10
		(HMD Augmented Reality)	

Source: Author

Table 12. Test sessions, participants and sequences of testing

Session / Group	Participants	Sequence	1st test	2nd test	3rd test
1-1	P1, P2, P3	1	VR_1	VR_ODT_1	----
1-1	P4, P5 P6	2	VR_ODT_1	VR_1	----
2-2	P7, P8	3	VR_2	AR	----
2-2	P3, P6	4	AR	VR_2	---
2-2	P9, P10, P11	5	VR_2	AR	VR_ODT_2
2-2	P4	6	AR	VR_2	VR_ODT_2

Source: Author

B.1. Pre-virtual reality discomfort questionnaire (Q1).

The Q1 questionnaire is presented in Appendix A section A.1. Table 13. Answers to the Pre-virtual reality discomfort questionnaire (Q1) for Session 1 (Group 1) and Session 2 (Group 2)

Table 13. Pre-virtual reality discomfort questionnaire (Q1) answers.

Session/ Sessão	Participant/ Participante	Q1-1	Q1-2	Q1-3	Q1-3	Q1-4	Q1-5	Q1-6
1	P1	No	No	Yes	Only in childhood on public transport on long trips.	No	No	No
					“Somente na infância em transporte público em longas viagens.”			
1	P2	No	No	Yes	Sometimes on the bus	No	No	No
					“As vezes no ônibus”			
1	P3	No	No	Yes	Ship, 15 days ago at Disney park.	No	Yes	No
					“ Navio, há 15 dias no parque da Disney.”			
1	P4	No	Yes	No	---	No	No	No
1	P5	No	No	No	---	No	No	No
1	P6	No	No	Yes	Car, train, plane, bus.	No	Yes	Yes
					“ Carro, Trem, avião, ônibus.”			
2	P7	No	No	Yes	Airplane and boat, a long time ago	No	Yes	No
					“Avião e barco, há muito tempo”			
2	P8	No	No	No	---	No	Yes	Yes
2	P9	No	No	No	---	No	Yes	No
2	P10	No	No	No	---	No	Yes	No
2	P11	No	No	No	---	Yes	Yes	No

Q1-1 Are you feeling any discomfort currently?

Q1-2 Have you had episodes of motion sickness or vomiting today or recently?

Q1-3 Do you have a history of motion sickness?

Q1-4 Have you ever felt dizzy or nauseous while watching a movie on a large screen (e.g. cinema)?

Q1-5 Do you feel dizzy or sick when reading from a moving car or bus?

Q1-6 Do you prefer to be the driver, rather than the passenger, because otherwise you feel dizzy or nauseous?

Source: Author

B.2. Technology use questionnaire (Q2).

The questions of this questionnaire are presented in Appendix A section A.2.

Table 14. Technology use questionnaire (Q2). Participants answers table questions 1 to 3.

Participant/ Participante	Q2-1	Q2-1.1	Q2-1.1.1	Q2-1.2	Q2-2	Q2-3	Q2-3.1	Q2-3.2
P1	Yes	Yes	4	1	4	3	Smarthphone, 3DS	3DS
P2	Yes	Yes	4	3	4	3	PC, Smarthphone, tablet, XBOX ONE, XBOX 360, Wii	Smarthphone
P3	Yes	Yes	4	4	4	1		
P4	Yes	Yes	4	4	4	1		
P5	Yes	Yes	2	1	4	2	PC, tablet, XBOX ONE, Wii	PC, tablet, XBOX 360, Wii
P6	Yes	Yes	4	1	4	1		
P7	Yes	Yes	4	2	3	1	PC, Smarthphone, Playstation 3	Smarthphone
P8	---	---	---	---	---	---	---	---
P9	Yes	Yes	4	2	4	4	PC, Playstation 4	PC
P10	Yes	Yes	4	1	4	2	NES	NES
P11	Yes	Yes	4	1	4	1		

Q2-1 Do you have a cell phone?
Q2-1.1 Does your mobile phone have internet access?
Q2-1.1.1 How often do you use mobile internet?
(1) Never (2) Around once a month (3) Around once a week (4) Almost every day
Q2-1.2 Do you play any games on your mobile phone?
(1) Never (2) Around once a month (3) Around once a week (4) Almost every day
Q2-2 How often do you use a computer?
(1) Never (2) Around once a month (3) Around once a week (4) Almost every day
Q2-3 How often do you currently play video games?
(1) Never (2) Around once a month (3) Around once a week (4) Almost every day
Q2-3.1 What platforms do you use to play? (write them all down)
Q2-3.2 Which platform do you use most often to play? (write one down only)

Source: Author

Table 15. Answers to the Technology use questionnaire (Q2), question Q2-4, for all participants (in the case of P3, P4 and P6, they were asked once, at Session 1)

Table 15. Technology use questionnaire (Q2). Participants answers table question 4.

Participant/ Participante	Q2-4	Q2-4.1	Q2-4.2	Q2-4.3	Q2-4.4
P1	Yes	Oculus Rift	Interactive experience, Games *"Experiência interativa, Jogo"*	3	*Recreatively with family members and weekly applying tests on scientific research participants.* *"De forma recreativa com familiares e semanalmente aplicando testes em participantes de pesquisa científica."*
P2	Yes	GearVR	Games *"Jogo"*	2	---
P3	Yes	Jogo/Games	---	3	---
P4	Yes	GearVR	Games *"Jogo"*	1	---
P5	Yes	Oculus Rift, GearVR, Google CardBoard	Video, Games *"Video, Jogo"*	3	---
P6	Yes	Oculus Rift	---	2	---
P7	Yes	Oculus Rift	Experiencia interativa, Jogo/ Interactive experience, Games	1	---
P8	---	---	---	---	---
P9	No	---	---	---	---
P10	Yes	GearVR	Jogo/Games	1	---
P11	Yes	Oculus Rift	Experiencia interativa/Interactive experience	1	---

Q2-4 Have you ever used any virtual reality gadgets?
Q2-4.1 Which?
Q2-4.2 What type of content?
Q2-4.3 How often do you use virtual reality?
(1) Rarely (2) Around once a month (3) Around once a week (4) Almost every day
Q2-4.4 In what situations do you use, or have you used virtual reality? Please comment. (note in as much detail as possible)

Source: Author

Table 16. Answers to the Technology use questionnaire (Q2), questions Q2.5 and Q2.6, for all participants (in the case of P3, P4 and P6, they were asked once, at Session 1)

Table 16. Technology use questionnaire (Q2). Participants answers table questions 5 to 6.

Participant/ Participante	Q2-5	Q2-5.1	Q2-5.2	Q2-5.3	Q2-6
P1	No	---	---	---	---
P2	Yes	GearVR	Game *"Jogo"*	Recreational - I use wii fit from nephews. oculus rift for research that belongs to USP. Recreativa - utilizo wii fit de sobrinhos. pesquisa com oculus rift que pertence a pesquisa da USP.	---
P3	Yes	Video, Game "Video, Jogo"		From the volunteer herself. Used by the whole family. *"Da própria voluntária. Utilizado por toda a família."*	
P4	No	---	---	---	---
P5	No	---	---	---	---
P6	No	---	---	---	---
P7	No	---	---	---	---
P8	---	---	---	---	---
P9	No	---	---	---	---
P10	No	---	---	---	---
P11	No	---	---	---	Despite my little experience with VR, I understand that it is an increasingly promising tool and aid for rehabilitation and entertainment . “Apesar da minha pouca experiência com RV, entendo se tratar de uma ferramenta cada vez mais promissora e auxiliar para a reabilitação e entretenimento".

Q2-5 Are there any virtual reality devices in your home?
Q2-5.1 Which?
Q2-5.2 What type of content?
Q2-5.3 Who does it belong to and who does it use? Please comment. (note in as much detail as possible)
Q2-6 Would you like to add any information that you consider relevant about your past experiences related to technology use? (note in as much detail as possible)

Source: Author

B.3. Post-test questionnaires (Q3).

The questions of this questionnaire are presented in Appendix A section A.3.

B.3.1. Part A - Discomfort questionnaire after virtual reality (safety and tolerability) (Q3-A).

The questions of this questionnaire are presented in Appendix A section A.3.1.

B.3.1.1. Group 1

Table 17. Part A - Discomfort questionnaire after virtual reality (safety and tolerability) (Q3-A). Answers Group 1.

Part.	Tech	Q3-A1	Q3-A2	Q3-A3	Q3-A4	Q3-A5	Q3-A6	Q3-A7	Q3-A8	Q3-A9	Q3-A10	Q3-A11	Q3-A12	Q3-A13	Q3-A14	Q3-A15
P1	VR_1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P2	VR_1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P3	VR_1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P4	VR_1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P5	VR_1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P6	VR_1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P1	VR_ODT_1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P2	VR_ODT_1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P3	VR_ODT_1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P4	VR_ODT_1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1
P5	VR_ODT_1	1	1	1	1	1	1	2	1	1	1	2	1	1	1	1
P6	VR_ODT_1	1	1	1	2	1	1	1	1	1	1	2	2	1	1	1

Q3-A-1: general discomfort - “desconforto geral“
Q3-A-2: tiredness - “cansaço“
Q3-A-3: headache - “dor de cabeça“
Q3-A-4: tiredness in sight - “cansaço na vista“
Q3-A-5: increased salivation - “aumento da salivação“
Q3-A-6: sweat - “suor“
Q3-A-7: nausea - “náusea“
Q3-A-8: difficulty concentrating - “dificuldade de concentração“
Q3-A-9: palpitation - “palpitação“
Q3-A-10: blurred vision - “visão borrada“
Q3-A-11: dizziness - “tontura“
Q3-A-12: vertigo - “vertigem“
Q3-A-13: mental confusion - “confusão mental“
Q3-A-14: abdominal discomfort - “desconforto abdominal“
Q3-A-15: reflux - “refluxo“

Source: Author

B.3.1.2. Group 2

Table 18. Answers to the Discomfort questionnaire after virtual reality - safety and tolerability (Q3-A), for participants in Session 2 (Group 2), with different technology solutions

Table 19. Part A - Discomfort questionnaire after virtual reality (safety and tolerability) (Q3-A). Answers Group 2.

Part.	Tech	Q3-A1	Q3-A2	Q3-A3	Q3-A4	Q3-A5	Q3-A6	Q3-A7	Q3-A8	Q3-A9	Q3-A10	Q3-A11	Q3-A12	Q3-A13	Q3-A14	Q3-A15
P3	VR_2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P4	VR_2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P6	VR_2	2	2	2	2	1	1	1	2	1	1	1	2	1	1	1
P7	VR_2	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1
P8	VR_2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P9	VR_2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P10	VR_2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P11	VR_2	1	1	1	1	1	1	1	1	1		1	1	1	1	1
P4	VR_ODT_2	2	3	2	2	2	3	3	1	1	1	2	2	1	3	1
P9	VR_ODT_2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P10	VR_ODT_2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1
P11	VR_ODT_2	1	1	1	1	1	1	1	1	1		1	1	1	1	1
P3	AR	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P4	AR	1	3	1	2	1	1	1	1	1	1	1	1	1	1	1
P6	AR	2	2	2	2	2	1	1	1	1	1	1	2	1	1	1
P7	AR	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1
P8	AR	2	1	1	1	1	1	1	2	1	1	1	1	1	1	1
P9	AR	2	1	2	2	1	1	1	1	1	1	1	1	1	1	1
P10	AR	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P11	AR	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Q3-A-1: general discomfort - “desconforto geral“
Q3-A-2: tiredness - “cansaço“
Q3-A-3: headache - “dor de cabeça“
Q3-A-4: tiredness in sight - “cansaço na vista“
Q3-A-5: increased salivation - “aumento da salivação“
Q3-A-6: sweat - “suor“
Q3-A-7: nausea - “náusea“
Q3-A-8: difficulty concentrating - “dificuldade de concentração“
Q3-A-9: palpitation - “palpitação“
Q3-A-10: blurred vision - “visão borrada“
Q3-A-11: dizziness - “tontura“
Q3-A-12: vertigo - “vertigem“
Q3-A-13: mental confusion - “confusão mental“
Q3-A-14: abdominal discomfort - “desconforto abdominal“
Q3-A-15: reflux - “refluxo“

Source: Author

B.3.2. Part B - Satisfaction questionnaire (acceptability) (Q3-B).

The questions of this questionnaire are presented in Appendix A section A.3.2.

B.3.2.1. Group 1

Table 20. Answers to the Satisfaction questionnaire (acceptability) (Q3-B), for participants in Session 1 (Group 1), with different technology solutions

Table 20. Part B - Satisfaction questionnaire (acceptability) (Q3-B). Answers Group 1.

