

MESTRADO

MULTIMÉDIA - ESPECIALIZAÇÃO EM TECNOLOGIAS INTERATIVAS E JOGOS
DIGITAIS

Accessibility in digital games: Combining interaction techniques for improved experience of users with motor impairments

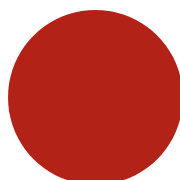
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Accessibility in digital games: Combining interaction techniques for improved experience of users with motor impairments

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MASTER'S THESIS



Mestrado em Multimédia

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July 26, 2024

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Abstract

The gaming industry has been focusing on accessibility features more and more as the years pass by, focused on a more inclusive society and searching for expanding the number and diversity of gamers. However, there is still a lot of work to be done in order to make games completely accessible.

Accessibility technologies could, in theory, substitute the need for using the hands with dexterity to play a game. However, in a game that needs more than one action at once, using only one of the technologies, as most studies report, would prove futile and overly complicated.

With this study, we aimed to expand the research of accessibility in video games, specifically for people with motor disabilities that have some type of incapacity in the usage of the hands. We aimed to study how the integration of two technologies compares to the use of only one (complemented by traditional input methods), and hypothesize that the implementation will prove more immersive and fun to play, as well as be more accessible. With a preliminary interview, we gathered insight into disabled users' issues and what they think about the effort being made to accommodate them.

In the game we used for the research, a top-down 3D shooter, there are two main actions: movement and shooting. Our integrated system consists of a nose tracker and a gaze tracker, linked to different actions in the game. The nose tracker is used for the movement action while the gaze tracker is used for the shooting action. The individual systems use, each, one of these technologies and the keyboard, a traditional input method, for the complementing action. Following the implementation of the two technologies individually, we tested them against the original input devices to understand how the technologies performed when compared to the original experience.

Through a second phase of user tests, we tested the integration of these two technologies against their individual implementation. Our results indicate that users did not prefer the combination of technologies over their individual use. However, they liked the experience with the gaze tracker, finding it fun and enjoyable, and accessible enough, provided you had movement in one hand.

Resumo

A indústria de jogos tem vindo a focar-se cada vez mais em recursos de acessibilidade ao longo dos anos, focando-se numa sociedade mais inclusiva e procurando aumentar o seu mercado. No entanto, ainda há muito trabalho a ser feito para que jogos sejam completamente acessíveis.

Tecnologias de acessibilidade poderiam, em teoria, substituir a necessidade do uso de mãos com dexteridade para jogar um jogo. Contudo, num jogo que precisa de mais de uma ação de cada vez, usar só uma das tecnologias, como maior parte dos estudos relatam, provaria fútil e excessivamente complicado.

Com este estudo, visámos expandir a investigação sobre acessibilidade em videojogos, especificamente para pessoas com deficiências motoras com dificuldade em usar as mãos. Visámos estudar como a integração de duas tecnologias se compara ao uso destas individualmente (com o complemento de métodos de “input” tradicionais) e propomos a hipótese de que a implementação provará ser mais imersiva e divertida de jogar, assim como a opção mais acessível. Com uma entrevista preliminar, recolhemos informações sobre os problemas que utilizadores deficientes encontram e o que eles acham sobre o esforço a ser feito para os acomodar.

No jogo com o qual desenvolvemos este estudo, um jogo de tiro 3D com perspectiva “top-down”, existem duas ações principais: movimento e disparar. O nosso sistema integrado consiste num rastreador de nariz e num rastreador de olhar, ligados a diferentes ações no jogo. O rastreador de nariz é usado para a ação de movimento e o de olhar é usado para a ação de disparar. Os sistemas individuais usam, cada um, uma destas tecnologias em conjunto com o teclado, um método de “input” tradicional, para a ação complementar. Depois da implementação das tecnologias individualmente, testámo-las contra o “input” original para compreender como as tecnologias eram percebidas quando comparadas com a experiência original.

Por meio de uma segunda fase de testes de utilizador, testámos a integração destas duas tecnologias contra a sua implementação individual. Os resultados indicam que os utilizadores não preferiram a integração das tecnologias ao seu uso individual. No entanto, gostaram da experiência com o rastreador de olhar, achando-a divertida e agradável, e acessível o suficiente, desde que o utilizador tenha movimento numa mão.

Acknowledgements

I would like to express my sincere gratitude to my advisor, Professor António Coelho, for all the help provided through the course of this dissertation, for all the reassurance and encouragement shown through our meetings, for believing in me and my project's idea through the whole course of it. His continuous support and constructive feedback have been invaluable through this journey.

In addition, I would like to express my deepest gratitude to Teresa Matos, my supervisor at Mindera, and professor at FEUP, who supported me through this academic journey, and helped me through the beginning of my professional journey as well. I would also like to thank all my colleagues at the Mindera Gaming team, who took me in and helped me through my struggles with the implementation. A special thank you to the colleagues that shared an office with me, Inês, Diogo Oliveira, Luís, Raúl, Gean, Diogo Alves and Marco. Their support and Teresa's, both professionally and emotionally, was invaluable to this project.

I would also like to extend my gratitude to Associação Salvador, and their associates who were willing to test my research. This research project is for them, and although I could not test it solely with their associates in order to draw conclusions, I am eternally grateful for their help.

I would like to express my deepest gratitude towards my family, who supported me through my academic journey, since I started out at kindergarten up until this moment, and who I know will continue to support me through life. My grandparents, who walked me home from school for as long as they could and were always there with a kind word to calm me down through my studies. My mother, who has been the best role model I could wish for, with her strength and determination. My father, who is the reason I see math as logic and not as a three-headed monster. My siblings, who were always there for a shouting match to release pent-up anxiousness. My godmother, and my godfather, and all extended family, who albeit not as informed about my progress as my closer family, still made an effort to support me through the journey.

My sincere gratitude to my closest friends, Margarida, Marta, Maria, Luísa and Carolina, and my boyfriend, Tomás, who have been my rocks through the self-doubt waters of this anxious sea that is the academic life. Without them, I would not have the courage to even start this research.

Without all of the people mentioned above, this research would not have been possible. People say it takes a village to raise a child, and I think it still takes a village to keep that child supported through their adult years. Thank you to my village.

Margarida Nazaré Santos

“Alone we can do so little. Together we can do so much.”

Helen Keller

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Abbreviations

GDC	Game Developers Conference
UI	User Interface
AP	Accessibility Player
AI	Artificial Intelligence
GEQ	Game Experience Questionnaire
FEUP	Faculdade de Engenharia da Universidade do Porto
WHO	World Health Organization
FCC	Federal Communications Commission
INS	International Neuromodulation Society

Chapter 1

Introduction

In this chapter, we present the context for the research, the author's motivations and objectives, as well as specify the research questions. We also present the proposed solution in summary, to detail it in a later chapter.

The structure of the thesis is included in the last section, so that the reader can better understand how the document was organized.

1.1 Context

Games are widely appreciated by a variety of audiences. Although different demographics like different types of games, everyone enjoys playing. Because all people enjoy games, it is very important that we make gaming accessible to everyone.

Games also have a lot of uses, such as entertainment, education and health. By making inaccessible games, we are depriving disabled people of entertainment, educational tools, and therapeutic tools as well.

Right now, according to the Game Developer's Conference (GDC) State of The Game Industry 2024, an event for game developers focusing on exchanging ideas, solve problems and shape the future of game development, 48% of the game developers report that their companies implement accessibility measures in their games, while 27% said their companies do not. Although these are great improvements from the previous year (38% and 32%, respectively), there is still a lot of work that can be done. The most implemented strategies are already considered industry standards, for example, closed captions, color blind mode and key remapping, and even these do not appear in all games [Eld24].

Unfortunately, due to the amount and variety of disabilities there are, we can never have one game that is completely accessible for everyone. However, we can keep working towards that goal.

1.2 Motivation and Objectives

As stated above, games are widely appreciated and used for many purposes. Disabled people cannot play games that do not accommodate their needs. That stops them from using games for any of their purposes. Until all games implement as much accessibility features as they can, there is a need for improvements and new research into this issue.

Although there is already quite a lot of research, there is still a gap in the knowledge of how to address these accessibility problems. Interaction techniques have been studied, but we identified close to zero studies using more than one technology at the same time to interact with the game, and zero studies that focus on this particular idea. Since it is considered that no game can be completely accessible right now [AGH⁺20] for all people, we wondered if mixing technologies could be a step in the right direction when it came to making all games accessible to everyone with motor impairments.

From these ideas, our concept was created. We implemented two simultaneous accessibility technologies in one game, with the objective of studying if having the two technologies working in simultaneous is better than having only one technology.

If the two chosen technologies proved to work greatly together, the research would create a beta version of an accessibility tool that could be improved on and eventually released to the public. Regardless of the results, though, the main goal of this research was to study if the two technologies worked better together or separately.

1.3 Research Questions

From the motivation and objectives, we extrapolated the research question:

RQ1: Will the usage of two interaction techniques that do not require hands integrated together perform better than these same two technologies used individually by people with motor impairments?

As mentioned above, there is a gap in interaction techniques research for accessibility in video games. By answering RQ1, we aimed to start closing this gap. Since most authors consider only one technology at once when studying interaction techniques, RQ1 aimed at guiding our research through the path of combining interaction techniques.

1.4 Proposed Solution

The solution we propose is a system that integrates two technologies for accessibility inside the game. We used the game "Metallic Mayhem", by Mindera Gaming, with whom we partnered through an internship, for the implementation and testing phases, and decided on using a nose tracker and a gaze tracker for the technologies. We chose these two technologies because they eliminated any necessity to use the hands, and had different focus on the face.

Introduction

Starting with a literature review, we researched what technologies existed and how they were used. We came to the conclusion that most authors never tried to mix up technologies to try and make games more accessible. We decided on testing a nose tracker and a gaze tracker together, and also separately, in order to compare how each implementation performed, and if the two technologies work together better than they work separately.

Firstly, we conducted a preliminary interview, to complement the literature review with end users' opinions. Then, we implemented the technologies individually, with each technology having two different versions. The four implemented versions were then: movement through nose tracker and shooting through IJKL keys; movement through nose tracker and automated shooting; movement through WASD keys; and shooting through gaze tracker; automated movement and shooting through gaze tracker. Upon implementing the technologies individually, we tested the four versions with users in order to identify possible issues that could be solved for the final tests.

Finally, we implemented the integration, where the nose tracker was kept for movement and the gaze tracker for the shooting action. We then tested three different systems with users: movement through nose tracker and shooting through IJKL keys; movement through WASD keys and shooting through gaze tracker; and the integration of the two technologies already described. Each user tested the three in sequence, with a variation in order of play to avoid learning bias in the results.

Through chapters 3, 4, and 5, we explain how the technologies were used and adapted in "Metallic Mayhem", how the research was conducted, and what results came from the research.

1.5 Structure of Thesis

Other than the introduction, this dissertation has 6 chapters more.

In chapter 2, the state of the art is presented and some related works are reviewed. Through chapter 3, we explain how the systems were implemented in the game. Chapter 4 goes through the methodologies used in detail and how each testing phase was planned out. In chapter 5 we present the results obtained through the methodologies previously explained, and in chapter 6 we extrapolate what we can conclude from our testing of the system.

Introduction

Chapter 2

Literature Review

As stated in the last chapter, digital games are a part of everyday life nowadays [AGH⁺20]. The objective of this research is to study game accessibility and hopefully create an integration that helps people with physical disabilities. Since disabilities are so varied, we will be focusing only on motor ones.

Through this chapter, accessibility and disability will be defined, and also each type of disability. Digital game guidelines found for each type of disability are presented as well as the state of accessibility in digital games. The interaction technologies studied from the literature review are also reviewed, to get a better understanding of what has been done, and what each author found about their experiences. Finally, we present a summary of the findings and the idea for the project. We followed a traditional literature review.