Part.	Tech	Q3-B1	Q3-B2	Q3-B3	Q3-B4	Q3-B5	Q3-B6	Q3-B7	Q3-B8	Q3-B9	Q3-B10	Q3-B11
P1	VR_1	5	5	4	5	5	5	5	5	5	1	1
P2	VR_1	5	5	5	5	5	5	5	5	5	4	4
P3	VR_1	5	3	5	3	5	5	5	5	5	1	1
P4	VR_1	5	5	5	5	5	5	5	5	5	2	2
P5	VR_1	4	5	5	5	4	4	5	5	5	4	1
P6	VR_1	4	5	5	5	5	5	5	4	4	1	2
P1	VR_ODT_1	5	5	5	5	5	5	5	5	5	1	4
P2	VR_ODT_1	5	5	4	5	5	4	5	4	5	4	5
P3	VR_ODT_1	5	5	2	5	4	1	1	5	5	1	1
P4	VR_ODT_1	4	5	5	2	4	2	5	4	5	2	3
P5	VR_ODT_1	4	5	5	5	4	3	5	5	4	4	1
P6	VR_ODT_1	4	4	3	4	4	3	4	2	4	1	2

Q3-A-1: general discomfort - “desconforto geral“
Q3-A-2: tiredness - “cansaço“
Q3-A-3: headache - “dor de cabeça“
Q3-A-4: tiredness in sight - “cansaço na vista“
Q3-A-5: increased salivation - “aumento da salivação“
Q3-A-6: sweat - “suor“
Q3-A-7: nausea - “náusea“
Q3-A-8: difficulty concentrating - “dificuldade de concentração“

Q3-A-9: palpitation - “palpitação“
Q3-A-10: blurred vision - “visão borrada“
Q3-A-11: dizziness - “tontura“
Q3-A-12: vertigo - “vertigem“
Q3-A-13: mental confusion - “confusão mental“
Q3-A-14: abdominal discomfort - “desconforto abdominal“
Q3-A-15: reflux - “refluxo“

Source: Author

B.3.2.2. Group 2

Table 21. Answers to the Satisfaction questionnaire (acceptability) (Q3-B), for participants in Session 2 (Group 2), with different technology solutions

Table 21. Part B - Satisfaction questionnaire (acceptability) (Q3-B). Answers Group 2.

Part.	Tech	Q3-B1	Q3-B2	Q3-B3	Q3-B4	Q3-B5	Q3-B6	Q3-B7	Q3-B8	Q3-B9	Q3-B10	Q3-B11
P3	VR_2	5	5	5	5	5	5	5	5	5	5	2
P4	VR_2	5	5	5	5	5	4	5	5	5	1	1
P6	VR_2	4	5	5	5	4	4	4	3	5	2	1
P7	VR_2	4	4	4	3	5	3	3	4	5	5	5
P8	VR_2	5	5	5	5	5	4	5	5	5	1	1
P9	VR_2	5	5	4	5	4	4	3	4	5	1	5
P10	VR_2	5	5	5	4	5	5	5	4	5	1	1
P11	VR_2	5	5	5	5	5	4	5	4	5	1	1
P4	VR_ODT_2	4	5	4	4	5	3	5	4	5	1	1
P9	VR_ODT_2	2	5	2	5	2	1	2	3	5	5	2
P10	VR_ODT_2	5	5	5	5	5	4	5	5	5	1	3
P11	VR_ODT_2	1	5	1	5	1	1	1	5	5	1	1
P3	AR	5	5	3	5		3	4	5	5	1	1
P4	AR	3	5	3	5	2	2	1	5	5	2	1
P6	AR	2	5	2	5	2	2	2	4	4	1	1
P7	AR	2	4	4	5	4	4	2	5	5	5	5
P8	AR	5	5	1	5	4	3	1	5	2	4	1
P9	AR	4	5	3	5	5	3	3	3	4	1	3
P10	AR	2	5	2	5	2	2	1	5	4	1	1
P11	AR	1	5	1	5	1	1	1	5	1	5	1

Q3-A-1: general discomfort - “desconforto geral“
Q3-A-2: tiredness - “cansaço“
Q3-A-3: headache - “dor de cabeça“
Q3-A-4: tiredness in sight - “cansaço na vista“
Q3-A-5: increased salivation - “aumento da salivação“
Q3-A-6: sweat - “suor“
Q3-A-7: nausea - “náusea“
Q3-A-8: difficulty concentrating - “dificuldade de concentração
Q3-A-9: palpitation - “palpitação“
Q3-A-10: blurred vision - “visão borrada“
Q3-A-11: dizziness - “tontura“
Q3-A-12: vertigo - “vertigem“
Q3-A-13: mental confusion - “confusão mental“
Q3-A-14: abdominal discomfort - “desconforto abdominal“
Q3-A-15: reflux - “refluxo“

Source: Author

Table 22. Q3 – B, Answers Group 2, Question 11 added questions.

Participant /Participante	Age/ Idade	Sex/ Sexo	System/ Sistema	Q3-B-11-Y/N	Q3-B-11-Borg
P3	58	F	System 1	Yes	2
P4	27	F	System 1	No	1
P6	35	F	System 1	No	1
P7	30	F	System 1	Yes	3
P8	41	F	System 1	No	1
P9	24	M	System 1	Yes	5
P10	31	F	System 1	No	1
P11	43	F	System 1	No	2
P4	27	F	System 2	No	2
P9	24	M	System 2	Yes	3
P10	31	F	System 2	Yes	3
P11	43	F	System 2	No	1
P3	58	F	System 3	No	1
P4	27	F	System 3	No	1
P6	35	F	System 3	No	1
P7	30	F	System 3	Yes	3
P8	41	F	System 3	No	3
P9	24	M	System 3	Yes	3
P10	31	F	System 3	No	1
P11	43	F	System 3	No	1

Source: Author

B.3.3. Part C - Satisfaction Interview (Acceptability) (Q3-C).

The questions of this questionnaire are presented in Appendix A section A.3.3.

B.3.3.1. Group 1 - System 1

Table 23. Q3 -C-12, Answers Group 1 – System 1.

	Q3-C-12		
		Translation (English)	Original (Portuguese)
		Do you think it would be possible for someone to play this game in a rehabilitation clinic? ( )Yes ( )No	O(a) Sr(a). acha que seria possível alguém jogar este jogo numa clínica de reabilitação? ( ) Sim ( ) Não
P1	Yes	I find a safe game where the movements use within a general context. I believe it to be a possible training, mainly for reaching cognitive and motor spheres.”	Achei um jogo seguro onde os movimentos usão dentro de um contexto geral. Acredito que ser um treino possível, principalmente por atingir esferas cognitivas e motoras.
P2	Yes	motivating game, interacts well with the environment with security is possible to insert in the environment of the rehabilitation clinic.	jogo motivador, interage bem com o ambiente com segurança é possível inserir no ambiente de clínica de reabilitação.
P3	Yes	easy understanding is safe and motivating.	fácil entendimento, é seguro e motivador.
P4	Yes	It's easy to play.	É lúdico fácil de jogar.
P5	Yes	Yes, super viable and safe.	Sim super viável e seguro.
P6	Yes	Patients with balance complaints and upper limb movements.	Pacientes com queixa de equilíbrio e movimentos em membros superiores.

Source: Author

Table 24. Q3 -C-13, Answers Group 1 – System 1.

	Q3-C-13		
		Translation (English)	Original (Portuguese)
		Do you think it would be possible for someone to play this game at home? ( ) Yes ( )No	O(a) Sr(a). acha que seria possível alguém jogar este jogo em casa? ( ) Sim ( ) Não
P1	Yes	In parts. I believe it is possible for young and young adults, but it requires caring for the elderly, perhaps because it is not possible to have a seat belt at home.	Em partes. Acredito ser possível em jovens e jovens adultos, porem requer cuidados com idosos, talvez por não ser possível ter o cinto de segurança em casa.
P2	Yes	Game with easy understanding, able to be inserted in the home environment.	Jogo com fácil entendimento, capaz de ser inserido no ambiente domiciliar.
P3	Yes	The game is easy to play.	O jogo é fácil de ser jogado.
P4	Yes	Safer.	Mais seguro.
P5	No	I do not think I'm safe enough for the absence of a vest.	Não acho seguro o suficiente pela ausência de colete.
P6	No	If the patient needs weight support, it would not be recommended besides the risk of hitting things without the support.	Se o paciente precisar do suporte de peso não seria recomendado além do risco de bater nas coisas sem o suporte.

Source: Author

Table 25. Q3 -C-14, Answers Group 1 – System 1.

	Q3-C-14	
	Translation (English)	Original (Portuguese)
	Do you have any suggestions, compliments or criticisms? Write.	O(a) Sr(a) tem alguma sugestão, elogio ou crítica? Escreva.
P1	really liked the idea and I believe that it would benefit many people, especially in clinical rehabilitation.	gostei muito da ideia e acredito que beneficiaria muitas pessoas, principalmente em uma reabilitação clinica.
P2	Very cool the game and the way it was conducted. Only glasses a little heavy.	Muito legal o jogo e a forma que foi conduzido. Somente oculos um pouco pesado.
P3	Waistcoat limits movement. It would be better on the flat ground and without later. There were times when the balloons were beyond reach.	Colete limitou o movimento. Seria melhor no chão plano e sem depois. Houve momentos em que os balões estaram além da capicadade de alcance.
P4	Consideration of the score, the balloons beat by themselves (Take away the balloons). Spotlight, small plate. less fear. less tired. You could practice for more than 5 minutes.	Consideração da pontuação, os balões batiam por si mesmos(Afastar os balões). Pontuaçãp clara, placa pequena. menos medo. menos cansado. Darai para praticar mais de 5 minutos.
P5	Same as above. Although I have enjoyed the use of the vest rather than the other system.	As mesma do anterior. Embora tenho gostado mais do uso do colete ao inves do outro sitema.
P6	Same as the previous form.	Idem do formulario anterior.

Source: Author

B.3.3.2. Group 1 – System 2

Table 26. Q3 -C-12, Answers Group 1 – System 2.

	Q3-C-12		
		Translation (English)	Original (Portuguese)
		Do you think it would be possible for someone to play this game in a rehabilitation clinic? ( )Yes ( )No	O(a) Sr(a). acha que seria possível alguém jogar este jogo numa clínica de reabilitação? ( ) Sim ( ) Não
P1	Yes	Yes, I found the game safer and easier to understand, as well as motivating.	Sim, achei o jogo muito seguro e fácil entendimento, além de motivador.
P2	Yes	It will be possible to use the game in the clinic, but the cost will be much more expensive, I do not know if it would be accessible to everyone.	Será possível o uso do jogo na clínica, mas o custo será bem mais caro, não sei se seria acessível a todos.
P3	Yes	A lot of security.	Muita segurança.
P4	Yes	To combine with conventional physiotherapy because it is playful.	Para combinar com a fisioterapia convencional pois é ludico.
P5	Yes	Yes, I think it's feasible because security is guaranteed. However, the head should be better adjusted so that there is greater correspondence on the gesture of the participant and the response in the glasses.	Sim acho viável, pois a segurança estava garantida. No entanto a cabeça deve ser melhor ajuste para que haja correspondência maior sobre o gesto do participante e a resposta no óculos.
P6	Yes	Maybe the elderly or patients restricted the movement.	Talvez idosos ou pacientes restritos a movimentação.

Source: Author

Table 27. Q3 -C-13, Answers Group 1 – System 2.

	Q3-C-13		
		Translation (English)	Original (Portuguese)
		Do you think it would be possible for someone to play this game at home? ( ) Yes ( )No	O(a) Sr(a). acha que seria possível alguém jogar este jogo em casa? ( ) Sim ( ) Não
P1	Yes	As long as I was able to understand the game and did not have any motor deficits, I think so.	Desde que fosse capaz de compreender o jogo e não ter nenhum deficit motor, acredito que sim.
P2	No	Due to the high cost and putting all the equipment in the house.	Devido ao custo elevado e colocar todo equipamento na casa.
P3	No	For the cost.	Pelo custo.
P4	Yes	Provided you have follow-up	Desde que tenha um acompanhamento
P5	No	Not in this setup. Without another maybe. I think security would be compromised.	Não nesse setup. Sem um outro talvez. Mas acho que segurança ficaria comprometida.
P6	No	Pela complexidade de transporte e manipulação.	Pela complexidade de transporte e manipulação.

Source: Author

Table 28. Q3 -C-14, Answers Group 1 – System 2.

	Q3-C-14	
	Translation (English)	Original (Portuguese)
	Do you have any suggestions, compliments or criticisms? Write.	O(a) Sr(a) tem alguma sugestão, elogio ou crítica? Escreva.
P1	I really enjoyed the game and think promising for clinical application.	Gostei muito do jogo e acho promissor para aplicação clinica.
P2	Nice game and equipment. This was a bit harder to catch the balloons as they were out of my reach.	Jogo e equipamento bem legais. Neste foi um pouco mais dificil de pegar os blões, pois estavam fora do meu alcance.
P3	Less range of movements. less freedom of movement.	Menos amplitude dos movimentos. menos liberdade de movimento.
P4	Good game (score is too small). Feeling insecure as a smooth platform, for an elderly faller can be insecure and difficult.	jogo bom (pontuação está muito pequena). Sensação insegura por ser plataforma lisa, para um idoso caidor pode ser inseguro e dificil.
P5	Increase the size of the dots and change the white color in the help! Calibrate better for the distance of the targets to be closer to the individual. Avoid balloons very close to the body of the participant, because he touches it without having seen, Without intention. This changes the punctuation and planning for the player.	Aumenta o tamanho dos pontos e mudar a cor branca na ajuda! Calibrar melhor para a distancia dos alvos ser mais proxima do individuo. Evitrar bolas muito proximas do corpo da participant, pois ele toca nele sem ter visto, Sem intenção. Isso muda a pontuação eo planejamento para o jogador.
P6	Maybe if it is possible to signal where the balloons will appear and improve the movement on the scene.	Talvez se for possivel sinalizar aonde os balões aparecerão e melhorar a movimentação em cena.

Source: Author

B.3.3.3. Group 2 – System 1

Table 29. Q3 -C-12, Answers Group 2 – System 1.

	Q3-C-12		
		Translation (English)	Original (Portuguese)
		Do you think it would be possible for someone to play this game in a rehabilitation clinic? ( )Yes ( )No	O(a) Sr(a). acha que seria possível alguém jogar este jogo numa clínica de reabilitação? ( ) Sim ( ) Não
P3	Yes	It is possible, yes, very safe. Stimulant!	É possível sim, com muita segurança. Estimulante!
P4	Yes	Playful game, easy to pop the balloons and reach the goal of the game	Jogo lúdico, fácil de estourar os balões e atingir o objetivo do jogo
P6	Yes	The game seems to be safe and a good tool to achieve clinical goals.	O jogo parece ser seguro e uma boa ferramenta para alcançar os objetivos clínicos.
P7	Yes	Because it is a game that stimulates various angles and range of motion	Porque é um jogo que estimula diversos ângulos e amplitudes de movimento
P8	Yes	Because it is a game that stimulates various angles and range of motion	Treino de equilíbrio, reação antecipatória e reativa, estímulo cognitivo, dupla tarefa
P9	Yes	It could be used as an alternative strategy for rehabilitation and may improve patients' adherence	Poderia ser utilizado como uma estratégia alternativa para reabilitação, podendo melhorar a aderência dos pacientes
P10	Yes	Simple game with a clear objective. I felt safe performing the proposal.	Jogo simples, com objetivo claro. Me senti segura realizando a proposta.
P11	Yes	Easy understanding and handling stimulate displacement and cognition.	Fácil entendimento e manejo, estimula o deslocamento e a cognição.

Source: Author

Table 30. Q3 -C-13, Answers Group 2 – System 1.

	Q3-C-13		
		Translation (English)	Original (Portuguese)
		Do you think it would be possible for someone to play this game at home? ( ) Yes ( )No	O(a) Sr(a). acha que seria possível alguém jogar este jogo em casa? ( ) Sim ( ) Não
P3	Yes	Lower cost, possible to have at home. Exercise more often.	Menor custo, possível ter em casa. Exercitar mais vezes.
P4	Yes	For being a playful game	Por ser um jogo lúdico
P6	Yes	In a safe space, it could be possible.	Em um espaço seguro poderia ser possível.
P7	Yes	Because it's fun and encourages you to exercise	Porque é divertido e estimula a realizar exercício físico
P8	Yes	If the game is financially accessible and has security features. In addition to not having any contraindication.	Se o jogo for acessível financeiramente e tiver dispositivos de segurança. Além de não possuir nenhuma contra-indicação.
P9	Yes	Provided you have the same safety support used during exercise at the rehabilitation center. This can greatly limit the use of this game in a home environment	Desde que se tenha o mesmo suporte de segurança utilizado durante o exercício no centro de reabilitação. Isso pode limitar muito o uso desse jogo em um ambiente domiciliar
P10	Yes	I do not see the difficulty in applying such a game in any environment, since the demand for space is small, and I see no risk involved in the activity.	Nao vejo dificuldade em aplicabilidade de tal jogo em qualquer ambiente, uma vez que a demanda por espaço é pequena, e não vejo risco envolvido na atividade.
P11	No	No, if the person's safety is monitored by another.	Não, contanto que a segurança da pessoa seja monitorada por outra.

Source: Author

Table 31. Q3 -C-14, Answers Group 2 – System 1.

	Q3-C-14	
	Translation (English)	Original (Portuguese)
	Do you have any suggestions, compliments or criticisms? Write.	O(a) Sr(a) tem alguma sugestão, elogio ou crítica? Escreva.
P3	Fairly motivating	Bastante motivador.
P4	This version is good; I do not see any need for changes.	Está versão está boa, não vejo necessidade de alterações.
P6	I think the system is within the expectation.	Acho que o sistema está dentro da expectativa.
P7	Explain better the game, to say that they are balloons with scores, that can mobilize in all the way. That will show punctuation and errors.	Explicar melhor o jogo, dizer que são balões com pontuações, que pode mobilizar em todo o trajeto. Que irá mostrar pontuação e erros.
P8	I thought it was great! The question of punctuation could be clearer.	Achei ótimo! Poderia ser mais claro a questão da pontuação.
P9	Add a tutorial, presenting a static balloon, causing the patient to touch first before the exercise already starts Alternating the color of the balloons, to increase the cognitive challenge, at the end of the exercise becomes very automated the color of the balloon with the number it represents.	Adicionar um tutorial, apresentando um balão estático, fazendo com que o paciente faça o toque primeiro, antes de o exercício já iniciar Alternar a cor dos balões, para aumentar o desafio cognitivo, no final do exercício fica muito automatizado a cor do balão com o número que ele representa.
P10	Reaching for some balloons was difficult as they were beyond my reach.	Alcançar alguns balões foi difícil, pois estavam além do meu alcance.
P11	I found the game motivating, but I felt restricted as to the space available. This has reduced my performance in the game. For people with reduced mobility, perhaps, the game is enough to present itself as it is, but not for the robust elderly.	Achei o jogo motivante, mas me senti restringida quanto ao espaço disponibilizado. Isso reduziu meu desempenho no jogo. Para pessoas com mobilidade reduzida, talvez, seja suficiente o jogo se apresentar como está, mas não para idosos robustos.

Source: Author

B.3.3.4. Group 2 – System 2

Table 32. Q3 -C-12, Answers Group 2 – System 2.

	Q3-C-12		
		Translation (English)	Original (Portuguese)
		Do you think it would be possible for someone to play this game in a rehabilitation clinic? ( )Yes ( )No	O(a) Sr(a). acha que seria possível alguém jogar este jogo numa clínica de reabilitação? ( ) Sim ( ) Não
P4	Yes	Playful game, the treadmill makes the game more interactive, although depending on the target audience the fear of falling would be an obstacle	Jogo lúdico, a esteira torna o jogo mais interativo, apesar de que, dependendo do público alvo o medo de cair seria um empecilho
P9	Yes	Yes, with the safety and supervision equipment	Sim, com os equipamentos de segurança e supervisão
P10	Yes	Safe; with immediate relation between the action of the player and the game.	Seguro; com relação imediata entre a ação do jogador e o jogo.
P11	No	O jogo não funcionou. Não foi possível interagir.	O jogo não funcionou. Não foi possível interagir.

Source: Author

Table 33. Q3 -C-13, Answers Group 2 – System 2.

	Q3-C-13		
		Translation (English)	Original (Portuguese)
		Do you think it would be possible for someone to play this game at home? ( ) Yes ( )No	O(a) Sr(a). acha que seria possível alguém jogar este jogo em casa? ( ) Sim ( ) Não
P4	Yes		
P9	No	It involves more advanced technology to run in a home environment	Envolve uma tecnologia já mais avançada para ser executado em um ambiente domiciliar
P10	No	A estrutura necessária me parece ser um fator complicador.	A estrutura necessária me parece ser um fator complicador.
P11	No	The game does not work	O jogo não funcionou.

Source: Author

Table 34. Q3 -C-14, Answers Group 2 – System 2.

	Q3-C-14	
	Translation (English)	Original (Portuguese)
	Do you have any suggestions, compliments or criticisms? Write.	O(a) Sr(a) tem alguma sugestão, elogio ou crítica? Escreva.
P4	Improve the calibration of the treadmill that sometimes and backward instead of forward and vice versa.	Melhorar a calibragem da esteira que por vezes ia para tras ao inves de para frente e vice-versa.
P9	During the exercise, the "treadmill" presented a problem, not performing backward or forward movements, going only in one direction (right), impairing grip and performance to exercise, and not requiring a high level of physical activity , as would the proposal of the exercise, make me walk to reach the balloons.	Durante o exercício, a "esteira" apresentou problema, não realizando movimentos para frente ou para trás, indo apenas em um sentido(direita), prejudicando a aderência e o desempenho para fazer o exercício, além de não exigir um grande nível de atividade física, como seria a proposta do exercício, me fazer caminhar para alcançar os balões.
P10	Very interesting game. The interaction between gait and movement in the game is very useful and motivating. The only point that punctuated is that I had to carry out a march in the later direction, to reach goals that were before me. The playing shoe is very slippery and may pose a risk before the player accesses the seat belt.	Jogo interessantíssimo. A interação entre marcha e movimentação no jogo é muito útil e motivador. Único ponto que pontuo é que eu precisei realizar marcha no sentido posterior, para atingir objetivos que estavam anteriores à mim. A sapatilha para jogar é muito escorregadia, e pode oferecer risco antes de o jogador acessar o cinto de segurança.
P11	The game does not work.	O jogo não funcionou.

Source: Author

Table 35. Q3 -C-12, Answers Group 2 – System 2.

	Q3-C-12		
		Translation (English)	Original (Portuguese)
		Do you think it would be possible for someone to play this game in a rehabilitation clinic? ( )Yes ( )No	O(a) Sr(a). acha que seria possível alguém jogar este jogo numa clínica de reabilitação? ( ) Sim ( ) Não
P3	Yes	It is possible and motivating however the cost of these glasses should be high.	É possível e motivante, porém o custo destes óculos deve ser alto.
P4	No	Due to the difficulty with the system, where the balloons often do not burst, and you cannot see the numbers	Devido dificuldade com o sistema, onde muitas vezes os balões não estouram e não dá para enxergar os números
P6	Yes	In order to achieve objectives related to reasoning and cognitive issues.	A fim de atingir objetivos referentes ao raciocínio e questões cognitivas.
P7	Yes	Yes, it stimulates spatial perception	Sim, estimula a percepção espacial
P8	Yes	An easy and safe game, just lacking the suitability of motion sensors and glasses	Um jogo fácil e seguro, falta apenas adequação dos sensores de movimento e dos óculos
P9	Yes	It can be used as a complementary therapy, improving adherence of patients	Pode ser utilizado como uma terapia complementar, melhorando aderência dos pacientes
P10	No	I believe that the difficulties imposed by gambling posture, the dependence on the interaction between hands and the look and the delay between my action and the understanding by the system can compromise how much the individual can be involved and motivated with the game.	Acredito que as dificuldades impostas por postura de jogo, dependência de interação entre mãos e olhar e atraso entre a minha ação e a compreensão pelo sistema podem comprometer o quanto o indivíduo pode se envolver e se motivar com o jogo.
P11	No	O jogo não funcionou. Não obedecia aos comandos.	O jogo não funcionou. Não obedecia aos comandos.

Source: Author

Table 36. Q3 -C-13, Answers Group 2 – System 2.

	Q3-C-13		
		Translation (English)	Original (Portuguese)
		Do you think it would be possible for someone to play this game at home? ( ) Yes ( )No	O(a) Sr(a). acha que seria possível alguém jogar este jogo em casa? ( ) Sim ( ) Não
P3	No	High cost	Alto custo
P4	Yes		
P6	Yes	Having the necessary equipment, I see no reason not to.	Tendo os equipamentos necessários não vejo motivo para não.
P7	Yes	Yes, it stimulates mobility	Sim, estimula a mobilidade
P8	Yes	For entertainment purposes and with safety devices.	Para fins de entretenimento e com os dispositivos de segurança.
P9	Yes	However, with the need for safety equipment	Porém, com a necessidade dos equipamentos de segurança
P10	Yes	I believe it is possible to play at home, however, I believe that the interaction between the player and the device is not attractive.	Acredito ser possível jogar em casa, no entanto acredito que a interação entre o jogador e o aparelho não é atrativa.
P11	No	There was no game.	Não houve jogo.

Source: Author

B.3.3.5. Group 2 – System 3

Table 37. Q3 -C-12, Answers Group 2 – System 3.