2.1 Accessibility

According to the Cambridge Dictionary, accessibility is the "fact of being able to be reached or obtained easily". It can also be thought of as the degree to which something is available to someone [Wha]. Aguado-Delgado et al. defined accessibility as "the condition to be met by environments, products, and services to be understandable, usable and workable for all people" [AGH⁺20]. The Game Accessibility Guidelines website, a compilation of the existing guidelines for implementing accessibility in digital games, also defines accessibility as the avoidance of unnecessary barriers that hinder the enjoyment of a product [Gam].

Accessibility in a video game can then be defined as the degree to which that video game is available, understandable to the general public. [Acc24]

Pinto et al. have identified, in the Instituto Superior de Ciências Sociais e Políticas' accessibility report of 2023, that 6.1% of the Portuguese population finds it difficult to climb the stairs and 3% has difficulties with self-hygiene, according to the latest Census' data [PBPN23]. Although the report states that disability is quite rare at younger ages, it goes up into the relevant number as

young as the demographic of 25-64 year olds, with almost 30% of the demographic having some form of incapacity, and reaching the 65.6% for the older generations.

2.1.1 Disabilities

According to the Cambridge Dictionary, disability is "an illness, injury, or condition that makes it difficult for someone to do some things that other people do, and that is usually permanent or lasts for a long time" [Dis24]. Most authors, including the World Health Organization, tend towards an environmental view of the issue, shifting the problem from the person who suffers from a disability, who cannot change their state, into the way that society deals with and perceives these disabilities [Dis].

Disabilities can be divided into four main categories: visual, auditory, cognitive, and physical (or motor). Each one of these four categories has different implications when it comes to video-games. Most authors focus on one specific type of disability at a time, in order to better investigate solutions to that type. However, some authors focus on trying to create games that are accessible universally. Each of these types of disabilities causes different struggles for a person, and each person can have more than one type of disabilities.

Visual disabilities are linked to sight. WHO defines this type of disability as what happens when an eye condition affects the person's vision [Vis]. Steinmetz et al. state that the main causes for this type of disability are cataracts, undercorrected refractive error, glaucoma, age-related macular degeneration, diabetic retinopathy, and residual causes of vision loss [SBB⁺21]. Of these, they consider that only cataracts and undercorrected refractive error are avoidable. However, they also found that cataracts are the leading cause of blindness globally with a 45.4% of relative contribution to blindness in individuals with fifty or more years of age. These impairments, regardless of what caused them, have serious consequences. They can hinder a child's development, impact an adult's employment prospects and contribute to social isolation in older adults [Vis].

Auditory disabilities are linked to hearing. They can go either way, from loss of hearing [Dea] and to hyper hearing [Kon]. Hyper hearing, called hyperacusis, is when sounds appear much louder than they actually are [Kon]. It can be caused by a variety of injuries and other disorders, and affects one's ability to socialize, while also being able to cause pain. Hearing loss, on the other hand, is quite the contrary. A person with hearing loss or complete deafness cannot hear certain sounds [Dea]. It can also be caused by a variety of issues, ranging from before the child is born to age-related hearing loss. Like hyperacusis, hearing loss affects the social aspects of one's life, as well as their communication development. It can also impact one's employment prospects and education in developing countries.

Cognitive disabilities are linked to cerebral activity. HealthDirect, an Australian website for health information considers that cognitive disabilities can hinder one's ability to recall, pay attention, recognise and experience new things [Aus23]. Speaking and understanding skills may also be affected. Friedman and Bryen define cognitive disabilities as [FB08] including autism, mental

retardation, brain injury, aphasia (language disorder), dyslexia and learning disabilities. The authors also note that sometimes, Alzheimer's, and Attention Deficit and Hyperactivity Disorder are also considered in the definition of this type of disabilities.

Physical disabilities (as in motor impairments) are linked to movement. INS defines it as the "partial or total loss of function of a body part" [Mot]. Usually, it affects limbs, but it can also affect more parts of the body. It ranges from weakness to total paralysis. According to Younger, it can be manifested through spasticity (stiff muscles), weakness, tremors, and ataxia (loss of muscle control) [You23].

2.1.2 Digital Game Accessibility Guidelines

The Game Accessibility Guidelines website compiles guidelines that exist for developing digital games with accessibility in mind [Gam]. It divides the guidelines in three categories, depending on their reach, impact and value. It then subdivides each of these by categorizing them into what they aim to solve (motor, cognitive, vision, hearing, speech, and general difficulties). It is a practical list of what should be considered when developing a game, and provides an excel sheet to be used as a checklist. They find that the most complained about issues are remapping of controls, text size, colorblindness and subtitle presentation. According to GDC 2024 State Of The Game Industry, at least remapping and colorblind mode are already industry standards [Eld24].

Vickers et al. aimed to develop an accessibility framework to be used on future games, so as to make it easier for developers to implement accessibility techniques and guidelines [VIH13]. Their device handler recognizes other, specialist, input devices and acts according to the communication between them.

In their 2021 article, "Designing for Disability: Evaluating the State of Accessibility Design in Video Games", Brown and Anderson studied 50 games released in 2019, for their design trends and pitfalls in terms of accessibility. In that publication, the authors consider that although disability is an emergent area of research, "it is still in its infancy" [BA21].

For auditory disabilities, Brown and Anderson found that while most games try to include accessibility options, with subtitles, and visual effects paired with their sound clues, a lot can still be improved. Some games, like Resident Evil 2, still did not include visual effects for critic sound clues, which makes the game completely unplayable to deaf and hard-of-hearing players. In addition to this oversight, a lot of games still had missing subtitles, or subtitles that mismatch with the sound. On top of that, complex fonts make the text harder to read and the smaller the font, the harder it will be to read also [BA21].

Likewise, text size is also an issue when it comes to visual disabilities, and Brown and Anderson found that is where games fail most. The Outer Worlds and John Wick Hex provided no support for reading, with minuscule text that rendered some critical information unreadable. Other games, however, used much bigger font sizes, which allows for non-blind people with visual disabilities to actually read the texts. Others even let the player choose their own font-size, or the entire UI size, to visualize the icons better, along with the text. Another issue regarding visual disabilities is the accommodation of color blindness. Although there has been a lot of evolution

in this front, the existing solutions are not perfect. For example, Call of Duty: Modern Warfare's protanopia filter does not stop red names from blending into background, but they did change their team colors from red versus green to red versus blue [BA21].

When it comes to motor accessibility, Brown and Anderson found that the most requested feature is remapping of controls. Unfortunately, some games still do not offer this feature, and some others allow remapping through preset options. However, there are games that already implement this feature fully [BA21]. The authors found that 2019's most impressive game in this matter was Gears 5. It implemented controller remapping, camera following character, and option to use left stick for aiming, making the game basically playable with one hand. Toggles are also very important when it comes to motor disabilities, and if not the default, should be an option presented to the players in the game's settings. Brown and Anderson also consider game difficulty as a resource for accessibility, stating that more lenient challenges can help players with disabilities by giving them more time to deal with threats [BA21].

2.1.3 State of accessibility in video games

Accessibility in video games has been a largely discussed topic between disabled gamers, reaching game companies as more and more people ask for accessibility features.

Bierre et al. [BCE⁺05], in 2005, found that there was a lot of work to be done still. They propose a set of questions as the basis for additional action in video-game accessibility.

In 2018, Aguado Delgado et al. [AGH⁺20] conducted a systematic review of accessibility in video games. They came to the conclusion that video games developed at the time were not truly accessible, although there had been attempts at bettering accessibility in the area. Aguado-Delgado et al. [AGH⁺20] found no answer to whether "a specific development methodology arising from the adaptations and/or modifications of existing solutions have a notable impact on the level of accessibility of the video games", but argued that a specific methodology for development, inspired by the existing solutions could have a "notable impact on the level of accessibility" [AGH⁺20]. The authors also came to the conclusion that universal accessibility is a very difficult task, being even considered impossible.

Kämäräinen [Käm21] compared the two first iterations of The Last of Us games by the Naughty Dog studios for their bachelor's thesis. The student analysed the gameplay sequence of the "Hotel Lobby" level for The Last of Us, and the level "The Tunnels" for The Last of Us II. Both levels include both human and infected enemies, environment manipulation, traversal methods and game state interactions. taking from 30 minutes to one hour to complete.

For The Last of Us, the author found that, in the studied level, there were four obligatory plot progression interactions that could be critical accessibility barriers, related to quick-time-events. Running, in the game, required one button to be pressed constantly, which constitutes a significant accessibility barrier. Some interactions with items also proved to be inaccessible, as they were dependent on long presses or console movements. Combat presented the most significant accessibility barriers. Aiming required a long button press, while shooting required a press with another button, being impossible to shoot without aiming. This means that the game requires the player to

perform a long press in simultaneous with a quick press, presenting two accessibility problems in the same mechanic.

The Last of Us Part II provides 60 accessibility measures. Kämäräinen [Käm21] found that the second game implemented a significant amount of accessibility solutions, even though it still had some issues. Although the games share plenty of similarities in accessibility barriers, The Last of Us II includes much more customization of the experience, allowing for a more accessible game.

Kämäräinen [Käm21] found that the second installment provided game-based solutions for most of the accessibility barriers, proving to be a great improvement on the previous game on the series. This is a practical example of the evolution of accessibility in video games, and a statement to how far we have already come.

2.2 Interaction Technologies

Interaction technologies are intrinsically linked with video games, and so it comes as no surprise that it would be used to better accessibility in them. With both hardware and software being created and experimented with, developers have worked towards more accessibility in digital games.

In this section, we will talk about the interaction technologies found through research and how they were used for accessibility.

2.2.1 Hardware

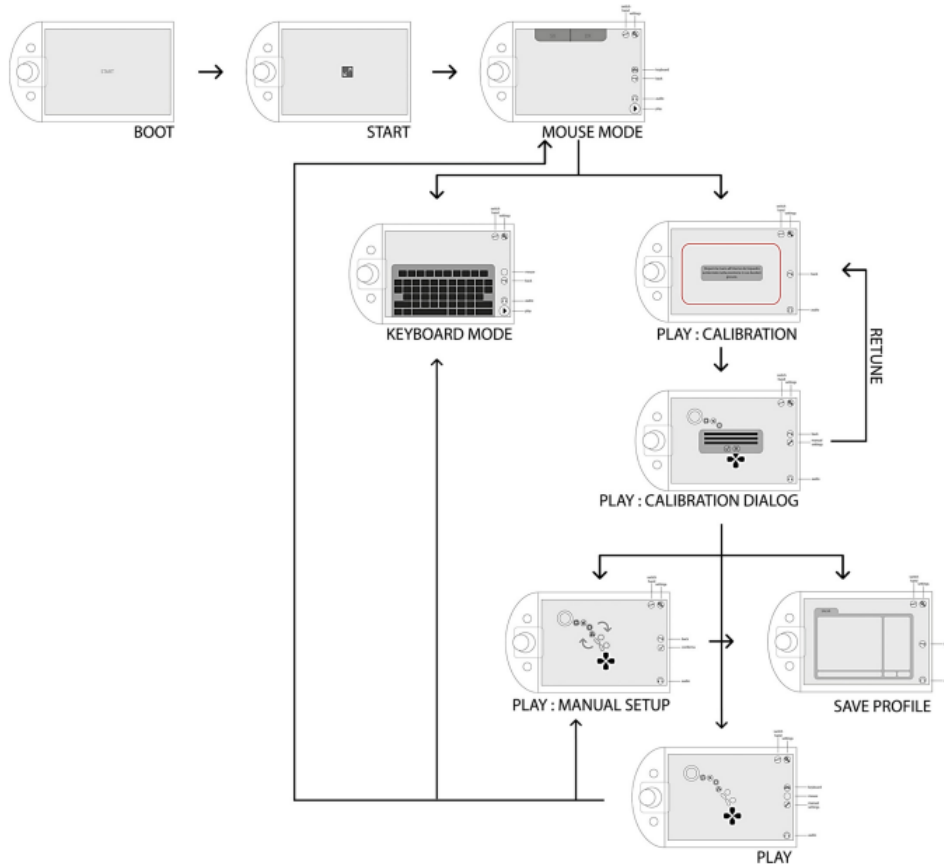
Hardware that substitutes the traditional gaming controllers can be used to allow disabled people to play digital games. However, it can be an incredibly expensive alternative, as most gaming consoles already come with their own traditional controllers, and these technologies need to be bought separately.