	Q3-C-12		
		Translation (English)	Original (Portuguese)
		Do you think it would be possible for someone to play this game in a rehabilitation clinic? ( )Yes ( )No	O(a) Sr(a). acha que seria possível alguém jogar este jogo numa clínica de reabilitação? ( ) Sim ( ) Não
P3	Yes	It is possible and motivating however the cost of these glasses should be high.	É possível e motivante, porém o custo deste óculos deve ser alto.
P4	No	Due to the difficulty with the system, where the balloons often do not burst, and you cannot see the numbers	Devido dificuldade com o sistema, onde muitas vezes os balões não estouram e não dá para enxergar os números
P6	Yes	In order to achieve objectives related to reasoning and cognitive issues.	A fim de atingir objetivos referentes ao raciocínio e questões cognitivas.
P7	Yes	Yes, it stimulates spatial perception	Sim, estimula a percepção espacial
P8	Yes	An easy and safe game, just lacking the suitability of motion sensors and glasses	Um jogo fácil e seguro, falta apenas adequação dos sensores de movimento e do óculos
P9	Yes	It can be used as a complementary therapy, improving adherence of patients	Pode ser utilizado como uma terapia complementar, melhorando aderência dos pacientes
P10	No	I believe that the difficulties imposed by gambling posture, the dependence on the interaction between hands and the look and the delay between my action and the understanding by the system can compromise how much the individual can be involved and motivated with the game.	Acredito que as dificuldades impostas por postura de jogo, dependência de interação entre mãos e olhar e atraso entre a minha ação e a compreensão pelo sistema podem comprometer o quanto o indivíduo pode se envolver e se motivar com o jogo.

Source: Author

Table 38. Q3 -C-13, Answers Group 2 – System 3.

	Q3-C-13		
		Translation (English)	Original (Portuguese)
		Do you think it would be possible for someone to play this game at home? ( ) Yes ( )No	O(a) Sr(a). acha que seria possível alguém jogar este jogo em casa? ( ) Sim ( ) Não
3	No	High cost	Alto custo
4	Yes		
6	Yes	Having the necessary equipment, I see no reason not to.	Tendo os equipamentos necessários não vejo motivo para não.
7	Yes	Yes, it stimulates mobility	Sim, estimula a mobilidade
8	Yes	For entertainment purposes and with safety devices.	Para fins de entretenimento e com os dispositivos de segurança.
9	Yes	However, with the need for safety equipment	Porém, com a necessidade dos equipamentos de segurança
10	Yes	I believe it is possible to play at home, however, I believe that the interaction between the player and the device is not attractive.	Acredito ser possível jogar em casa, no entanto acredito que a interação entre o jogador e o aparelho não é atrativa.
11	No	There was no game.	Não houve jogo.

Source: Author

Table 39. Q3 -C-14, Answers Group 2 – System 3.

	Q3-C-14	
	Translation (English)	Original (Portuguese)
	Do you have any suggestions, compliments or criticisms? Write.	O(a) Sr(a) tem alguma sugestão, elogio ou crítica? Escreva.
P3	Be a little more active.	Ser um pouco mais ativo.
P4	Improve ease in bursting the balloons and put the number on top of them instead of the side, given that they see from bottom to top.”	Melhorar facilidade em estourar os balões e colocar o número em cima dos mesmos ao inves da lateral, tendo em vista que eles veem de baixo para cima.
P6	It would be best to adjust the value of the balloons so that the practitioner would soon identify the balloon's score and not drop balloons too far from the field because the vest prevents movement beyond a certain radius	Seria melhor ajustar o valor dos balões de modo que o praticante identificasse logo a pontuação que o balão vale e não soltar balões muito longe do campo pois o colete impede a movimentação além de um determinado raio.
P7	The game is slower, can be used in the early stages of training. The reaction time of the hand with the balloon is time-consuming.	O jogo é mais lento, pode ser usado em fases iniciais de treinamento. O tempo de reação da mão com o balão é demorado.
P8	Suitability of motion sensors, review choice of glasses and clarify punctuation as stimulus.	Adequação dos sensores de movimento, rever a escolha do óculos e esclarecer a pontuação, como estímulo.
P9	Tapping on the balloons was inaccurate at times, and the lightness interferes with the proper viewing of the balloons	Toque nos balões foi impreciso em alguns momentos, e a luminosidade interfere na visualização adequada dos balões
P10	Difficult gameplay and interaction between player and game.	Difícil jogabilidade e interação entre jogador e jogo.
P11	Adjustments to concretize the proposal of the game and allow the user the proper interaction with the system can bring a good activity proposal.	Ajustes para concretizar a proposta do jogo e permitir ao usuário a devida interação com o sistema pode trazer uma boa proposta de atividade.

Source: Author

B.4. Questionnaire and evaluation interview of physiotherapists (applicability)(Q4).

The questions of this questionnaire are presented in Appendix A section A.4.

B.4.1. Part A – Questionnaire (Q4-A).

The questions of this questionnaire are presented in Appendix A section A.4.1.

B.4.1.1. Group 1

Table 40. Q4-A, Group 1 Answer table questions 1 to 9.

Participant/ Participante	Age/ Idade	Sex/ Sexo	System/ Sistema	Q4-A-1	Q4-A-2	Q4-A-3	Q4-A-4	Q4-A-5	Q4-A-6	Q4-A-7	Q4-A-8	Q4-A-9
P1	34	F	System 1	5	5	5	5	5	5	5	5	5
P2	37	F	System 1	5	5	5	5	5	5	5	5	5
P3	58	F	System 1	5	5	5	5	5	5	5	5	5
P4	27	F	System 1	5	3	4	4	4	5	5	5	4
P5	39	F	System 1	5	2	5	3	5	5	5	5	5
P6	34	F	System 1	3	3	2	3	3	4	3	4	4
P1	34	F	System 2	5	5	5	5	5	5	5	5	5
P2	37	F	System 2	5	5	5	5	5	5	5	5	5
P3	58	F	System 2	5	5	5	5	5	5	5	5	5
P4	27	F	System 2	3	4	3	4	4	4	3	4	5
P5	39	F	System 2	3	2	4	3	5	5	2	5	5
P6	34	F	System 2	2	3	2	3	4	4	3	4	4

Source: Author

B.4.1.2. Group 2

Table 41. Q4-A, Group 2 Answer table questions 1 to 9.

Participant/ Participante	Age/ Idade	Sex/ Sexo	System/ Sistema	Q4-A-1	Q4-A-2	Q4-A-3	Q4-A-4	Q4-A-5	Q4-A-6	Q4-A-7	Q4-A-8	Q4-A-9
P3	58	F	System 1	5	5	5	5	5	5	5	5	5
P4	27	F	System 1	5	5	5	5	5	5	5	5	5
P6	35	F	System 1	4	3	4	4	4	4	4	4	3
P7	30	F	System 1	5	5	4	5	3	5	5	4	5
P8	41	F	System 1	4	4	4	4	5	5	3	4	5
P9	24	M	System 1	4	4	5	4	5	5	5	4	5
P10	31	F	System 1	5	5	5	5	5	5	5	5	5
P11	43	F	System 1	5	5	5	5	4	4	5	5	4
P4	27	F	System 2	4	4	3	5	5	5	5	5	5
P9	24	M	System 2	2	2	3	5	5	3	2	4	5
P10	31	F	System 2	5	5	5	5	5	5	5	5	5
P11	43	F	System 2	1	1	1	1	1	1	1	1	1
P3	58	F	System 3	5	5	5	5	5	5	5	5	5
P4	27	F	System 3	5	5	5	5	4	4	4	5	4
P6	35	F	System 3	3	3	3	4	4	5	4	4	3
P7	30	F	System 3	4	5	4	5	3	5	4	5	5
P8	41	F	System 3	3	4	4	3	3	3	4	3	4
P9	24	M	System 3	4	4	5	5	5	4	5	3	4
P10	31	F	System 3	5	5	3	1	4	4	4	1	3
P11	43	F	System 3	1	1	1	1	1	1	1	1	1

Source: Author

B.4.2. Part B – Interview (Q4-B).

The questions of this questionnaire are presented in Appendix A section A.4.2.

B.4.2.1. Group 1

Table 42. Q4-B-7, Group 1 answers.

	Q4-B-7	
	Translation (English)	Original (Portuguese)
	Do you have any suggestions, compliments or criticisms? Please comment.	O(a) Sr(a) tem alguma sugestão, elogio ou crítica? Por favor, comente.
P1	I would like to compliment you from the idea of creating the game to worrying about all security measures.	Gostaria de elogiar desde a ideia de criação do jogo até a preucupação com todas as medidas de segurança.
P2	Very cool, interactive game. I was motivated to pick up the balloons in both systems.	jogo bem legal, interativo. Me senti motivada a pegars os balões em ambos os sistemas.
P3	Missing adjustment and calibration	Falta ajustar e . calibragem
P4	Playful game, easy to understand; however, limiting facts in COGMIS-G is the fear of falling (slippery platform); In both the score is difficult to see and also the balloons hit the control changing the score unintentionally. Suggestion: Leave them further and in the same direction at the same time.	jogo ludico, de facil compreensão; porém fatos limitantes no COGMIS-G é o medo de cair (plataforma escorregadia); em ambos o placar é dificil de visualizar e tambem os balões esbarram no controle mudando a pontuação sem querer. Sugestão: DEIXO-LOS MAIS LONGE E EM MEMAS DIREÇÕES AO MESMO TEMPO.
P5		
P6	There is a delay between the end of the song and the continuity of the task, when the song ends it seems like the game is over too.	Existe um delay entre, o final da música e a continuidade da tarefa, quando a musica acaba parece que o jogo tambem acabou.

Source: Author

Table 43. Q4-B-8, Group 1 answers

	Q4-B-8	
	Translation (English)	Original (Portuguese)
	Do you believe that virtual rehabilitation can be an alternative to or complementary to traditional rehabilitation methods?	Você acredita que reabilitação virtual pode ser uma alternativa aos métodos tradicionais da reabilitação ou complementar a eles?
1	I believe very much, being able to reach various spheres, both cognitive and motor, and can use working in a fuller way beyond motivating.	Acredito muito, por ser capaz de atingir várias esferas, tanto cognitivas como motoras, podendo usar trabalhando de uma forma mais completa além de motivadora.
2	I believe RV will go to complement traditional rehab by adding	Acredito que a RV vaio para complementar a reabilitação tradicional, agregando.
3	Complementary only. The physical therapist is needed both to guide the use of the program and to adjust and plan various exercises for global rehabilitation. Viable and motivating.	Somente complementar. O fisioterapeuta é necessário tanto para orientar o uso do programa como para ajustar e planejar exercícios diversos para reabilitação global. Viável e motivante.
4	Yes, I believe it can complement and intensify the same conventional method.	Sim, acredito que possa complementar e intensificar o mesmo método convencional.
5		
6	It may be complementary outside.	Pode estar de fora complementar.

Source: Author

Table 44. Q4-B-9, Group 1 answers.

	Q4-B-9	
	Translation (English)	Original (Portuguese)
	What do you think is already good and useful? Why?	O que você acha que já está bom e que seria útil? Porque?
P1	I really enjoyed the virtual environment all the colors used in the game and the ease of entertainment by people of all ages.	Gostei muito do ambiente virtual todas as cores utilizadas no jogo e a facilidade de entretenimento, por pessoas de todas as idades.
P2	Both systems will be good and will be useful for rehabilitation.	Ambos os sistemas estar bom e serão uteis para a reabilitação.
P3	balloons, colors, simple and unpolluted scenarios. It is easy to understand and work the double task.	balões, cores, cenários simples e não poluído. é de fácil entendimento e trabalho a dupla tarefa.
P4	The characteristic of the task itself is easy to understand and attractive.	A característica da tarefa em si, fácil de compreensão e atrativo.
P5	good scenery / goal / music / game goal, colors can improve sensitivity can improve.	cenário bom/ meta / música / o objetivo do jogo, cores podem melhorar sensibilidade pode melhorar
P6	It would be useful and good for therapeutic purposes without exercise pressure and a bit more playful as well as motivating.	Seria útil e bom para fins terapêuticos sem a pressão do exercício e um pouco mais lúdico, além de motivador.

Source: Author

Table 45. Q4-B-10, Group 1 answers.

	Q4-B-10	
	Translation (English)	Original (Portuguese)
	What do you think needs improvement?	O que você acha que precisa melhorar?
P1	I only felt a slight difficulty when the balloons came very close to me, not giving time to choose the score. Otherwise, everything is perfect.	Só senti uma dificuldade mínima quando os balões vinham muito próximos a mim, não dando tempo de escolher a pontuação. No demais, tudo perfeito.
P2	In system 2 I had a little difficulty reaching the balloons, but it was motivating.	No sistema 2 tive um pouco de dificuldade de alcançar os balões, mas foi motivador.
P3	P floor single level, G calibration.	P piso em único nível, G calibragem.
P4	I answered in question 7.	Respondi na questão 7.
P5	---	---
P6	balloon movement and signaling.	movimentação e sinalização de balões.

Source: Author

Table 46. Q4-B-11, Group 1 answers.

	Q4-B-11	
	Translation (English)	Original (Portuguese)
	What do you think would be ideal?	O que você acha que seria ideal?
P1	The way it was developed and how it is applied I found it very interesting. Maybe just change the issue of balloons leave a little more distant to allow time to choose the score. In others, Congratulations!	A forma como foi desenvolvida e como é aplicado já achei muito interessante. Talvez só mudaria a questão dos balões saírem um pouco mais distantes para dar tempo de escolher a pontuação. No demais, Parabéns!
P2	That the systems were accessible to use everywhere. System 2 I believe will be more difficult to use in a clinic or at home.	Que sistemas fosse acessíveis para usar em todos os locais. O sistema 2 creio será mais difícil do uso em uma clínica ou em domicilio.
P3	P level ground, more freedom vest. G calibration, Convergence of sensory and visual response. Example: walk forward and see yourself walking forward. Treadmill - parkinson, stroke safer.	P piso nivelado, mais liberdade do colete. G calibragem, Convergência de resposta sensorial e visual. Exemplo: andar para frente e se ver andando para frente. Esteira - Parkinson, avc mais seguro.
P4	see question 7.	ver questão 7.
P5	Clarity in the score, catch the most significant objects and functional relevance, sharing hands instead of square, change the goal randomly to maintain motivation, always add 10 is boring, Every 2 minutes change music.	Clareza na pontuação, pegar objetos de maior significado e relevância funcional, compartilhar das mãos ao invés de quadrados, mudar a meta aletoriamente para manter motivação, somar sempre 10 é chato, A cada 2 minutos mudar música.
P6	That they had objects they couldn't touch to compete with the game's purpose.	Que tivessem objetos que não pudessem tocar para concorrer com o objetivo do jogo.

Source: Author

B.4.2.2. Group 2

Table 47. Q4-B-7, Group 2 answers.

	Q4-B-7	
	Translation (English)	Original (Portuguese)
	Do you have any suggestions, compliments or criticisms? Please comment.	O(a) Sr(a) tem alguma sugestão, elogio ou crítica? Por favor, comente.
P3	It would be more challenging if you were on stable ground.	Seria mais desafiador se estivesse num solo estável.
P4	Yes, I believe that the most viable system to be applied to the elderly is COGMIS-P, I see nothing that needs to be modified in it, but the COGMIS-G system if the treadmill calibration is improved would be more interesting the applicability (depending on the target audience, who could not be afraid of falls and a history of labyrinthitis). COGMIS-AP would need to change the location of the balloon numbering and the way we need to touch it, as it often wouldn't.	Sim, acredito que o sistema mais viável para ser aplicado com idosos é o COGMIS-P, não vejo nada que precise ser modificado no mesmo, porém o sistema COGMIS-G se melhorado a calibração da esteira seria mais interessante a aplicabilidade (a depender do público alvo, que não poderia ter medo de quedas e histórico de labirintite). O COGMIS-AP seria necessário mudar o local da numeração dos balões e o modo com que necessitamos tocar nele, pois muitas vezes não ia.
P6	No	Não
P7		
P8	The project is beautiful. Suitability of eyewear and safety devices only. As for the game, I missed victory and scoring stimuli.	O projeto está lindo. Apenas adequação do óculos e dispositivos de segurança. Quanto ao jogo, senti falta de estímulos de vitória e pontuação.
P9	The game is very simple (which with the elderly audience is ideal). With a nice interface, appropriate music too, I believe that after half of the experience it starts to get a little repetitive, and may have more challenges depending on the patient's score, such as increased speed, changing balloon values, some kind of " Super special balloon "that has a high score but at the same time brings a greater challenge, requiring speed, or greater accuracy to be achieved. A short tutorial could also be added at the beginning, to increase patient familiarity.	O jogo é bem simples (o que com o público idoso, é o ideal). Com uma interface agradável, música apropriada também, acredito que após metade da experiência ele começa a se tornar um pouco repetitivo, podendo ter mais desafios propostos dependendo do Score do paciente, como aumento da velocidade, mudança de valores nos balões, algum tipo de "Balão super especial" que tenha pontuação elevada, mas que ao mesmo tempo traga um desafio maior, exigindo velocidade, ou maior precisão para ser alcançado.Também poderia ser adicionado um pequeno tutorial no começo, para maior familiaridade dos pacientes
P10	Interesting experience using different interfaces. I believe that the use of virtual reality can add a lot as complementary therapy.	Experiência interessante, utilizando diferentes interfaces. Acredito que a utilização da realidade virtual possa acrescentar muito como terapia complementar.
P11	The game did not work.	O jogo não funcionou.

Source: Author

Table 48. Q4-B-8, Group 2 answers.

	Q4-B-8	
	Translation (English)	Original (Portuguese)
	Do you believe that virtual rehabilitation can be an alternative to or complementary to traditional rehabilitation methods?	Você acredita que reabilitação virtual pode ser uma alternativa aos métodos tradicionais da reabilitação ou complementar a eles?
P3	Complement to them.	Complementar a eles.
P4	Yes.	Sim.
P6	VR can act as a tool to complement therapy.	A RV pode atuar com uma ferramenta, de forma complementar a terapia.
P7	I believe that virtual rehabilitation can be complementary to traditional methods.	Acredito que a reabilitação virtual pode ser complementar aos métodos tradicionais.
P8	Complementary. I believe it is another tool in patient rehabilitation.	Complementar. Acredito ser mais uma ferramenta na reabilitação do paciente.
P9	Yes for sure	Sim, com toda certeza
P10	Yes, no doubt. It is a strand that uses more than 1 sense for interaction.	Sim, sem dúvidas. É uma vertente que se vale de mais de 1 sentido para a interação.
P11	Yes, as long as it is possible to interact with the game.	Sim, contanto que seja possível interagir com o jogo.

Source: Author

Table 49. Q4-B-9, Group 2 answers.

	Q4-B-9	
	Translation (English)	Original (Portuguese)
	Do you believe that virtual rehabilitation can be an alternative to or complementary to traditional rehabilitation methods?	Você acredita que reabilitação virtual pode ser uma alternativa aos métodos tradicionais da reabilitação ou complementar a eles?
P3	The games are better, and the music did not disturb.	Os jogos estão melhores e a música não atrapalhou.
P4	The easy-to-apply COGMIS-P system makes it easy to understand commands, view numbers and punctuation, and pop balloons.	O sistema COGMIS-P, pois está de fácil aplicabilidade, é fácil de entender os comandos, visualizar os números e a pontuação, bem como, estourar os balões.
P6	The cognitive challenge posed by the task is already good.	Já está bom o desafio cognitivo imposto pela tarefa.
P7	Different distances that the balloons rise because it stimulates balance and reaches strategies.	Diferentes distâncias que os balões sobem, porque estimula estratégias de equilíbrio e alcance.
P8	I believe in helping the patient to adhere to the treatment, being a more creative and playful way during therapy.	Acredito ajudar na aderência do paciente ao tratamento, sendo mais uma forma criativa e lúdica durante a terapia.
P9	Interface, music, number of balloons and their respective speed, because they are simple and easy to understand.	Interface, música, quantidade de balões e sua respectiva velocidade, porque são simples e de fácil entendimento.
P10	I believe the goal of the game is excellent. The use of ankle and hip strategies, as well as reach training, seem to me to be very effective.	Acredito que o objetivo do jogo é excelente. O uso de estratégias de tornozelo e quadril, além de treino de alcance me parecem ser muito eficientes.
P11	The proposal, the music, the safety devices, the willingness of the researchers to get it right, the possibility of access to another tool for rehabilitation.	A proposta, a música, os dispositivos de segurança, a boa vontade dos pesquisadores em acertar, a possibilidade de acesso a mais uma ferramenta para a reabilitação.

Source: Author

Table 50. Q4-B-10, Group 2 answers.

	Q4-B-10	
	Translation (English)	Original (Portuguese)
	What do you think needs improvement?	O que você acha que precisa melhorar?
P3	The environment	O ambiente
P4	The COGMIS-AP system improves the location of numbers and the way balloons pop.	O sistema COGMIS-AP, melhorar a localização dos números e o modo com que se estoura os balões.
P6	Awareness and distribution of balloons	A sensibilização e distribuição dos balões
P7	There are balloons that farther away, even closer, the protection of the vest does not allow them to reach them. - Leave the control safer in hands.	- Tem balões que mais ao longe, mesmo chegando perto, a proteção do colete não permite alcançá-los. - Deixar o controle mais seguro nas mãos.
P8	Suitability of glasses and stimuli for score, further stimulating the cognitive.	Adequação dos óculos e estímulos para pontuação, estimulando ainda mais o cognitivo.
P9	Some inaccurate movements where you seem close enough but can't touch the balloon, some balloon bugs make you fly a little over them	Alguns movimentos imprecisos, onde parece que você está perto o suficiente, mas não consegue tocar o balão, alguns bugs dos balões fazerem você voar um pouco sobre eles
P10	I believe that gameplay can improve in the game that makes use of the holographic feature.	Acredito que jogabilidade possa melhorar no jogo que faz uso de recurso holográfico.
P11	The game needs to work	O jogo funcionar.

Source: Author

Table 51. Q4-B-11, Group 2 answers.

	Q4-B-11	
	Translation (English)	Original (Portuguese)
	What do you think would be ideal?	O que você acha que seria ideal?
P3	Be performed on stable ground.	Ser realizado em solo estável.
P4	The COGMIS-G system would be ideal from a physiotherapeutic point of view to evaluate more variables, as the treadmill is an interesting mechanism.	O sistema COGMIS-G seria o ideal do ponto de vista fisioterapêutico para avaliar mais variáveis, pois a esteira é um mecanismo interessante.
P6	Do not exaggerate the amount of balloons at the same time with different values as this causes the subject to pop balloons that he does not want to burst.	Não exagerar na quantidade de balões soltos ao mesmo tempo com valores diferentes pois isso faz com que o sujeito estoure balões que ele não quer estourar.
P7	---	---
P8	Moving from one phase to another could be more explicit, with visual stimuli when the patient completes a task. Glasses could be more comfortable and spatial boundaries could be more defined as well.	A passagem de uma fase para outra poderia ser mais explícito, com estímulos visuais quando o paciente cumprir uma tarefa. Os óculos poderiam ser mais confortáveis e as delimitações espaciais poderiam ser mais definidas também.
P9	Tutorial Add new velocities, other balloon colors with other numbers A Challenge balloon, with high scores and being harder to reach Fixed some bugs mentioned above In the future, you could think of a few other scenarios, you might even get feedback from patients to develop it in the future”	Tutorial Adicionar novas velocidades, outras cores de balão com outras numerações Um balão Desafio, com pontuação elevada e sendo mais difícil de alcançar Correção de alguns bugs citados acima No futuro, poderia pensar em alguns outros cenários, podendo até mesmo pegar o feedback dos pacientes para desenvolvê-lo no futuro
P10	I believe that understanding the system against player actions needs to be refined.	Acredito que a compreensão do sistema frente às ações do jogador precisa ser refinada.
P11	That the game work.	Que o jogo funcionasse.