In this subsection, we will go through the evolution of hardware in accessibility, and some video game hardware created specifically to help people with motor disabilities.

2.2.1.1 Evolution of game controllers

Game controllers started off as sharp edged metal boxes, which were not ergonomic even for able-bodied players. In the early 1970s, we finally started seeing some changes, with coin-operated machines and gaming consoles. Coin-operated machines offered the controllers attached to the bigger machine, and gaming consoles, used for home entertainment, adopted detachable controllers. These however, needed two hands to be operated, and were therefore still mostly inaccessible to disabled players. [MGR⁺19]

In the late '70s, gaming consoles took many shapes with different functionalities. The two that are still mainstream are the joystick and the game pad. According to Maggiorini et al., the operation of the joystick proved to be accessible to perform, even by gamer with severe limitations of the upper limbs. [MGR⁺19].

Figure 2.1: OHC sample from [MGR⁺19]

In the 90's, with the introduction of 3D games, a 2D axis proved inefficient for navigation. Because of that, developers merged the joystick back into the gamepad, with the first one being Nintendo 64 [MGR⁺19]. This was a step back for disabled gamers as now they had to coordinate the usage of a thumb-sized joystick with the pressing of the gamepad's already existent buttons.

Gamepads have not changed much from there on until recently, changing their hold to a more favorable one, but keeping the same functionalities established with Nintendo 64 [MGR⁺19].

In 2019, Maggiorini et al. designed the One-Hand Controller (OHC, Fig. 2.1) in order to improve accessibility for people with mobility issues in the upper limbs. [MGR⁺19] Specifically, they designed a controller with a joystick and a screen where the buttons are placed according to the user's level of finger mobility.

Over the years, game controllers have been evolving towards inclusion, and although we are far from total inclusion, we have come a long way. Big companies like Xbox and PlayStation now have controllers specifically targeted to people with motor disabilities [SU23]. PlayStation's Access Controller (Fig. 2.2), released in December 2023, consists of an adjustable round controller with interchangeable buttons so the user can adapt it to their own needs and preferences.

Controllers can also be developed with other technologies and other means of interaction.

Malone et al. [MMM⁺23] developed a controller system that could allow people with mobility



Figure 2.2: PlayStation's Access Controller from [SU23]

impairments to play Active Video Games (AVG). Active video games consist of video games that require movement, to promote fitness.

The system is made of two parts: the electronics and an application to enable customization of the settings. The electronics consist of a custom printed circuit board stack and an LED matrix display (the last one is necessary for instant feedback reasons), and handrails to ensure the safety of the player (Fig. 2.3). There were also external buttons that were used for actions such as jumping, shooting and acceleration, with customazible positioning.

The system was tested with 21 adults between the ages of 18 and 75. Participants could play standing up, seated in a 4-legged chair or seated in their own wheelchair. 8 participants played standing up, while 7 played seated in a chair and the other 6 played in their own wheelchair.

The study found that the system was of adequate accessibility, with no participant reporting difficulty in mounting or dismounting the GAIMplank. The included handrails also provided support and a sense of security for the players. Participants found that the customization of the button's positioning helped with game play. However, one participant reported that the surface friction on them could be improved.

The participants reported some issues with the calibration of the device, and the responsiveness to weight shifts. They also acknowledged that they needed some time to get used to the system. Regardless of these issues, several participants admitted that this was the first time they were able to play Active Video Games, because of accessibility issues with other AVG systems.

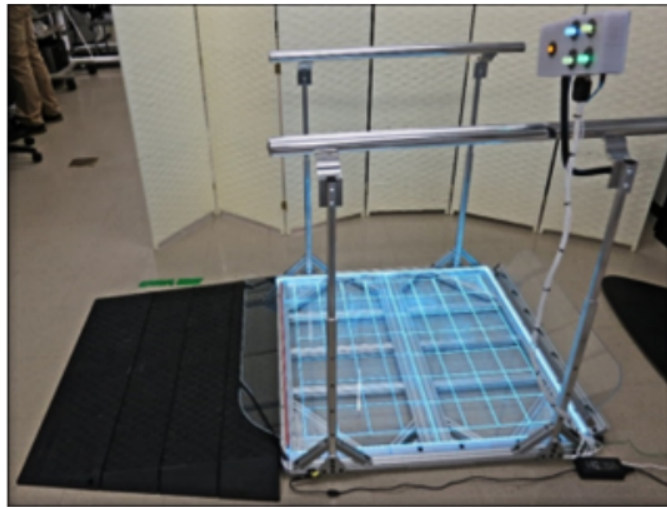


Figure 2.3: GAIMPlank's proof-of-concept prototype from [MMM⁺23]

2.2.1.2 Smart Wearables

Smart wearables are wearable devices that "embed computational capabilities in garments" in order to provide information for end users [Mot19]. These technologies have been studied for accessibility purposes by some authors.

Motti, in 2019, considered that smart wearables provided many opportunities for disabled users. [Mot19]. They can provide monitoring and assistance, and more discreet interaction, like quick vibrations or texts on screen. However, they also present the challenge of data governance, and the author notes that proper policies need to be applied. Personalization is also considered a challenge by Motti, with the author considering that disabilities are too multi-faceted for a one-size-fits-all application of the wearables [Mot19].

Ungurean and Vatuva [UV22] conducted a study about smart wearables, for people with motor impairments.

The authors interviewed 21 people with motor impairments. In the interviews, they evaluated how difficult to use the participants thought conventional computing and input devices were. For the participants that had used wearable devices prior to the interview, they also asked about the perceived difficulty on those. They also studied the participants' perception of preference for different smart wearables, in relation to different applications.

Ungurean and Vatuva [UV22] considered 5 categories of wearables (smartwatch, smart bracelet, smartglasses, smart earbuds, and smart ring) and 9 of applications (fitness & health, control home appliances, music, notification delivery, make payments, control the pc, interact with public systems, control video games, and apps for the workplace). They collected 308 preferences of associations between the categories of wearables and categories of applications. Out of the five types of wearables, smart glasses were found to be the favourite for controlling video games, although only 7 associations were made between smart wearables and controlling video games, meaning the users did not find a great association between these two [UV22].



Figure 2.4: Scarvodelli and Frère's system from [SF15]

2.2.2 Software

Software is also an option when it comes to raising accessibility in video games. Instead of requiring the player to buy expensive specialized consoles that fit their needs, sometimes, accessibility problems are solvable with software instead. Software can be external to the games, as a support technology, or it can also be implemented directly in the games.

2.2.2.1 Hand Recognition

One solution that enables some disabled gamers to keep playing is hand recognition tools, although this may not work for gamers who have severe limitations of the upper limbs.

Manresa et al. [MYVMP10] developed a system that tracks a user's hand gestures and collect them as input for a 3D environment on an undisclosed videogame.

Before the program can perform gesture recognition, it needs to locate and segment the hand to be considered. The authors used skin-color to determine where the hand was positioned and segment it. Along with the segmentation, the program also uses a tracking procedure to maintain the hand state over time. The chosen gestures were open hand (start), closed fist (stop), open hand with closed fingers (movement - depending on where camera was located and how it was rotated, movement varied).

The system was tested with 40 users, with each performing a set of 40 gestures (total of 1600 samples).

The authors found the system to be adequately accurate, with the gesture recognition working well 98% of the cases [MYVMP10]. Because of the system's performance results, the authors consider that this is a reliable low-cost substitute for traditional interaction methods.

Scardovelli and Frère [SF15] developed a system consisting of a 3D game and a supervisory system for the character (meaning the system controls the character, in this case through the image captured by a webcam), each on a different window of the computer. The user camera and interface are shown in the window destined for the supervisory system.

In this window, three regions are shown for the commands, and analyzed by the program. The rest of the image (the whole capture) was used to reference the user to where they should point. These regions were squares and could be placed in any part of the supervisory window, allowing for user customization.

Each square was labelled and linked to an action in the game: square R was used to turn right, square L was used to turn left and square F was used to move forward or to interact with the world. Every time the user touches one of these squares, the corresponding action is performed, and the square gets filled in green, for feedback purposes.

The study participants were 20 volunteers without motor impairments and 13 with motor impairments. The volunteers without motor impairments were divided into with or without video gaming experience while the totality of the disabled users were considered by the authors to not be accustomed to playing [SF15]. The 20 abled-bodied participants tested the game both using a standard keyboard and the developed system, while the 13 disabled participants only used the developed system.

Before each test with the system, the user calibrated it to their liking. The testers also took into account the preserved range of motion when it came to camera placement: bigger range of motion meant that the camera was placed further away from the user, while if the range of motion was small, it was placed closer, to focus more on the available range.

The study found that the created system would be available to all users, and the game was found to be satisfactory. There was also apparent interest in both the game and the peripheral device. Some of the volunteers even showed interest in playing more. Scardovelli and Frère [SF15] also found that the lack of familiarity with the new system could be a relevant factor in performance, but after the user familiarized with the device, the performance was higher. Although it took longer to complete the actions using the peripheral device, no user complained about the time it took for them to play. Furthermore, there was no real difference between the performance of the volunteers with motor limitations and the ones without.

Khademi et al. studied the use of hand-interaction for stroke rehabilitation [KMHM⁺14]. Using the Leap Motion sensor, an hand tracking device, the authors adapted the game Fruit Ninja to be played with hand movements, instead of mouse events. Fruit Ninja consists of a game where the player needs to cut the fruits as they appear, with a slashing movement from the mouse input. Instead of the typical lose condition for the game (three misses), the authors introduced a one minute time limit in order to conduct a fair research. Khademi et al. compared the scores obtained by the patients using the game with clinical outcome tests [KMHM⁺14]. With that, they found that the developed system could accurately evaluate a user's ability to use their hand. The authors also found that the gameplay was engaging, and most users also thought the game was addressing the need of practicing hand movements for rehabilitation.

2.2.2.2 Eye and Head Tracking

Varona et al. [VMP08] presented a vision-based interface in order to achieve better accessibility for disabled users with motor impairments. Along with their software, they also made sure that the

input was done through a standard webcam. Often, accessibility tools require expensive extras, making them less accessible. By using a standard webcam to collect image input, the authors achieved a low-cost system.

Their system uses the nose for head tracking and the eyes for gesture recognition. For the gesture recognition, the authors chose to use left and right winks, which are detected through colour distributions. Nose tracking is done through image features such as appearance and color. This application's objective was to replace completely the need for the traditional mouse input device. In this system, the need to use the hands is zero, making it a hands-free system for interaction with technology.

Varona et al. [VMP08] found that a new user (untrained in the system) was able to use the system with 85.9% of accuracy and with only 5 pixels of distance error. They found that most of the errors were performed when the clickable item the user wanted to click on was placed furthest from the center of the screen. Trained users averaged an accuracy of 97.3% and only 2 pixels of distance error, and they was no relation between position of the click and the system's accuracy.

Isokoski et al. found that interest in eye controlled game has increased [IJSM09]. For people with physical disabilities that hinder their capability of using manual control for gaming, the authors consider that eye control offers opportunity to play. They also found that adapting turn-based and puzzle games is easier than adapting games that require finer control, although the games that require finer control offer the "greatest opportunities to improve the gaming experience" [IJSM09].

Isokoski et al. state that eye trackers may elicit positive reactions on a first encounter with them. They consider that, if the tracking is adequately integrated, it looks to users as if things happens with a thought [IJSM09]. However, without smooth game play, after the novelty wears out the users may turn against the tracker.

2.2.2.3 Facial Expressions

Taheri et al. [TWS21] developed a hands-free video game controller that used facial expressions mapped to commands in order to play. The authors also included speech recognition as a secondary input tool, although it was not studied in depth. The system is slightly customizable for the users, with each expression's sensitivity being adjustable.

The system used the standard webcam of the personal computer running it to capture the image input. Facial expressions can, in this way, be a low-cost way to integrate accessibility features into video gaming, since most personal computers now-a-days have a standard webcam.

In this system, the webcam input is sent to a keyboard mapper, which then converts it to a keyboard input. The program was integrated in two generic games created for testing purpose: Temple Looter and First Person Shooter (FPS). Temple Looter was used to introduce the player to the input system, while the user study was the FPS [TWS21]. 8 people with motor impairments participated in the study, and another one helped conduct a pilot study.

The study found that the developed system was efficient and satisfactory. Players were happy about being able to play without their hands, and also about the speech alternative. However, the

users wished they could map the expressions to their liking, instead of having a fixed mapping. The system's sensitivity and learnability also received high ratings, although some considered the system too sensitive. One player even suggested that for each sensitivity slider, there could be a tooltip that tells the users what that sensitivity slider changes [TWS21]. Users found the game mostly comfortable, but referred that it could become tiring if played for extended periods, although it was fairly easy to use.

Ilves et al. also created gameplay based on facial expressions [IGSV14]. Their system only considers smiling and frowning as inputs. The developed game's goal was to get a drunk soldier home, avoiding obstacles, while also picking up as many items as possible. A smile would make moving obstacles stop and not collide with the drunk soldier, while a frown would make stationary obstacles move out of their way to let the drunk soldier pass. 20 users played the game both with traditional input (joystick) and with the developed system.

The users found that the game was much easier to play with the joystick, getting through the game quicker and picking up more items than with the developed system [IGSV14]. Although their gameplay improved in both cases from the first round to the last, showing that there is learnability to the game, the joystick kept performing better through the rounds. They also felt more validated and in dominance while playing with the joystick, although the arousal metric scored higher for the developed system. The study found that the game was considered faster, easier, and more accurate, efficient and natural when played with the joystick, although it was more enjoyable with the developed system [IGSV14]. Although more entertaining, the developed system did not prove very efficient when compared to the traditional input method.

2.2.2.4 One-Switch Commands

A one-switch command offers the user one single switch (button) for all interactions, working alongside software to adapt the game into only needing that one switch for input [LCDR17].

López et al. [LCDR17] studied the NOMON and created a new iteration of it directed at action video games, called the Gaming NOMON (GNomon).

The NOMON is a one-switch way of interacting with technology, originally presented by Tamara Broderick and David MacKay [LCDR17]. It allows the selection of one element of an interface at a time, from a group of elements. It works by presenting the user with a clock for each of the elements. When the user wants to select an element, they need to click the button as precisely as possible when the black hand of that element's clock (which rotates at a fixed speed) crosses the red hand (which is fixed at noon). Furthermore, the program takes into account the probability of each element being selected, based on previous selections from the user. This makes the elements that the user tends to select more easier to access. Based on its predecessor, the GNomon framework [LCDR17] also associates a small clock widget to each selectable element on screen, which functions in the same way. It differentiates itself from NOMON by providing functions that create sets of selectable game objects.

The authors tested their software with three games: a demo to explain how the system worked, a ladybug game as an introduction to the system with multiple elements on screen, and an invaders

game to test the system for action-oriented gameplay [LCDR17]. The study was divided in two sessions, to evaluate memorability, and also learnability, effectiveness, the error ratio and the satisfaction of the users. There were 8 participants in the first session, but one could not make it to the second, so there were only 7 participants for the second session.

According to the study results, the gameplay was memorable enough, with 5 out of 7 participants recalling the game on the second session. The authors deemed that the results supported that the system was learnable by children with severe motor disabilities [LCDR17]. From the first session to the second, participants either maintained or increased the speed at which the black hand in the clock rotates but increased or at least maintained the error ratio. They also found the system to be effective in its task, with 7 out of the 8 participants completing all tasks in the first session in less than 20 minutes, and all 7 participants playing satisfactorily through the second session, when they were already familiarized with the game [LCDR17]. Most of the participants also found the gameplay fun. The authors also comment that the system allows for disabled children to experience leisure gaming which they rarely have the chance to experience [LCDR17].

However, Medeiros and Coutinho found that in order for a game to use one-switch it needs to automate some of its aspects, which takes away from the user's experience and perception of freedom to play [MC15]. They set out to create a game with a one-switch input technique, interested in building an environment in which this particular issue would not be as perceptible. Their one-switch technique consisted of "A scanning system [...] to present choices in which each option is highlighted by changing the background color and a squirrel icon points at the focused option" [MC15]. The user can define the time span in which the focus on the option is moved. Character movement is automated, but allows for up, down, left and right movement, determined by the system on the button press. The game's objective was to help a squirrel cross the road.

The authors tested the game with 6 users in total, disabled and non-disabled. They found that neither one-switch nor traditional were preferred, although the answers for the fun and challenge factors were varied. All users who liked the game genre also commented that they would play again. With this, the authors conclude that their one-switch technique proved efficient for the game created [MC15]. They also concluded that the one-switch commands showed themselves very useful to make gaming accessible for users with physical disabilities, and that it is feasible to have accessible modes that equal the traditional ones in terms of freedom of control and difficulty.

2.3 Summary

In the above sections, we went through some of the research that has been done when it comes to interaction techniques that can make games more accessible, focusing on some of the most relevant technology. Although the accessibility issues in digital games undergo continuous study, the field still requires much work.

Although one study did try to combine technologies, we noticed that none of the reviewed research focused on comparing the usage of one auxiliary technology aided by traditional techniques with the usage of more than one auxiliary technology with no traditional input techniques.

Literature Review

With that, we want to take two technologies and combine them in the same game, with the purpose of comparing whether or not combining technologies would be a viable course of action when it comes to accessibility issues in digital games. For this study, we have implemented three main versions of gameplay, one with each technology aided by traditional input techniques and one where the input is solely through the chosen technologies. We have conducted user tests to compare the two and come to a conclusion. We theorized that the integration of the two technologies would perform better than their separate usage aided by traditional input techniques.

Chapter 3

Proposed solution

In this chapter, we describe the implementation of the proposed solution to the presented research problem. The proposed solution consisted of implementing a system which integrates two interaction technologies in order to evaluate if those two technologies performed better together or on their own. We also implemented other interaction methods, with each technology individually with traditional input methods.

An internship was established with Mindera, a software company, and with that, the opportunity to use their game, Metallic Mayhem (MM) as a base on which to develop our accessibility solutions.

"Metallic Mayhem" is an action-packed, top-down multiplayer 3D shooter game that takes place in futuristic arenas filled with robots. Features multiple game modes, including team-based matches and free-for-all battles, as well as a variety of different arenas with unique layouts and hazards. With fast-paced gameplay, strategic depth, and an ever-changing battlefield.

– The team's description of the game in itch.io [[Met](#)]

MM (fig. 3.1) can be played through keyboard, controller or mobile phone. For this research, we focused on just the keyboard mode. The player moves through the WASD keys and shoots through the IJKL keys, turning to their respective direction. We decided to use a nose tracker for the movement action and a gaze tracker for the shooting action. For the research, five new versions of gameplay were implemented: two for each interaction technology individually (nose tracker and IJKL keys; nose tracker and automated shooting; gaze tracker and WASD keys; gaze tracker and automated movement) and one for the integration.



Figure 3.1: Metallic Mayhem

3.1 Methodologies

After deciding on the technologies to be used, we searched how to implement them into the game. We decided to use OpenCV's Unity free plugin ¹ for the implementation of the nose tracking system, and Tobii's technology for the gaze tracking system.

Although we wanted the integration to be completely free of outer hardware, making it more financially accessible, many forums on the internet considered that gaze tracking through a web-cam is still not viable, so we looked for alternatives. We found Tobii through researching ways to track the user's gaze and decided to use it. We used the TobiiEyeX hardware, with the Unity plugin software. TobiiEyeX's accuracy is limited, and each user needs to calibrate the hardware to their own specifications before using the system. Even after user calibration, the system fails sometimes, which limits the user's experience.

OpenCV's Unity free plugin offers face recognition tools. Since the nose is somewhat in the middle of the face, we used that facial recognition for our system.

3.2 Accessibility Player

The original player character (Player) can be played with through the keyboard, a gaming console, or the user's phone. The bot version of this player (PlayerBot) is an AI agent that moves and shoots automatically, adapting its movement and shooting actions to different situations in-game.

The Accessibility Player (AP) is a variant of the Player. There are five versions of it, for the five implemented versions of gameplay. In some of its versions, it has been combined with elements of the PlayerBot.

¹OpenCV+Unity

Proposed solution

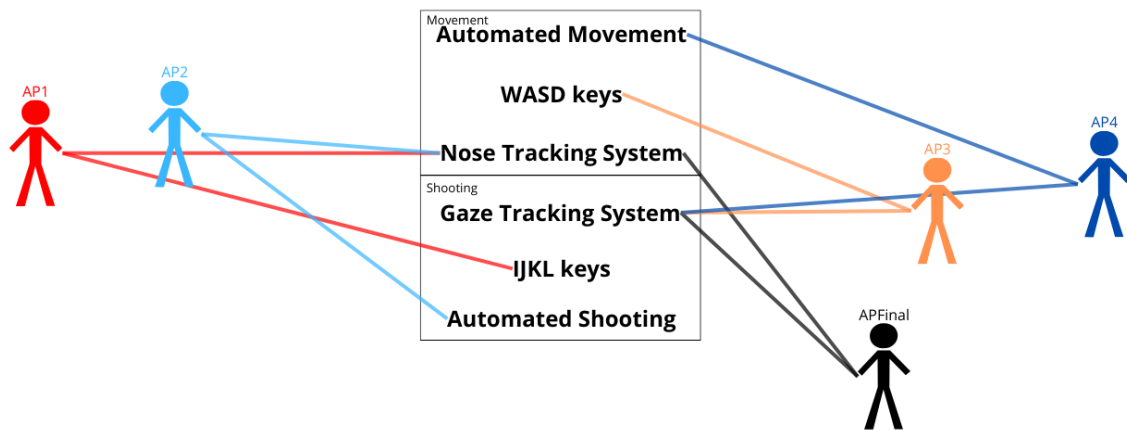


Figure 3.2: Various Versions of AP

We started by creating a prefab variant from the existing Player prefab. A prefab is a component from a Unity project that allows for game objects to be created from them, saving one configuration for all game objects that have been created from them (if the prefab suffers a change, all of its children will suffer the change as well). A variant of a prefab is also a prefab, who inherits their parent's properties but can have their own as well.

From the creation of the prefab, it varied depending on the implementation (Fig. 3.2). We will be referring to each different variant as:

- AP1 - AP created for the implementation of movement through nose tracking and shooting through keyboard
- AP2 - AP created for the implementation of movement through nose tracking and automated shooting
- AP3 - AP created for the implementation of movement through keyboard and shooting through gaze tracking
- AP4 - AP created for the implementation of automated movement and shooting through gaze tracking
- APFinal - AP created for the implementation of movement through nose tracking and shooting through gaze tracking

For AP1, we removed the existent movement script and created our own. This script initializes the webcam and tracks the nose, mapping it to movement in-game. AP2 is a version of AP1, with the same movement script, but for AP2, we also removed the ability to shoot through keys, instead adding part of the PlayerBot script, to have it shoot automatically.

Since the PlayerBot script contained both the automated movement and the automated shooting intertwined, we needed to create new scripts and divide this pre-existent system into two parts for the different implementations.