Source: Author

B.5. Participants scores

B.5.1. Group 1

Table 52. Scores of participants Group 1. Scores of participants Group 1 (session 1)

Participant *(participante)*	Age *(idade)*	Sex *(sexo)*	System *(sistema)*	Count *(contagem)*	Score *(pontuação)*	Correct *(acertos)*	Incorrect *(erros)*
P1	34	F	1	5	130	13	10
P2	37	F	1	6	240	24	7
P3	58	F	1	6	70	7	3
P4	27	F	1	5	190	19	4
P5	39	F	1	2	180	18	2
P6	34	F	1	2	190	19	0
Mean					166.6	16.6	4.3
Median					185	18.5	3.5
P1	34	F	2	2	100	10	6
P2	37	F	2	7	130	13	3
P3	58	F	2	7	10	1	0
P4	27	F	2	8	130	13	1
P5	39	F	2	4	110	11	4
P6	34	F	2	8	110	11	1
Mean					98.3	9.8	2.5
Median					110	11	2

B.5.2. Group 2

Table 53. Scores of participants Group 2 Scores of participants Group 2 (session 2)

Participant (participante)	Age (idade)	Sex (sexo)	System (sistema)	Count (contagem)	Score (pontuação)	Correct (acertos)	Incorrect (erros)
P3	58	F	1	8	110	7	8
P4	27	F	1	16	210	12	2
P6	35	F	1	8	190	11	8
P7	30	F	1	18	90	6	12
P8	41	F	1	14	270	15	6
P9	24	M	1	13	90	6	9
P10	31	F	1	6	130	8	11
P11	43	F	1	4	150	9	11
Mean					155	9.25	8.375
Median					140	8.5	8.5
P4	27	F	2	8	130	8	3
P9	24	M	2	18	210	12	6
P10	31	F	2	8	130	8	5
P11	43	F	2	6	20	2	0
Mean					122.5	8.09	6.61
Median					130	8	4
P3	58	F	3	0	30	3	0
P4	27	F	3	4	0	0	2
P6	35	F	3	1	20	2	1
P7	30	F	3	9	10	1	2
P8	41	F	3	9	10	1	2
P9	24	M	3	0	10	1	1
P10	31	F	3	3	30	3	2
P11	43	F	3	6	20	2	0
Mean					16.25	1.62	1.25
Median					15	1.5	1.5

Source: Author

ATTACHMENT A - ISHIHARA COLOR TEST

Anexo 1 - Teste de Ishihara Adaptado (daltonismo)

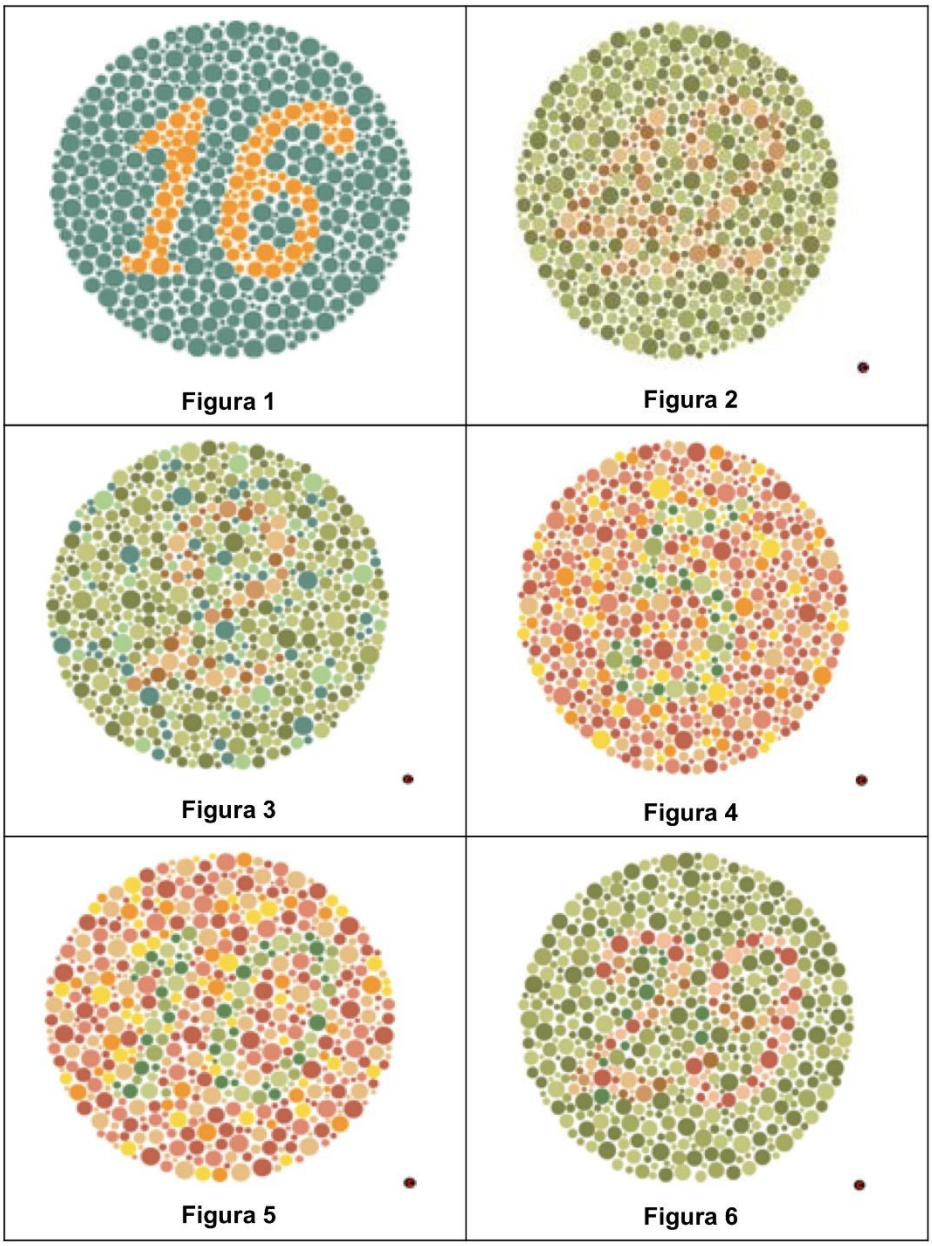

Figura 1 | Figura 2

Figura 3 | Figura 4

Figura 5 | Figura 6

Respostas: 1: 16; 2: 42; 3: 2; 4: 5; 5: 10; 6: 29.

ATTACHMENT B- CONSUBSTANCED OPINION OF THE RESEARCH ETHICS COMMITTEE

This attachment contains information about the submission and appreciation of the research plan by the Research Ethics Committee, original version in Portuguese.

USP - FACULDADE DE MEDICINA DA UNIVERSIDADE DE SÃO PAULO - FMUSP

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: AVALIAÇÃO DA APLICABILIDADE, SEGURANÇA, TOLERABILIDADE E ACEITABILIDADE DE UM SISTEMA DE REALIDADE VIRTUAL IMERSIVA PARA O TREINAMENTO COGNITIVO-MOTOR

Pesquisador: José Eduardo Pompeu

Área Temática: Equipamentos e dispositivos terapêuticos, novos ou não registrados no País;

Versão: 1

CAAE: 03310818.0.0000.0065

Instituição Proponente: Faculdade de Medicina da Universidade de São Paulo

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 3.138.105

Apresentação do Projeto:

Trata-se de um projeto de mestrado da Escola Politécnica, curso de engenharia Elétrica. Nesses termos, o projeto está corretamente apresentado.

Objetivo da Pesquisa:

A pesquisa tem como objetivo testar algumas técnicas de realidade virtual para ajudar idosos a superar problemas posturais e de equilíbrio podendo, assim, reduzir o risco de quedas.

Avaliação dos Riscos e Benefícios:

Durante a realização das atividades do ensaio, os participantes serão auxiliados por fisioterapeutas de modo a reduzir o risco de quedas. Assim, dado que os benefícios são óbvios, a relação risco/benefício é boa.

Comentários e Considerações sobre a Pesquisa:

Num país cuja população está envelhecendo, esse tipo de pesquisa é muito bem vinda.

Considerações sobre os Termos de apresentação obrigatória:

O TCLE está bem apresentado.

Recomendações:

O protocolo foi analisado pela CONEP, que emitiu a seguinte lista de pendências ou inadequações:

1. Quanto à folha de rosto referente ao arquivo "ic.pdf", postado na Plataforma Brasil em

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Bairro: PACAEMBU **CEP:** 01.246-903
UF: SP **Município:** SAO PAULO
Telefone: (11)3893-4401 **E-mail:** cep.fm@usp.br

14/11/2018, todos os campos devem estar devidamente preenchidos e datados. Solicita-se adequação (Norma Operacional CNS nº 001 de 2011, item 3.3.a).

2. Quanto ao termo de consentimento livre e esclarecido – referente ao arquivo "Assentimento.pdf", postado na Plataforma Brasil em 16/11/2018:

2.1. Na página 4 de 5 lê-se: "O(a) senhor(a) deve estar ciente de que estaremos acompanhando os testes o tempo todo e que há um baixo risco de sentir possíveis desconfortos, como náuseas, tontura, vista cansada e dor de cabeça. Nestes casos, o teste será interrompido e, se houver a necessidade, receberá a devida assistência para que se recupere.

Solicita-se que seja expresso, de modo claro e afirmativo no TCLE, o direito a assistência integral gratuita devido a danos diretos/ indiretos e imediatos/ tardios, pelo tempo que for necessário ao participante da pesquisa (Resolução CNS nº 466 de 2012, itens II.3.1 e II.3.2).

2.2. Na página 4 de 5 lê-se: "Não há despesas pessoais para o participante em qualquer fase do estudo, incluindo exames e consultas. Se existir qualquer despesa adicional, ela será absorvida pelo orçamento da pesquisa. Não há compensação financeira relacionada à sua participação".

Deve ser garantido ao participante de pesquisa e seu acompanhante o ressarcimento de despesas decorrentes da participação no estudo nos dias em que for necessária sua presença para consultas ou exames. Sendo assim, solicita-se que o trecho seja reescrito garantindo, de forma clara e afirmativa, o ressarcimento das despesas tidas pelo participante da pesquisa e de seu acompanhante em decorrência de sua participação na pesquisa, podendo -se citar como exemplo, o transporte e a alimentação, mas não se restringindo a eles (Resolução CNS nº
466 de 2012, itens II.21 e IV.3.g).

2.3. Para melhor informar o participante da pesquisa, solicita-se incluir no TCLE uma breve descrição do que é o CEP e qual sua função no estudo.

2.4. O TCLE não apresenta a numeração nas páginas. Com o objetivo de garantir a integridade do documento, solicita-se que sejam inseridos os números de cada página, bem com a quantidade total delas, como por exemplo: "1 de X" e assim sucessivamente até a página "X de X".

Conclusões ou Pendências e Lista de Inadequações:

Após ajustes seguindo as recomendações da CONEP, o projeto deverá ser submetida à análise do CEP para verificação sobre o cumprimento das questões
acima, antes do início do estudo.

Considerações Finais a critério do CEP:

USP - FACULDADE DE MEDICINA DA UNIVERSIDADE DE SÃO PAULO - FMUSP

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_1241557.pdf	16/11/2018 14:08:36		Aceito
Declaração de Instituição e Infraestrutura	CITI.pdf	16/11/2018 14:05:16	GUIDO AUGUSTO FARIA PEREIRA	Aceito
Declaração de Instituição e Infraestrutura	LACOM.pdf	16/11/2018 14:03:25	GUIDO AUGUSTO FARIA PEREIRA	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	Assentimento.pdf	16/11/2018 14:01:33	GUIDO AUGUSTO FARIA PEREIRA	Aceito
Projeto Detalhado / Brochura Investigador	Completo_projeto.pdf	16/11/2018 13:55:31	GUIDO AUGUSTO FARIA PEREIRA	Aceito
Folha de Rosto	ic.pdf	14/11/2018 13:44:20	GUIDO AUGUSTO FARIA PEREIRA	Aceito

Situação do Parecer:
Pendente

Necessita Apreciação da CONEP:
Não

SAO PAULO, 08 de Fevereiro de 2019

Assinado por:
Maria Aparecida Azevedo Koike Folgueira
(Coordenador(a))

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ATTACHMENT C- CERTIFICATE OF PRESENTATION FOR ETHICAL APPRECIATION

This attachment contains information about the final appreciation of the research plan by the Research Ethics Committee, original version in Portuguese.

USP - FACULDADE DE MEDICINA DA UNIVERSIDADE DE SÃO PAULO - FMUSP

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: AVALIAÇÃO DA APLICABILIDADE, SEGURANÇA, TOLERABILIDADE E ACEITABILIDADE DE UM SISTEMA DE REALIDADE VIRTUAL IMERSIVA PARA O TREINAMENTO COGNITIVO-MOTOR

Pesquisador: José Eduardo Pompeu

Área Temática: Equipamentos e dispositivos terapêuticos, novos ou não registrados no País;

Versão: 2

CAAE: 03310818.0.0000.0065

Instituição Proponente: Faculdade de Medicina da Universidade de São Paulo

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 3.316.190

Apresentação do Projeto:

N/A

Objetivo da Pesquisa:

N/A

Avaliação dos Riscos e Benefícios:

N/A

Comentários e Considerações sobre a Pesquisa:

Este projeto já passou pelo CONEP, que o aprovou no mérito. Entretanto, fez uma série de recomendações de correção na folha de rosto e no TCLE cuja execução deve ser verificada pelo CEP local.

Considerações sobre os Termos de apresentação obrigatória:

Verifiquei que o pesquisador fez todas as correções sugeridas pelo CONEP, na folha de rosto e no TCLE.

Conclusões ou Pendências e Lista de Inadequações:

O projeto está pronto para aprovação.