For AP3, we removed the existent shooting script and created our own as well. The new script connects to the TobiiEyeX and tracks the user's gaze, mapping it to in-game coordinates, and making this version of the AP shoot at where the user is looking in the screen. AP4 is to AP3 what AP2 is to AP1, except for this case, we made the movement automated through the same logic as before: using the PlayerBot script, we separated the automated movement and used that system in our implementation.

APFinal works by using the beforehand implemented nose tracking system for movement and the beforehand implemented gaze tracking system for shooting. After creating the variant, we removed both the movement and the shooting script from the new prefab, and added in our own scripts for the movement and shooting actions.

No matter the instance, the AP is initialized in game through the space bar on the keyboard.

3.3 Individual Implementations

For AP1 and AP2, we used a nose tracking system for the movement action. At first, we wanted the AP to follow the user's nose around. As the user moved, the AP would appear in the same place where the user's nose was found in screen. Initially, we explored this by tracking the nose with OpenCV's free available software for Unity. However, as we started working on this implementation, we realized that it was easier to use OpenCV's face tracker abilities, and then get the middle of the face, which corresponds roughly to the nose, when the user is facing forward.

Using OpenCV's free Unity plugin, we find the faces in the camera image, and mark the one being followed with a red dot. With the help of an interface, we transform the screen into a command, with 9 main areas: up, down, left, right, diagonals and no movement. These areas correspond to the corresponding WASD keypresses: W for up, S for down, A for left, D for right, and the diagonals correspond to two keys being pressed at the same time. We made a first implementation with the screen divided into 9 areas, but found that that interface was too far apart, so we changed it to be in a smaller space, later on (fig. 3.3).

The equivalent to a W key-press is mapped to the top of the screen, from where the up arrow starts, while the equivalent to the S key-press is mapped to the bottom of the screen, from where the down arrow starts. No movement on the y-axis is mapped to the middle of the screen.

In the same way, the equivalent to an A key-press is mapped to the left of the screen, starting at the left arrow, while the equivalent to a D key-press is mapped to the right of it, starting at its arrow. No movement in the x-axis is then mapped to the in-between.

Unfortunately, the OpenCV's algorithm has some accuracy issues. The algorithm kept confusing images and objects in the background with a face, and switching between considering the user's face and some object in the background. This was taken into consideration when testing the system.

For AP3 and AP4, we used a gaze tracking system for the shooting action. Gaze trackers consist of hardware that tracks to where the user is looking at. Tobii, a company that specializes on gaze tracking, describes it as a "sensor technology that can detect a person's presence and



Figure 3.3: Initial Interface for the Nose Tracker

follow what they are looking at in real-time" ². It can be used for analytics, or as an accessibility tool, which is the case for our implementation. The hardware requires calibration for each user that uses it, through software provided by the Tobii software, outside of the game.

We substituted the existent shooting script with a new one. The new script uses Tobii API through the library `Tobii.Gaming`, which connects automatically to the TobiiEyeX hardware. After any AP that uses gaze tracking is initialized, the developed program gets the gaze point in screen through `TobiiAPI.GetGazePoint().Screen()`. `TobiiAPI.GetGazePoint()` returns the gaze point in a variable type innate to Tobii API, `GazePoint`, and then `.Screen()` returns the two-dimensional vector that is the translation of that `GazePoint` in the Unity's screen coordinates. Once we get that vector, we can translate it directly into world coordinates through a Unity Camera's function, `ScreenToWorldPoint`. Since there is no limit of ammunition, the shooting itself is automatic, with the direction of shooting being controlled by the gaze tracker.

3.4 Integration of the gaze tracker and the nose tracker

During the testing of the individual technologies, some unnoticed bugs, such as issues with the movement speeds in the two axes, were pointed out by the testers, and also some issues that worsened the system's usability, such as the nose tracker's interface, and the fact that users were not able to comprehend where the gaze tracker was translating in screen their gaze. Most of these bugs and issues were solved for the integration tests.

We created a new interface for the nose tracker (fig. 3.5), and condensed it into the middle of the screen, and fixed the movement speeds issue. We also created a new interface for the gaze tracker, although this one had the objective of helping the user realize if the tracker was seeing them and where the tracker translated the user was looking at in the screen. This interface consisted simply of a red rectangle that appeared where the gaze tracker translated the user's gaze.

²Tobii's website: <https://www.tobii.com/>

Proposed solution



Figure 3.4: TobiiEyeX

Like with the individual implementation of the gaze tracker, the user needed to calibrate the device before playing, through Tobii's own software.

For the integration of the two technologies (fig. [3.6](#)), we kept their areas of focus: nose tracking is used for the movement and gaze tracking is used for the shooting. We reused the previous implementations for the trackers, and implemented the needed changes for them to work together, and to fix the found issues. The implementations of each technology works in accordance to what was described in the sections above.

Proposed solution

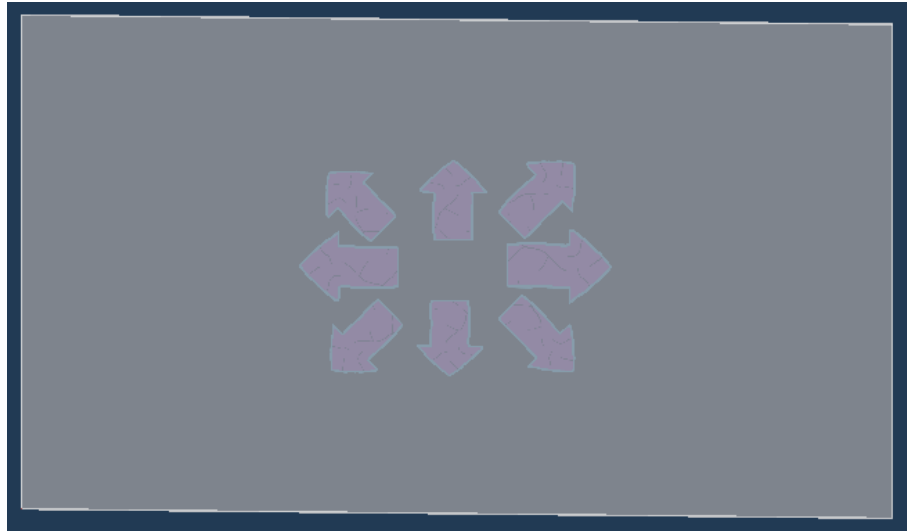


Figure 3.5: Nose Tracker's New Interface



Figure 3.6: Final Result

Proposed solution

Chapter 4

Research Methodologies

Through this chapter, we describe in detail the methodologies used for testing the implemented integration and comparing it to the technologies implemented individually.

We started off with a group interview with users who suffered from motor impairments, before beginning the implementations. After implementing each technology individually, we tested them to find what could still be improved for the integration. After the implementation of the integration, we tested it with physically disabled users, and with non-disabled users as well, since we had some problems while recruiting disabled users.

4.1 Preliminary interview

We wanted to conduct a focus group to grasp disabled people's perception of accessibility in video games. However, due to a lack of respondents, we decided it was best to conduct a group interview instead.

4.1.1 Recruitment

Associação Salvador is a Portuguese association for physically disabled people. It promotes their inclusion in society, with the goal of improving their quality of life.

We contacted Associação Salvador in July 2023, and heard back in the beginning of August 2023. The association gave us a positive answer in regards to collaboration, and in December 2023, we sent them another e-mail so they would spread the word through their associates, asking to participate in a focus group.

The association sent out that email in January 2024, reaching out and asking their associates to collaborate in the study. We heard back from ten respondents, but only three could make it to the interview.

4.1.2 Preparing the Interview

The first idea for the preliminary interview was to make a focus group with about 10 people. However, due to a lack of respondents, we ended up deciding to do an online group interview.

As we scheduled the interview, we worked on its guide. For this part of the research, we focused on the people's perception of accessibility in digital games, what were the main difficulties they faced and what they had tried and/or done to get over those difficulties. We also gauged out what the respondents thought would be a good idea for accessibility in digital games, with the objective of finding out possible future work.

4.1.3 Goals and Guide

With this interview, we wanted to find out what people with motor disabilities thought about the state of accessibility in video games. Although we spoke in very broad terms, our main focus was accessibility for people with motor disabilities.

We aimed at finding out if and what games people with motor disabilities feel they can play. We also gauged out the reach and general knowledge about accessibility technologies for video games.

The thought questions were as follows:

- Do you like playing games?
- What games do you like to play? Why?
- Can you play with traditional controllers?
- If not, what do you use as a controller?
- Do you feel that games are harder to play for you, than for able-bodied people?
- What were the problems with traditional input mechanisms?
- What do the new ones that you use solve?
- What do they don't solve?
- If you could do anything for accessibility in video games, what would it be?

We guided the interview through this script, and it allowed us to obtain the answers we wanted to obtain, which will be explained in further detail in the next chapter.

4.2 Usability tests - Base Game vs Individual Implementations

We implemented four versions of the individual technologies, two for each technology. For each technology, we had the option of the other action being played or automatic.

After implementing the technologies separately, we wanted to test them against the original game implementation, so we conducted usability tests with 16 people. Unfortunately, we could not collaborate with Associação Salvador for these tests, so we were unable to conduct these tests with disabled people.

Each of the participants played the original implementation and one of the accessibility implementations. Each accessibility implementation was hence played by four participants, while the original implementation was played by all of them. Hence, 4 users played using AP1, another 4 using AP2, and the same for AP3 and AP4, while all 16 users played with the Original Player.

Each user was welcomed to the experience, and briefed about the research's objective, which they could also read on the first page of each follow-up Google Forms. Then, they would be walked through how to play the original implementation, and we'd let them play a round to get a feel of the experience. The user was then prompted to answer a Google Forms about the game they had just played.

Once finished with the Google Forms about the original implementation, we chose an accessibility implementation randomly, but carefully so that it would be evenly distributed through the sixteen participants. The user played the chosen accessibility implementation, and answered a similar Google Forms to the first one, except this time, they were also prompted to compare the two experiences. The entirety of the two Google Forms used can be consulted in appendix [A](#).

4.3 Usability tests - Individual Implementations vs Integration

The users tested three versions of the gameplay, one after the other:

- Movement through nose tracker with IJKL keys for shooting (IN)
- Shooting through gaze tracker with WASD keys for movement (IG)
- Movement through nose tracker and shooting through gaze tracker (BOTH)

After each playing session, they would answer a forms regarding the implementation they had just played with.

4.3.1 Recruitment of disabled users

We partnered again with Associação Salvador. Considering how many users we got from their contacts, we also reached out to other associations. Unfortunately, those did not answer our emails.

Through Associação Salvador, and following the same structure of emails from the previous collaboration, we managed to recruit two disabled users. We consider them expert users for our case, since they both suffer from conditions that make them unable to properly use one or both hands.

4.3.2 Structure

The user was welcomed and briefed about the research's objective. They were then prompted to answer a Google Forms about their geodemographical data, and also about their previous experience with video games and with accessibility tools for video games. The entirety of the geodemographical and experience in videogames Google Forms can be consulted in appendix [B](#).

Then, we explained how each technology worked, re-explaining as the user played each different implementation.

In order to avoid learning bias, we had the users test the implementations in different orders. For example, UF1 (in which UF means User Final) tested in order IN, IG, BOTH, while UF2 tested in order IG, BOTH, IN. Since there were three different implementations, and we could not repeat implementations in the same set, there were six different combinations, and we aimed for a minimum of six different users so that each combination would be played by at least one user. This way, we could exclude learning bias from the variables. We ended up being able to recruit fourteen users, with each combination having at least two participants.

As each implementation was played, the user was prompted to answer a Google Forms about that implementation. The Google Forms' content was the same for each implementation. These Google Forms would serve the purpose of analyzing the comparison through more closed metrics. At the end of the whole experience, we asked for additional feedback on the different implementations. We also asked them how they thought the system could be improved on. Getting ideas from the end users was one of our first ideas, but we could not conduct as many testing phases as we would like in order to make that a reality, so this last question meant to give us some of that lacking feedback to understand what was wrong (and right) with our idea.

4.3.3 GEQ

We based our Google Forms' questions on the GEQ, taking most of its Core Module, and translating it to Portuguese, since our testers were from Portugal. We also took their Post-Game Module in almost its entirety, to measure the users's perception of the game played with each implementation.

From the Core Module, we took out items 3 ("I was interested in the game's story"), 12 ("It was aesthetically pleasing"), 18 ("I felt imaginative"), and 19 ("I felt that I could explore things"), We did this because these items did not fit the game's genre. The game has no history has of yet, and it is a closed world, meaning the player cannot explore.

From the Post-Game Module, we took out item 17 ("I had a sense that I had returned from a journey"). Again, the game itself, even in its original implementation, has no story or journey so to speak, so we felt it did not fit into the genre.

We took out the In-Game Module in its entirety because it consists of just part of the Core Module. Since we were already using the Core Module, we thought it would be redundant to have the users answer those same questions twice. We also took out the Social Presence Module in its entirety, since it had little to do with what we wanted to evaluate. The entirety of the Google Forms

Research Methodologies

used, which contained the same questions for all implementations, can be consulted in appendix [B](#).

Chapter 5

Results

In this chapter, we go through the results obtained from each of the conducted studies.

The preliminary interview gave us some insights into the perceived state of accessibility by end users, and their own struggles with gaming. In a first testing phase, we compared the individual implementations to the original game. For our final testing phase, we tested the integration of the nose tracker and the gaze tracker against their individual implementations.

5.1 Preliminary Interview Insights

We will be referring to each participant as P1, P2 and P3. All three participants suffered from some kind of motor impairment.

P1 commented that with most controllers that they had tried, it was basically impossible for them to play for long periods of time, because they required both hands. However, with the Wii controller, that only requires one hand to be used, they could play comfortably. They also commented that when they were younger, games were never created with accessibility in mind, which made it harder to enjoy games. Even the games that they could play would be active games, games that required physical effort, leaving them feeling tired instead of relaxed.

P2 liked playing games, although they referred they were never “addicted” to it. They could play quite well with standard controllers, but felt that quick-time events took away from the experience, because they could not perform them and ended up having to call someone to help them out.

P3 did not like playing games, because they found them redundant and repetitive, but mentioned that the repetitive movements necessary in video games raised difficulties for people with disabilities.

Both P1 and P2 suggested, when asked, that games should have an option to be played using only one hand. All participants liked our original idea for an implementation, but pointed out that it would be tricky, or even impossible, for people who had difficulties with using their head.

5.2 Usability Tests

We developed four different individual implementations, two for each technology.

We ran tests with sixteen users. Each user played the original implementation and one of the individual implementations. This meant that each implementation was played by four users, and each technology was tested by eight users.

As mentioned in previous chapters, the two techniques used were nose tracking and gaze tracking, and each was tested together with either the keyboard or the automatic version of the other action. Nose tracking was used for movement and gaze tracking was used for shooting.

The raw data for these results can be found in appendix C.

5.2.1 Original Implementation

The users liked the original game very much, with it scoring an average of 4.06 and a mode of 4. The first quartile was also 4 and the third was a 4.25.

They also evaluated the game's difficulty with an average of 2.81, and a mode of 3, meaning that they thought the game was moderately difficult. 6 users considered that the amount of enemies caused the most impact on the game's difficulty, while another 6 were of the opinion that the game was most affected by the shooting controllers (all users played with keyboard). Only 3 users considered that the movement controllers caused the most impact, and 1 chose none of those options, considering that the exploding enemies in particular were the most impactful on the game's difficulty.

When asked to evaluate each topic that could affect the game's difficulty on their own instead of against each other, the shooting controllers scored higher. Even though its average was the lowest, it had a mode of 4, and a median of 3. Following them were the movement controllers, with a mode of 3 and the same quartiles and median. Interestingly, the amount of enemies scored the highest average and third quartile, even though its mode was the lowest, at 2.

The game's entertainment scored high, with a 4.06 average, and a mode of 4. All the metric's quartiles scored 4 or above, and the lowest score given was a 3, meaning that the users found the original implementation of the game very entertaining.

The user's perception of the game's immersion was very good as well, although not as high as the game's entertainment. With an average of 3.81, and a mode of 3, the lowest score given by the users was also a 3. The first quartile was slightly lower than the game's entertainment, at a 3, but both the median and the third quartile scored a 4 and a 4.25, respectively. Overall, the users liked the game and had fun, finding it moderately difficult.

5.2.2 Individual Implementation - Gaze Tracker

Eight users out of the sixteen played the two implementations of the gaze tracker as the shooting controller, using TobiiEyeX. Four of these players played the movement action using the keyboard, while the other four had the help of automated movement.

Results

	Average	Mode	Median	
Difficulty of using tracker	2.5	2	2	
Difficulty of using keys	4.25	5	4.5	
Liked the game	4.25	5	4.5	
Difficulty	3.25	3	3	
Difficulty cause by amount of enemies	2	2	2	
Difficulty cause by movement control	2.25	1	2.5	
Difficulty cause by shooting control	2.875	4	3	
Entertainment	4	5	4.5	
Immersion	3.5	5	4	
Entertainment comparison	3.875	5	4	
Immersion comparison	3.25	4	3.5	

Table 5.1: Metrics used to evaluate gaze tracking system during the first testing phase

The user's found that the gaze tracker was somewhat difficult to use. The device scored a difficulty of 2.5 average, with a mode and median of 2. This perception could have been influenced by the device's calibration, which was the same for every user. For the next testing phase, we were careful to calibrate the device for each user separately, so as to reduce this bias. The users that used the keyboard for the movement evaluated its use as easy, with a mode of 5 and all quartiles over 3.

The users liked these versions of game-play, with this metric scoring an average of 4.5 and a mode of 5. All quartiles were also 3.75 or above, and the lower score given was a 3. However, they also found the game to be slightly difficult played like this, with a mode of 4 and a median of 3.5. They considered that the shooting controllers was what caused more difficulty through the game, with four out of the eight users signaling it as the most impactful. Three of the users considered that the movement controllers caused the most difficulty, and its important to note that two of these three users were using the automated movement. The other user considered that the game was lagging a bit, and that was what most affected their perception of the game's difficulty. The amount of enemies was not considered the most impactful at all for these users.

When evaluating each difficulty topic individually, the shooting controllers scored the highest out of the three topics. With a mode of 3, and an equal median, the users considered it to have considerable impact on the game's difficulty. In accordance to their previous answers, the amount of enemies scored the lowest, with a mode of 2, and even the highest score at just 3.

The users considered they were very entertained with the game, with this metric scoring a mode of 5, and a median of 4.5, with a third quartile of 5 as well. As with the original implementation, the users felt less immersed than entertained, with this metric scoring now a mode of 5 still, but a lower median, of 4, and lower average as well (4 versus 3.5).

Results

	Average	Mode	Median
Difficulty of using tracker	2.625	2	2
Difficulty of using keys	4	3	4
Liked the game	3.625	4	4
Difficulty	3.625	3	3.5
Difficulty cause by amount of enemies	2.375	1	2.5
Difficulty cause by movement control	3.875	5	4.5
Difficulty cause by shooting control	1.75	1	1
Entertainment	3.5	3	3.5
Immersion	3.125	3	3
Entertainment comparison	2.75	2	2.5
Immersion comparison	3.25	4	3.5

Table 5.2: Metrics used to evaluate nose tracking system during the first testing phase

5.2.3 Comparison between original implementation and gaze tracker usage

In the end of the accessibility implementation forms, the users were asked to evaluate the entertainment and immersion compared to the original implementation. Since they played the two implementations one right after the other, how they felt for each should still be fresh enough for them to compare.

The users classified the entertainment as being quite higher than with the original implementation, with a mode of 5 for this question, and a median of 4. Even the first quartile was over the middle score mark, at 3.5.

The users also found this implementation more immersive than the original, evaluating it with a mode of 4 in comparison. The comparison's median was also high, at 3.5.

5.2.4 Individual Implementation - Nose Tracker

The eight users that did not test the gaze tracker, tested the nose tracker instead. Like with the gaze tracker, four users tested the movement through nose tracker using the keyboard for shooting, and the other four tested it with automated shooting.

These eight users found that the nose tracker was kind of difficult to use, evaluating it with a mode of 2, equal to the median, although the third quartile was a 4. The users that played with keyboard as well evaluated its use as easy, with a mode of 3 and a median of 4.

The users still liked the game with this implementation, with a mode of 4, equal to the median. The first quartile was also pretty high, at 2.75, almost the middle value. They found that the game was somewhat difficult played with the nose tracker, with this metric scoring a mode of 3 and all quartiles at 3 or higher.

The users mostly agreed that what most impacted the difficulty was the controller for the movement, which was the nose tracker for these implementations. Seven out of the eight users considered that the movement controllers caused the most difficulty, with one disagreeing and considering the amount of enemies to have caused the most impact on the game's difficulty. In

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agreement with the above mentioned feeling, the metric for how much the users felt that the game's difficulty was impacted by the movement controllers scored a mode of 5. With a median of 4.5 and a first quartile already at 2.75, we can determine that the users were of the opinion that this mechanic impacted the game's difficulty a lot. In comparison, the other two topics, amount of enemies, and controllers for shooting, had much lower scores, with both having modes of 1, and medians under 3 (2.5 and 1, respectively).

The users were both moderately entertained with and immersed in the game. The metrics, for the nose tracker implementations, scored very similarly, with modes of 3, and medians of 3.5 and 3, respectively. The immersion scored slightly lower than the entertainment, still.

5.2.5 Comparison between original implementation and nose tracker usage

In the end of the accessibility forms, these eight users were also asked to evaluate the entertainment and the immersion felt in comparison with the original implementation. Like the users who used the gaze tracker, these users played the two implementations one right after the other, so each experience was still fresh in their minds when they answered.

They evaluated the nose tracker game-play as slightly less entertaining when compared to the original game-play, with a mode of 2, and even the third quartile was at a 2.5. However, they considered the immersion as slightly higher than the original implementation's. Although the mode was 4, it was equal to the third quartile, and the median was 3.5, indicating a slight preference, instead of a big one.

5.3 Final Implementation Tests

Although our main goal was to test the integration entirely with users who had motor disabilities, that ended up not being possible, due to a lack of respondents who suffered from motor disabilities. However, we gathered valuable information still, about the three developed systems' usability. In table 5.3, you can see the user-disability pairing. Of the fourteen users, five were disabled, with two of those five suffering from motor disabilities.

Most of the users, regardless of suffering from a motor disability or not, commented that the research was very interesting. UF2, who suffered from Friedreich's ataxia, leaving them with severe movement difficulties, even commented that they thought the research had potential, and that they hoped to see it implemented in real-life someday. The raw data for these results can be found in appendix D.

It's important to note, before any conclusion is drawn, that through tests, UF9, who wore glasses, insisted on trying the system with and without them and commented that they thought it worked more accurately without their glasses on. This knowledge may have affected some of the users' perception of the implementation's playability and usability.

Results

UserID	Motor Disability
UF1	Left-side paralysis due to stroke
UF2	Friedreich's ataxia
UF3	No motor disability
UF4	No motor disability
UF5	No motor disability
UF6	No motor disability
UF7	No motor disability
UF8	No motor disability
UF9	No motor disability
UF10	No motor disability
UF11	No motor disability
UF12	No motor disability
UF13	No motor disability
UF14	No motor disability

Table 5.3: Users' motor disabilities

5.3.1 Geodemographic data and previous experience gaming

Eight of our users were aged 18 to 24, three were aged 25 to 34 and the other three were aged 35 to 44. The feminine versus masculine ratio was 50/50, and no one identified as another gender. Four of our fourteen users had completed the obligatory schooling, while seven had completed their bachelor's degree and three had a master's degree.