Considerações Finais a critério do CEP:

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UF: SP **Município:** SAO PAULO
Telefone: (11)3893-4401 **E-mail:** cep.fm@usp.br

USP - FACULDADE DE MEDICINA DA UNIVERSIDADE DE SÃO PAULO - FMUSP

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_1241557.pdf	12/02/2019 16:07:43		Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE.pdf	12/02/2019 16:00:08	José Eduardo Pompeu	Aceito
Folha de Rosto	icr2.pdf	12/02/2019 15:46:51	José Eduardo Pompeu	Aceito
Declaração de Instituição e Infraestrutura	CITI.pdf	16/11/2018 14:05:16	GUIDO AUGUSTO FARIA PEREIRA	Aceito
Declaração de Instituição e Infraestrutura	LACOM.pdf	16/11/2018 14:03:25	GUIDO AUGUSTO FARIA PEREIRA	Aceito
Projeto Detalhado / Brochura Investigador	Completo_projeto.pdf	16/11/2018 13:55:31	GUIDO AUGUSTO FARIA PEREIRA	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

SAO PAULO, 09 de Maio de 2019

Assinado por:
Maria Aparecida Azevedo Koike Folgueira
(Coordenador(a))

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ATTACHMENT D- QUESTIONAIRES FOR CLINICAL RESEARCH - SYSTEM 1 – STEAMVR UPDATE

This attachment presents the questionnaires used for clinical research for System 4 that uses the HTC Vive. Table 54 presents an overview about the questionnaires presented in this attachment. Following, all the questionnaires are in the original version, in portuguese, as they were applied in this research

Table 54. Overview about the questionnaires for clinical research presented in attachment D

Set	Instrument	Authorship / reference	Page
Questionnaires for sample characterization *Questionários para caracterização das amostras*	(Annex 1) Questionnaire of technology use *(Anexo 1) Questionário de uso da tecnologia*	Costa, Raquel – Two new virtual reality tasks for the assessment of spatial orientation. Preliminary results of tolerability, sense of presence and usability. 2018. Disponível em: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6022 991 . Adapted for the research group.	184
	(Annex 2) IPAQ - International Physical Activity Questionnaire - short version *(Anexo 2) IPAQ - Questionário Internacional de Atividade Física - versão curta*	Matsudo S, Araujo T, Matsudo V, Andrade D, Andrade E, Oliveira LC, et al. Questionário Internacional de Atividade Física (IPAQ): Estudo de validade e reprodutividade no Brasil. Revista Atividade Física e Saúde. 2001; 6 (2): 5-18.	185
	(Appendix 3) Charlson Comorbidity Index (Anexo 3) Índice de Comorbidade de Charlson	Martins M, Blais R, Miranda NN. Avaliação do índice de comorbidade de Charlson em internações da região de Ribeirão Preto, São Paulo, Brasil. Cad. Saúde Pública. 2008; 24 (3); 643-652. Iucif JR, Nelson, ROCHA JSY. Estudo da desigualdade na mortalidade hospitalar pelo índice de comorbidade de Charlson. Rev. Saúde Pública. 2004; 38 (6); 780-786.	186
	(Annex 4) Montreal Cognitive Scale - MOCA - Brazilian experimental version (Anexo 4) Escala Cognitiva de Montreal - MOCA - versão experimental brasileira	Nasreddine ZS, Philips NA, Bédirian V, Charbonneau S, Whitehead V, Collin I. The Montreal Cognitive Assessment (MoCA): a brief screening tool for mild cognitive impairment. J Am Geriatr Soc. 2005; 53 (4): 695–699. Duro D, Simões MR, Ponciano E, Santana I. Validation studies of the Portuguese experimental version of the Montreal Cognitive Assessment	187

		(MoCA): confirmatory factor analysis. J Neurol. 2010; 257 (5): 728-34.	
	(Annex 5) Geriatric Depression Scale - GDS-15 (Anexo 5) Escala de depressão geriátrica - GDS-15	Paradela EMP, Lourenço RA, Veras RP. Validação da escala de depressão geriátrica em um ambulatório geral. Rev. Saúde Pública. 2005; 39 (6); 918-923.	188
	(Appendix 6) Time get up and go test (TUGT) - Fall Risk Assessment (Anexo 6) Time get up and go test (TUGT) - Avaliação do risco de quedas	Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. Journal of the American geriatrics Society. 1991 Feb;39(2):142-8.	189
Safety, tolerability and acceptability analysis questionnaires *Questionários para análise da segurança, tolerabilidade e aceitabilidade*	(Annex 6) Pre-virtual reality discomfort questionnaire (Anexo 6) Questionário de desconforto pré realidade virtual	Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. Journal of the American geriatrics Society. 1991 Feb;39(2):142-8.	190
	(Appendix 7) Post-virtual reality discomfort questionnaire (Anexo 7) Questionário de desconforto pós realidade virtual	Costa, Raquel – Two new virtual reality tasks for the assessment of spatial orientation. Preliminary results of tolerability, sense of presence and usability. 2018. Disponível em: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6022 991/. acesso em: 28.09.2018. Adaptado pelo grupo de pesquisa.	191
	(Annex 8) Satisfaction Questionnaire (Anexo 8) Questionário de satisfação	Costa, Raquel – Two new virtual reality tasks for the assessment of spatial orientation. Preliminary results of tolerability, sense of presence and usability. 2018. Disponível em: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6022 991/. acesso em: 28.09.2018. Adaptado pelo grupo de pesquisa.	192
	(Annex 9) Questionnaire and assessment interview of physical therapists (applicability) (Anexo 9) Questionário e entrevista de avaliação dos fisioterapeutas (aplicabilidade)	SIBLEY, K. M. (colab.) Using the systems framework for postural control to analyze the components of balance evaluated in standardized balance measures: a scoping review. Archives of physical medicine and rehabilitation, v. 96, n. 1, p. 122–132, 2015. DOI.org/10.1016/j.apmr.2014.06.021 Tahmosybayat R, Baker K, Godfrey A, Caplan N, Barry G. Movements of older adults during exergaming interventions that are associated with the Systems Framework for Postural Control: A systematic review. Maturitas. 2018 May 1;111:90-9.	194

		Questions Elaborated by Prof. José Eduardo Pompeu.	

5

QUESTIONÁRIOS PARA CARACTERIZAÇÃO DA AMOSTRA

ANEXO 1 - Questionário de uso de tecnologia

Data:

Nome:

Idade:

Sexo: M ( ) F ( )

1. Com que frequência o sr(a) utiliza o computador?

Sempre ( ) Às vezes ( ) Nunca ( )

2. O (a) sr(a) possui celular?

Sim ( ) Não ( )

Se sim, seu celular tem acesso à internet? Sim ( ) Não ( )

3. Com que frequência o sr(a) utiliza a internet do celular? (desconsidere caso tenha marcado não na pergunta 2)

Sempre ( ) Às vezes ( ) Nunca ( )

4. O (a) sr(a) joga algum jogo no celular?

Sim ( ) Não ( )

Se sim, com que frequência? Sempre ( ) Às vezes ( ) Raramente ( )

5. O (a) sr(a) joga ou já jogou videogame?

Sim ( ) Não ( )

Se sim, com que frequência? Sempre ( ) Às vezes ( ) Raramente ( )

ANEXO 2 - IPAQ

QUESTIONÁRIO INTERNACIONAL DE ATIVIDADE FÍSICA (versão curta)

Nome:
_____
Data: ___/___/___ **Idade :** ____**Sexo: F ( ) M ( )**
Ocupação: _____ **Cidade :** _____
Nós estamos interessados em saber que tipos de atividade física as pessoas fazem como parte do seu dia a dia. Este projeto faz parte de um grande estudo que está sendo feito em diferentes países ao redor do mundo. Suas respostas nos ajudarão a entender que tão ativos nós somos em relação à pessoas de outros países. As perguntas estão relacionadas ao tempo que você gasta fazendo atividade física na ÚLTIMA semana. As perguntas incluem as atividades que você faz no trabalho, para ir de um lugar a outro, por lazer, por esporte, por exercício ou como parte das suas atividades em casa ou no jardim. Suas respostas são MUITO importantes. Por favor responda cada questão mesmo que considere que não seja ativo. Obrigado pela sua participação!

Para responder as questões lembre que:

- atividades físicas VIGOROSAS são aquelas que precisam de um grande esforço físico e que fa zem respirar MUITO mais forte que o normal
- atividades físicas MODERADAS são aquelas que precisam de algum esforço físico e que fazem respirar UM POUCO mais forte que o normal

Para responder as perguntas pense soment e nas atividades que você realiza por
pelo menos 10 minutos contínuos de cada vez.

1a. Em quantos dias da última semana você CAMINHOU por pelo menos 10
minutos contínuos em casa ou no trabalho, como fo rma de transporte para ir de um
lugar para outro, por lazer, por pr azer ou como forma de exercício?
dias _____ por SEMANA ( ) Nenhum

1b. Nos dias em que você caminhou por pelo menos 10 minutos contínuos quanto
tempo no total você gastou caminhando por dia?
horas: _____ Minutos: _____

2a. Em quantos dias da última se mana, você realizou atividades MODERADAS por pelo menos 10 minutos contínuos , como por exemplo pedalar leve na bicicleta, nadar, dançar, fazer ginástica aeróbica leve, jogar vôlei recreativo, carregar pesos leves, fazer serviços domésticos na casa, no quintal ou no jardim como varrer, aspirar, cuidar do jardim, ou qualquer atividade que fez aumentar moderadamente sua respiração ou batimentos do coração (POR FAVOR NÃO INCLUA CAMINHADA)
dias _____ por SEMANA ( ) Nenhum

2b. Nos dias em que você fez essas atividades moderadas por pelo menos 10 minutos contínuos, quanto tempo no total você gastou fazendo essas atividades por dia?
horas: _____ Minutos: _____

3a. Em quantos dias da última semana, você realizou atividades VIGOROSAS por pelo menos 10 minutos contínuos, como por exemplo correr, fazer ginástica aeróbica, jogar futebol, pedalar rápido na bicicleta, jogar basquete, fazer serviços domésticos pesados em casa, no quintal ou cavoucar no jardim, carregar pesos elevados ou qualquer atividade que fez aumentar MUITO sua respiração ou batimentos do coração.
dias _____ por SEMANA ( ) Nenhum

3b. Nos dias em que você fez essas atividades vigorosas por pelo menos 10 minutos contínuos quanto tempo no total você gastou fazendo essas atividades por dia?
horas: _____ Minutos: _____

Estas últimas questões são sobre o tempo que você permanece sentado todo dia, no trabalho, na escola ou faculdade, em casa e durante seu tempo livre. Isto inclui o tempo sentado estudando, sentado enquanto descansa, fazendo lição de casa visitando um amigo, lendo, sentado ou deitado assistindo TV. Não inclua o tempo gasto sentando durante o transporte em ônibus, trem, metrô ou carro.

4a. Quanto tempo no total você gasta sentado durante um dia de semana ?
_____horas ____minutos

4b. Quanto tempo no total você gasta sentado durante em um dia de final de semana ?
_____horas ____minutos

7

ANEXO 3 - ÍNDICE DE COMORBIDADE DE CHARLSON

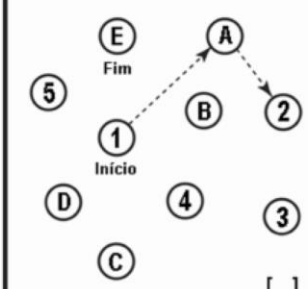
Peso	Condição Clínica
1	Infarto do miocárdio Insuficiência cardíaca congestiva Doença Vascular periférica Demência Doença cerebro-vascular Doença pulmonar crônica Doença tecido conjuntivo Diabetes leve, sem complicação Úlcera
2	Hemiplegia Doença renal severa ou moderada Diabetes com complicação Tumor Leucemia Linfoma
3	Doença do fígado severa ou moderada
6	Tumor maligno, metástase SIDA

ANEXO 4 - ESCALA COGNITIVA DE MONTREAL (MOCA)

MONTREAL COGNITIVE ASSESSMENT (MOCA)
Versão Experimental Brasileira

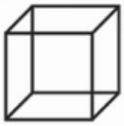
Nome:_____ Data de nascimento: __/__/__
Escolaridade:_____ Data de avaliação: __/__/__
Sexo:_____ Idade:____

VISUOESPACIAL / EXECUTIVA — Pontos



[ ] [ ]

Copiar o cubo

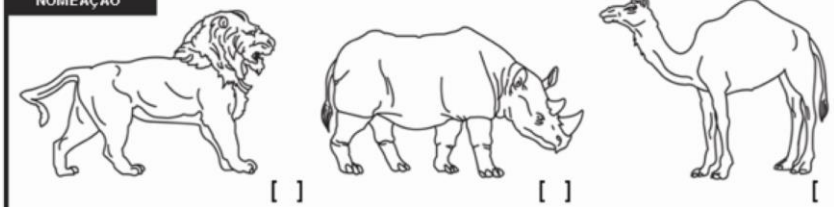


Desenhar um RELÓGIO (onze horas e dez minutos) (3 pontos)

[ ] Contorno [ ] Números [ ] Ponteiros

__/5

NOMEAÇÃO



[ ] [ ] [ ]

__/3

MEMÓRIA — Leia a lista de palavras, O sujeito de repeti-la, faça duas tentativas. Evocar após 5 minutos

	Rosto	Veludo	Igreja	Margarida	Vermelho
1ª tentativa					
2ª tentativa					

Sem Pontuação

ATENÇÃO — Leia a seqüência de números (1 número por segundo)

O sujeito deve repetir a seqüência em ordem direta [ ] 2 1 8 5 4
O sujeito deve repetir a seqüência em ordem indireta [ ] 7 4 2

__/2

Leia a série de letras. O sujeito deve bater com a mão (na mesa) cada vez que ouvir a letra "A". Não se atribuem pontos se ≥ 2 erros.
[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B