The users were overall pretty experienced with gaming, with a mode of 5, which was the highest evaluation. The median and the quartiles were also very high, with the first quartile at a 3. However, most users say they play less than one hour a week, as of right now.

5.3.2 Nose tracking with keyboard

The users did not feel competent while playing the game with the nose tracker and keyboard implementation. Although they did feel somewhat successful, as we can see in table E.1, they did not feel skillful with the nose tracker and keyboard combination, nor competent. UF6 commented that the game-play was not intuitive enough, and that the user needed more training before understanding what to do, even after the researchers' explanation on how the system worked. They were also of the opinion that the UI was too transparent, and that affected the intuitive learning process for the user. UF8 and UF10 also commented that this implementation lacked intuitiveness. UF10 even suggested that we should create a tutorial video or area, where the user could learn the way to play without the game's pressure. UF13 also agreed and commented on how the implementation's

Average	Mode	Median
3.64	5	4

Table 5.4: Users' experience with video games

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game play was not intuitive at all, asking to play another round, because they had not understood how the system worked until the end of the round. UF14 also commented on the nose tracker's intuitiveness, saying that they did not understand how it worked.

The users found the game impressive, and thought it was a good experience. On table E.2 we can see that most users found the experience rich, with a mode of 4, the highest score available.

The game's flow scored pretty high. Although most of the first quartiles of the metrics were on the lower half of the scale, the modes were either 3 or 4, with mostly good medians, and all third quartiles 3 or higher. However, UF5 and UF7 found that the UI proved too busy, with too many things trying to "steal" the user's attention at the same time. UF14 was of the opinion that the nose tracker demanded too much of their attention, being unable to concentrate on anything else.

The tension metrics showed that even though the users did not feel competent playing, they also did not feel much tension, although the users did feel slightly frustrated. In table E.4, we can see that the frustration metric scored slightly higher than the other tension metrics. This could be due to the users' difficulty in using the system, which they reported over and over again during the opinions section of the experience.

The users did not feel pressure, but they felt that the game was difficult to play, and felt extremely challenged by the game-play with this implementation. As is presented in table E.5, the users felt they were challenged and that they had to put too much effort into playing. They also felt the game was hard, with a mode equal to the median of 3, and a third quartile of 3.75. Users commented that the nose tracker UI was too far apart, and they felt the nose tracker was very difficult to use. UF7 commented that it was harder to move up using the nose tracker, than it was to move down or to the sides. UF10 thought the nose tracker was too complicated to use.

Even though the users found the game to be hard, the bad humour metric scored an average of 0.14 and only two users evaluated it with a 1 and everyone else with a 0. The negative aspect that scored higher, even if not very high, was the tiredness metric ("Tiresome" in table E.6). Even though the metric scored low, the users kept commenting that while one round of play like this was okay, they felt they could not play more than a few before getting tired. UF1 even commented that the movement of the head was tiring.

As is evidenced in table E.7, although the users thought the implementation was hard to play, they still had fun with the game, and felt satisfied while playing. However, UF2, who had very limited movement, did not find it fun, saying explicitly so after playing.

According to the values in table E.8, the users did not feel like the experience was greatly positive. Although they felt fairly satisfied, with a mode of 3, and all quartiles over or equal to 2, every other positive experience metric scored quite low, especially the victorious metric. Although the third quartile was decent, the mode, first quartile, and median were 1, meaning that the users did not feel victorious, which is central to this type of game.

Although the users did not find the experience overly positive, they also did not find it negative at all. The metric with the highest scores for this set is the useless metric, and even that one had a third quartile of 2.

Results

As is explicit in table E.10, the users did not feel tired at all. Although they evaluated these metrics so low, as they played, the users commented that playing this for more than one, round could become tiresome. As mentioned above, UF1 went as far as commenting directly on how moving their head could be tiring.

The users did not feel like it was hard to get back to reality, although they felt slightly disoriented after playing the game with this implementation. In table E.11, we can see that while the values for the disorientation metric were still pretty low, they were already substantial, with a mode of 2. This may be explained with the users' complaints about the UI and how it was far too busy that they kept getting lost in it.

5.3.3 Gaze tracking with keyboard

The users felt very competent while playing with the gaze tracker and keyboard combination. As is shown in table E.12, the results were good for these metrics, with modes of 2 and 3. The medians and third quartiles were also pretty high. The users felt very successful with this implementation, with this metric having the best scores of the set.

The users found the game impressive and the experience of playing with this implementation rich. The results for these metrics were very high, with the "rich experience" metric having a mode of 4, as we can see in table E.13.

They were concentrated in the game while playing, feeling that it flowed easily. In table E.14 we can see that the all the modes for these metrics were 3 or 4. Although the first quartile on the "surroundings", "track of time", and "outside world" metrics was pretty low, only for the "outside world" was the median also low, although the third quartile was almost 4.

The users felt little tension with this implementation, although some users felt frustrated, which is why the "frustrated" values in table E.15 appear higher. However, even for that metric, the mode was 0, and the median was under 1.

Although they did not feel pressured, the users felt they needed moderate effort to play, and felt the game was quite hard, with that metric scoring a mode of 3, as shown in table E.16. They also felt challenged, with that metric scoring a mode of 3 and the highest quartiles.

The users did not feel negatively about the game as they played with the gaze tracker and keyboard. According to the values on table E.17, they evaluated possible negative aspects very lowly. They even felt that the game played with this implementation was fun and likeable. The users felt quite happy and good, and also very satisfied. All modes in these positive metrics were 3, and even the first quartile for all metrics was over 2, as can be seen in table E.18. Users kept commenting repeatedly about how much fun they had with this version of the game play.

Although the users did not feel much positive change in their energy levels, table E.19 shows that they did feel quite victorious, with a mode of 4 and a median of 3. They also felt quite proud and very satisfied after playing with the combination of the gaze tracker and the keyboard.

So, the users felt this experience impacted them quite positively, with the negative experience metrics scoring very low, with most values under 1. The only values that were a bit higher, as seen

in table E.20, is the "useless" metric, whose respective question was "I felt that I could have done more useful things". Even that metric's scores were significantly low.

As we can extract from table E.21, the users agreed mostly that this implementation was not tiring at all. Only UF4 found it somewhat tiring, and they did comment that playing with a tracker and the keyboard was very hard, regardless of the tracker. The users did not find it hard to come back to reality, nor did they feel disoriented after playing with this combination, as we can see by the values present in table E.22.

5.3.4 Integration

The users did not feel very competent. Although the mode for "successful" metric was 3, every other metric for the set in table E.23 had a mode of 0, and a third quartile of 2 or under, with very low medians. However, they did think the game was impressive and that it was a rich experience, although not incredibly so.

The users also felt fully occupied by the game and were deeply concentrated in it while playing with the integration of the nose and gaze trackers. They did not lose track time, according to the values present in table E.25, but the implementation still captivated them.

The testers did not feel overly tense. However, they did report some frustration, with a mode of 2 for that metric, as seen in table E.26. This is possibly due to the difficulty reported with using the system.

Although the users felt very little pressure, with modes of 0 for both pressure metrics, they felt very challenged, as seen by the values in table E.27. All the values for whether they thought it was hard were all equal or over the middle evaluation value, 2. The values for the "challenge" metric were also very high, with a mode of 3, equal to the first quartile and to the median, and a third quartile of 4. Although the "effort" results were not as high, we can still see that the users felt they needed to put a lot of effort in to play the game like this.

Even though the users found the system hard to use, this did not affect their mood negatively. They found the game was not tiring, nor did they feel overly bored, according to table E.28. They also did not think of other things for the most part, and their humour was not affected negatively.

Regardless of finding the implementation difficult and frustrating, the users still had fun with the game, and liked it quite a lot. As specified in table E.29, the modes for the positive aspects metrics were mostly 3, with a 4 for how much they liked the game. Although the medians were not as high, this set still had medians all over the middle evaluation value, 2.

However, the users did not feel victorious at all, with a mode of 0, and a median of 1.5. They felt somewhat satisfied, but the "powerful" and "proud" metrics performed poorly E.30, meaning that while the users did not feel bad after playing, they also did not feel great.

Although not feeling overly positively about the experience, the users also did not feel negatively about it. In table E.31 we can see that the users evaluated these metrics mostly with 0s. The highest ranking metric was "useless", and even that one had a median of only 0.5 and a mode of 0, with the third quartile at a 1.75. The users also did not feel tired after playing, according to the values in table E.32.

Results

Returning to reality was not hard for the users, although they reported disorientation. In table E.33, we can see that the mode for the disorientation metric was 3, although the median was 1.5. The disorientation could be explained by the comments most users made about feeling that the UI had too much information.

5.3.5 User feedback on the comparison

The users were mostly impressed by the gaze tracker and how it worked, regardless of its accuracy issues. However, they were little impressed by the nose tracker, complaining that it was hard to use and understand and that it could become quite tiring to move around so much.

In the integration, UF1 mentioned they felt the gaze tracker was unusable while moving their head for the nose tracker. UF2 felt that the integration was too hard to play, and suggested that both trackers should be focused on the face. UF3 went as far as commenting that they felt the integration performed slower than the individual implementations - which could be due to the amount of tracking the integration does being double to the amount of tracking happening in the individual implementations. UF3 also mentioned that it was difficult to understand what they were supposed to do to play, and suggested that with more training, the system could be usable. UF5 commented that the two technologies "do not get along well", and that there were two many things demanding their attention at once.

UF4, UF6 and UF10 preferred the integration, but UF6 and UF10 commented that the users needed more training with the system for it to feel usable.

UF7 played the integration last, after playing both the nose tracker and the gaze tracker individually. Upon being told they were to play a version with an integration of these two technologies, they looked worried and somewhat scared. After playing, they also came to the conclusion that these two technologies did not work well together, because it is very hard to do both things at the same time. UF8 shared the same opinion, commenting that the integration "had too many things at once".

UF9 had a similar opinion to UF1, although they felt it the other way around - the gaze tracker worked very well, but they were unable to use the nose tracker, feeling as if it was not working correctly. UF11, UF12, UF13 and UF14 all liked the gaze tracker individually best. UF13 and UF14 found that the nose tracker lacked too much intuitiveness, with UF13 asking to play it one more time because they had just understood how it worked at the end of the sixty second round.

5.3.6 Comparison of some key metrics

As is evident in figure 5.1, the users felt more successful overall while using the gaze tracker, even though the mode was the same for all three implementations. The first quartile for the individual gaze tracker implementation for this metric was far higher than the first quartile of the other two implementations, suggesting a concentration of the values on the higher end of the spectrum.