__/1

Subtração de 7 começando pelo 100 [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65
4 ou 5 subtrações corretas: 3 pontos; 2 ou 3 corretas 2 pontos; 1 correta 1 ponto; 0 correta 0 ponto

__/3

LINGUAGEM — Repetir: Eu somente sei que é João quem será ajudado hoje. [ ]

O gato sempre se esconde embaixo do Sofá quando o cachorro está na sala. [ ]

__/2

Fluência verbal: dizer o maior número possível de palavras que comecem pela letra F (1 minuto). [ ]_____ (N ≥ 11 palavras)

__/1

ABSTRAÇÃO — Semelhança p. ex. entre banana e laranja = fruta [ ] trem - bicicleta [ ] relógio - régua

__/2

EVOCAÇÃO TARDIA — Deve recordar as palavras SEM PISTAS

	Rosto	Veludo	Igreja	Margarida	Vermelho
	[ ]	[ ]	[ ]	[ ]	[ ]

Pontuação apenas para evocação SEM PISTAS

__/5

OPCIONAL

Pista de categoria	
Pista de múltipla escolha	

ORIENTAÇÃO — [ ] Dia do mês [ ] Mês [ ] Ano [ ] Dia da semana [ ] Lugar [ ] Cidade

__/6

Versão experimental Brasileira: *Ana Luisa Rosas Sarmento*
Paulo Henrique Ferreira Bertolucci - José Roberto Wajman
(UNIFESP-SP 2007)

TOTAL
Adicionar 1 pt se ≤ 12 anos de escolaridade __/30

9

ANEXO 5 - ESCALA DE DEPRESSÃO GERIÁTRICA (GDS-15)

ESCALA DE DEPRESSÃO GERIÁTRICA - GDS

1. Está satisfeito (a) com sua vida? (não =1) (sim = 0)
2. Diminuiu a maior parte de suas atividades e interesses? (sim = 1) (não = 0)
3. Sente que a vida está vazia? (sim=1) (não = 0)
4. Aborrece-se com freqüência? (sim=1) (não = 0)
5. Sente-se de bem com a vida na maior parte do tempo? (não=1) (sim = 0)
6. Teme que algo ruim possa lhe acontecer? (sim=1) (não = 0)
7. Sente-se feliz a maior parte do tempo? (não=1) (sim = 0)
8. Sente-se freqüentemente desamparado (a)? (sim=1) (não = 0)
9. Prefere ficar em casa a sair e fazer coisas novas? (sim=1) (não = 0)
10. Acha que tem mais problemas de memória que a maioria? (sim=1) (não = 0)
11. Acha que é maravilhoso estar vivo agora? (não=1) (sim = 0)
12. Vale a pena viver como vive agora? (não=1) (sim = 0)
13. Sente-se cheio(a) de energia? (não=1) (sim = 0)
14. Acha que sua situação tem solução? (não=1) (sim = 0)
15. Acha que tem muita gente em situação melhor? (sim=1) (não = 0)

ANEXO 6 - TIME GET UP AND GO TEST

PREFEITURA DE SÃO PAULO
SAÚDE

PREFEITURA DO MUNICÍPIO DE SÃO PAULO
SECRETARIA MUNICIPAL DE SAÚDE
COORDENAÇÃO DAS REDES DE ATENÇÃO À SAÚDE E ÁREAS TEMÁTICAS
ÁREA TÉCNICA DE SAÚDE DA PESSOA IDOSA

NOME:		**DN:**
RAÇA/COR: ( ) Branca ( ) Preta ( )Amarela ( ) Parda ( ) Indígena	**CNS:**	**SEXO:** F ( ) M ( )
ENDEREÇO:		
UBS:	**EQUIPE:**	**TEL:**

TIME GET UP AND GO TEST (TUGT) – AVALIAÇÃO DE RISCO DE QUEDAS

INSTRUÇÕES

- Material/equipamento: cadeira (45 cm a 48 cm de altura) com braços, de pés fixos (sem rodinhas), cronômetro; fita adesiva; trena, ou barbante, ou fita com 3m (para demarcar a distância de 3m);
- Orientar o procedimento do teste e certificar-se de que o participante entendeu o que é para ser feito;
- Realizar uma tentativa de familiarização do teste, demonstrando o procedimento (apenas uma vez);
- Corrigir, se for necessário, e reforçar pontos importantes, tais como: chegar até a marca no chão e sentar-se encostando completamente o tronco no encosto da cadeira;
- Caso o idoso apresente alguma dificuldade de entendimento (ou esquecimento), que o faça interromper o percurso, refaça a orientação a respeito da forma correta de execução e reinicie o teste;
- Caso o participante faça qualquer pergunta durante o teste, como por exemplo: "É para sentar?", responda: "Faça como eu lhe disse para fazer";
- É permitido ao participante o uso de dispositivo de auxílio à marcha (bengala, ou andador);
- O participante deve estar usando seu sapato habitual;
- Para cronometrar o tempo: o cronômetro deve ser disparado, quando o participante projetar os ombros à frente (desencostar da cadeira) e deve ser parado, quando o mesmo encostar completamente o tronco no encosto da cadeira.

PROCEDIMENTO

O idoso deverá estar sentado em uma cadeira com apoio lateral de braço.
Solicite ao idoso, que se levante sem apoiar nas laterais da cadeira, caminhe 3 metros, virando 180º e retornando ao ponto de partida, para sentar-se novamente.

RESULTADO

Assinalar conforme a cronometragem do trajeto:

( )	< 10 segundos (acompanhar conforme o fluxo normal da AMPI/AB)
( )	10 a 19 segundos (acompanhar na UBS a não ser que tenha outras indicações para a atenção especializada) Segundo a literatura, **o tempo acima de 12,4 segundos** indica **risco aumentado** para quedas.
( )	20 segundos ou mais (deverá ser encaminhado para a URSI)

QUESTIONÁRIOS PARA ANÁLISE DA SEGURANÇA, TOLERABILIDADE E ACEITABILIDADE

ANEXO 6 - Questionário de desconforto pré realidade virtual

Data:

Nome:

Idade:

Sexo: M ( ) F ( )

1. O sr(a) está sentindo algum desconforto neste momento?

Sim ( ) Não ( )

Se sim, por favor, descreva: _____

2. O sr(a) teve episódios de enjôo ou vômito hoje ou recentemente?

Sim ( ) Não ( )

3. O sr(a) possui histórico de enjôo relacionado a meio de transporte?

Sim ( ) Não ( )

Se sim, por favor, descreva onde (carro, trem, avião, barco, etc) e quando (recentemente vs há muito tempo):

_____

4. O sr(a) já sentiu tontura ou náuseas enquanto assistia a um filme em uma tela grande (ex. cinema)?

Sim ( ) Não ( )

5. O sr(a) sente tontura ou enjôo quando lê em um carro ou ônibus em movimento?

Sim ( ) Não ( )

6. O sr(a) prefere ser o motorista, ao invés do passageiro, porque senão sente tontura ou náuseas?

Sim ( ) Não ( )

ANEXO 7- Questionário de desconforto pós realidade virtual

Data:

Nome:

Idade:

Sexo: M ( ) F ( )

Por favor, assinale com um X a intensidade do desconforto que o (a) sr(a) sentiu:

Desconforto geral: Nem um pouco ( ) Um pouco ( ) Bastante ( ) Muito ( )

Cansaço: Nem um pouco ( ) Um pouco ( ) Bastante ( ) Muito ( )

Dor de cabeça: Nem um pouco ( ) Um pouco ( ) Bastante ( ) Muito ( )

Cansaço na vista: Nem um pouco ( ) Um pouco ( ) Bastante ( ) Muito ( )

Aumento da salivação: Nem um pouco ( ) Um pouco ( ) Bastante ( ) Muito ( )

Suor: Nem um pouco ( ) Um pouco ( ) Bastante ( ) Muito ( )

Náusea: Nem um pouco ( ) Um pouco ( ) Bastante ( ) Muito ( )

Dificuldade de se concentrar: Nem um pouco ( ) Um pouco ( ) Bastante ( ) Muito ( )

Palpitação: Nem um pouco ( ) Um pouco ( ) Bastante ( ) Muito ( )

Visão borrada: Nem um pouco ( ) Um pouco ( ) Bastante ( ) Muito ( )

Tontura (com olhos abertos): Nem um pouco ( ) Um pouco ( ) Bastante ( ) Muito ( )

Tontura (com olhos fechados):Nem um pouco ( ) Um pouco ( ) Bastante ( ) Muito ( )

Vertigem: Nem um pouco ( ) Um pouco ( ) Bastante ( ) Muito ( )

Confusão mental: Nem um pouco ( ) Um pouco ( ) Bastante ( ) Muito ( )

Desconforto abdominal: Nem um pouco ( ) Um pouco ( ) Bastante ( ) Muito ( )

Refluxo: Nem um pouco ( ) Um pouco ( ) Bastante ( ) Muito ( )

ANEXO 8 - Questionário de satisfação

1. O que o (a) sr(a) achou do jogo?

Muito bom ( )

Bom ( )

Regular ( )

Ruim ( )

Péssimo ( )

2. O (a) sr(a) conseguiu entender o que deveria ser feito no jogo?

Completamente ( )

Parcialmente ( )

Não entendi ( )

3. O (a) sr(a) se sentiu seguro(a) ao jogar o jogo?

Completamente ( )

Parcialmente ( )

Não me senti seguro ( ) Por quê?: _____

4. O (a) sr(a) se sentiu motivado(a) ao jogar o jogo?

Muito motivado ( )

Motivado ( )

Pouco motivado ( )

Nem um pouco motivado ( )

5. O (a) sr(a) se imaginaria jogando esse jogo em casa?

Sim ( ) Não ( )

6. O (a) sr(a) indicaria esse jogo para alguém?

Sim ( ) Não ( )

7. O (a) sr(a) considera esse jogo como uma forma de exercício?

Sim ( ) Não ( )

8. O (a) sr(a) continuaria realizando esta intervenção após o fim desse projeto?

Sim ( ) Não ( )

9. O (a) sr(a) tem alguma sugestão, elogio ou crítica? Escreva.

_____
_____
_____
_____
_____
_____

Anexo 9– Questionário e entrevista de avaliação dos fisioterapeutas (aplicabilidade)

Nome: _____ Idade: ____ Sexo: M ( ) F ( )

Data: _____ Horário: _____

Grupo de estudo: ( ) E1 ( ) E2

15

PARTE A - Questionário

Item avaliado		Descrição	0,00	0,25	0,50	0,75	1,00
1. Limitação biomecânica: graus de liberdade, força, limites de estabilidade	Estabilidade Funcional: o teste capacita o movimento	Testa a capacidade de mover o centro de massa o máximo possível nas direções AP e ML dentro da base de suporte					
	Sistema Motor Central	Testa alongamento e coordenação suficiente através da atividade física do jogo					
	Estabilidade Estática	Testa a capacidade de manter a posição do centro de massa em posição não suportada quando a base do suporte não muda (pode incluir postura larga, postura estreita de 1 perna, tandem, alguma condição permanente)					
2. Orientação espacial: percepção da gravidade e verticalidade	Verticalidade	Testa a capacidade de orientar adequadamente em relação à gravidade (por exemplo, avaliação de lean)					
3. Estratégias motoras: reativo, antecipatório, voluntário	Controle Postural Reativo	Testa a capacidade de recuperar a estabilidade após uma perturbação externa para trazer o centro de massa dentro da base de apoio através de movimentos corretivos (por exemplo, tornozelo, quadril e estratégias)					

	Controle Postural Antecipatório	Testa a capacidade de mudar o centro de massa antes de um movimento voluntário discreto (por exemplo, levantando perna, levantar o braço, virar a cabeça)					
4. Controle dinâmico: marcha, proativo	Estabilidade Dinâmica	Testa a capacidade de exercer controle contínuo do centro de massa quando a base do suporte é mudando (por exemplo, durante a marcha e transições posturais)?					
5. Estratégia sensorial: integração, reponderação	Integração Sensorial	Testa a capacidade de repor a informação sensorial (visão, vestibular, somatossensorial) quando entrada alterada					
6. Processamento cognitivo: atenção, aprendizagem	Influência cognitiva	Testa a capacidade de manter a estabilidade enquanto responde aos comandos durante a tarefa ou comparecer para tarefas adicionais (por exemplo, dupla tarefa)					

PARTE B - Entrevista

7. O(a) Sr(a) tem alguma sugestão, elogio ou crítica? Por favor, comente.

_____
_____
_____
_____

8. Você acredita que reabilitação virtual pode ser uma alternativa aos métodos tradicionais da reabilitação ou complementar a eles?

_____
_____
_____
_____
_____

9. O que você acha que já está bom e que seria útil? Porque?

_____
_____
_____
_____
_____

10. O que você acha que precisa melhorar?

_____
_____
_____
_____
_____

11. O que você acha que seria ideal.

_____