When it came to competence, the users felt far more competent using the individual gaze tracker implementation, with it scoring the highest average, mode and quartiles. The integration,

Results

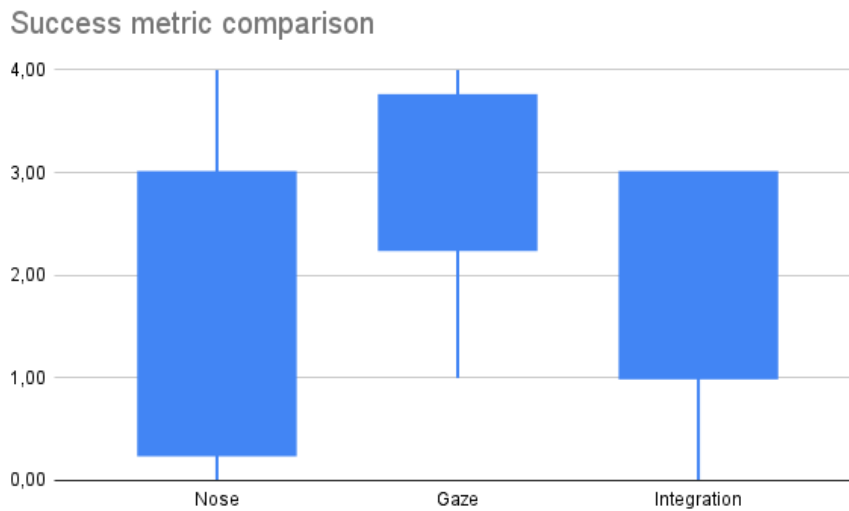


Figure 5.1: Success metric comparison

in this metric, scored the lowest, with a mode of 0, compared to the mode of 2 for the individual gaze tracker. (fig. 5.2)

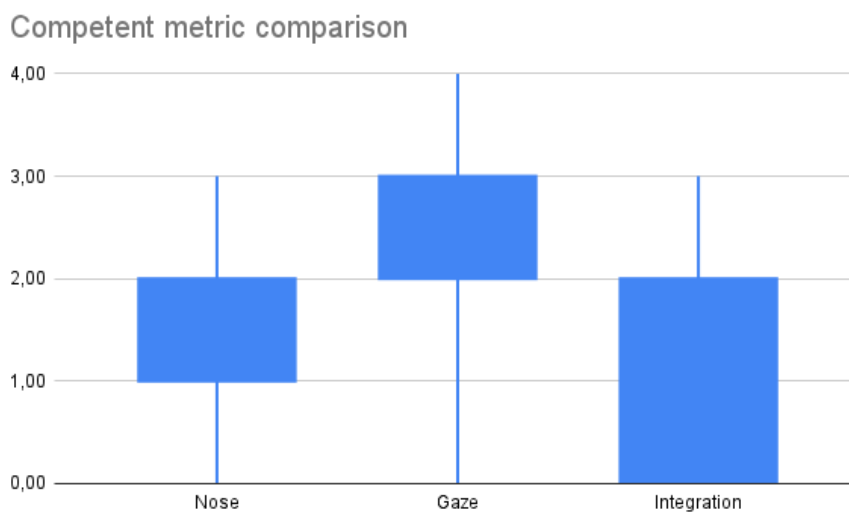


Figure 5.2: Competent metric comparison

Although the mode for the individual gaze tracker in the "was it hard" metric was higher than for the integration, and equal to the individual nose tracker's, the favourite implementation scored the lowest in all quartiles. This indicates that while the difficulty felt was more or less the same for the three implementations, the gaze tracker was overall perceived as slightly less difficult. (fig. 5.3)

As can be seen clearly in figure 5.4, the users felt they played better with the gaze tracker individually. With modes of 0 for the individual nose tracker and the integration, versus a mode of

Results

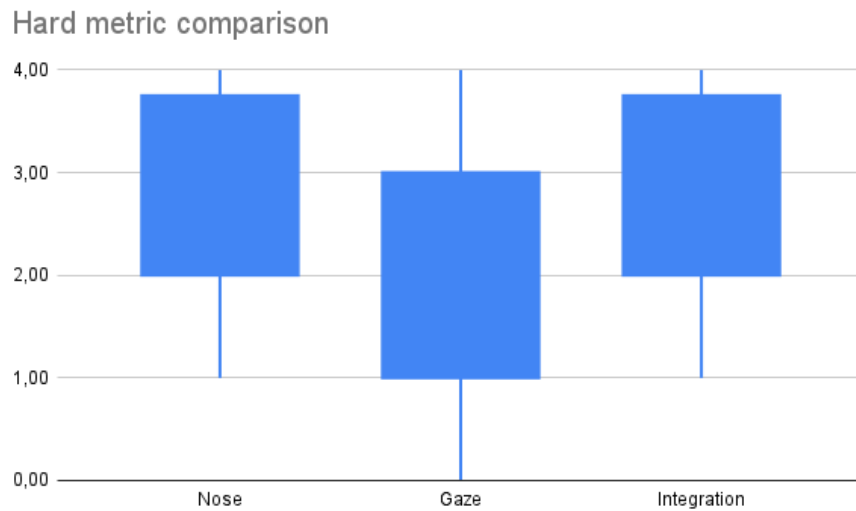


Figure 5.3: Hard metric comparison

3 for the individual gaze tracker, and great differences is the quartiles and median, the individual gaze tracker implementation was the clear favourite when it came to this metric.

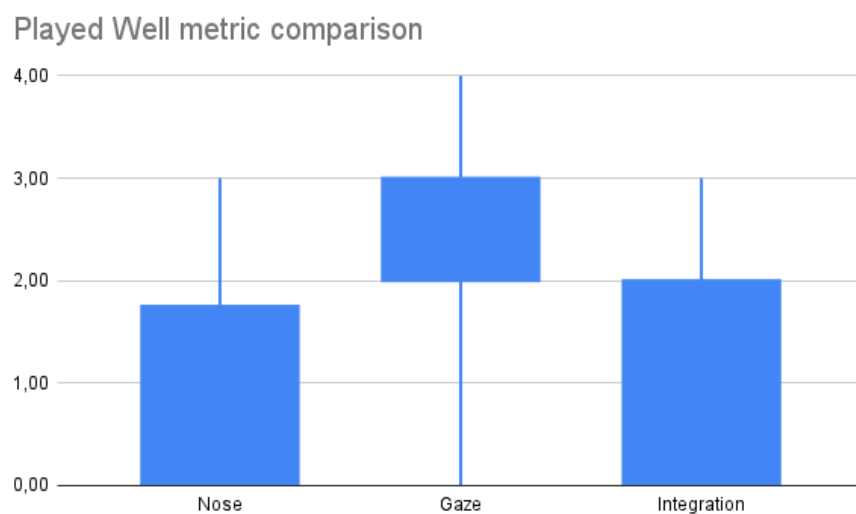


Figure 5.4: Played Well metric comparison

For the effort metric, the individual gaze tracker scored much lower than the other two implementations, which scored more or less the same. This means that when it came to the effort the users felt they needed to put in to play, the individual gaze tracker implementation required less effort to be used than the other implementations. (5.5)

For the victorious metric, we have, again, a great difference of results between the individual gaze tracker and the other two implementations. As shown in figure 5.6, the users felt much more victorious using the gaze tracker individually that while playing with the nose tracker individually

Results

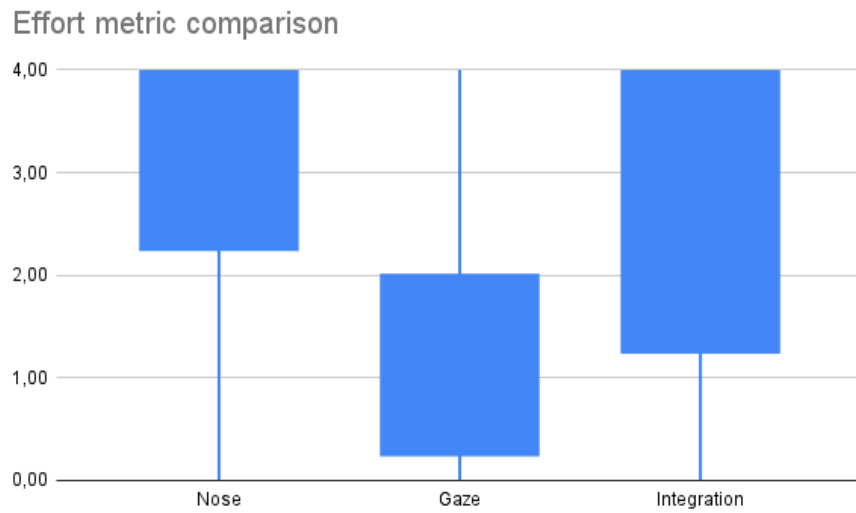


Figure 5.5: Effort metric comparison

or the integration. There was also slight differences between the individual nose tracker and the integration on this metric, with the nose tracker proving to make users feel slightly more victorious than the integration.

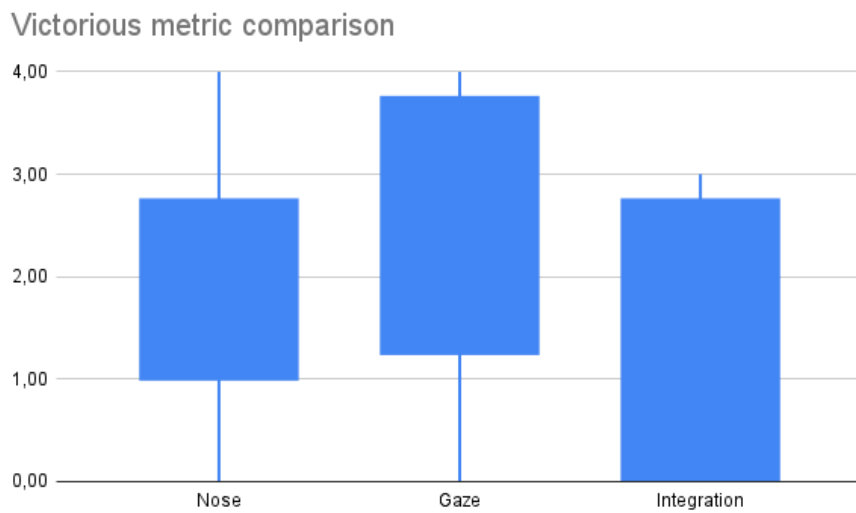


Figure 5.6: Victorious metric comparison

Results

Chapter 6

Conclusion

This research aimed at studying if the integration of two technologies would perform better than these same two technologies used individually. The interaction technologies were chosen prior to talking to any end users: a nose tracker and a gaze tracker.

Three phases of contact with users were conducted, a preliminary interview, and two testing phases. Through each of them new information to add to the research was learned.

Through the preliminary interview, we gathered valuable insight about what people with motor disabilities felt was the biggest issue with accessibility in video gaming and what they wanted to see done.

In the first round of testing, we found what needed to be addressed for both trackers in the integration and concluded that the users felt more entertained and immersed when playing with the trackers, in comparison to the original gameplay. The users also found the nose tracker to be very difficult through this phase. They commented that the interface was too far apart and it was hard to get from moving to one side to moving to the other, so we changed it for the next phase.

The second round of testing was used to answer our research question: will the usage of two technologies integrated together perform better than these same two technologies used individually? The answer was no, for the technologies tested.

Although the integration removed the need for the use of hands while playing, users found that this particular combination was not enjoyable at all. They much preferred the gameplay where they used the gaze tracker along with the keyboard. They felt they could win more easily, and that the gaze tracker was easier to use. The nose tracker's distance to change the movement was still too big for the users, which made it so they found it trickier to use. When using them as an integration, the users felt that there was too much going on, and the gaze tracker lost track of their eyes as they moved to use the nose tracker.

Although not the results we were expecting, these insights allow us to move forward and make contributions to the research of accessibility in video games.

6.1 Limitations

There was great difficulty found when it came to searching for users who were physically disabled. So, our preliminary interview only had three users, and although there were 14 users who tested the final product, only 2 of these were physically disabled.

There were also some issues with the trackers' calibration. The nose tracker kept confusing the background with faces, causing it to lose track of the user. The gaze tracker was very sensitive to distance and any slight adjustment the user would perform in their chair after the calibration would set off the system.

6.2 Future Work

In the future, more tests with disabled users could be performed on the integration, in order to better test the final product for their specific needs. Individual interviews with disabled users could also be viable for the same reason, and as a way to expand the knowledge on their perception of accessibility in digital games.

Since only a nose tracker and a gaze tracker were tested together, a logical next step would be to test these technologies integrated with different ones, and to integrate different technologies with each other as well. We now know that the produced system does not perform well, but other combinations could perform better. The nose tracking system proved to be very difficult to use, so it would be preferable to discard it all together, and continue working with the gaze tracking system, testing it with other interaction technologies.

The gaze tracker, although proving to be fun and moderately reliable, suffered from accuracy problems. Though the device itself is in part to blame, the system could be iterated to overcome this inaccuracy.

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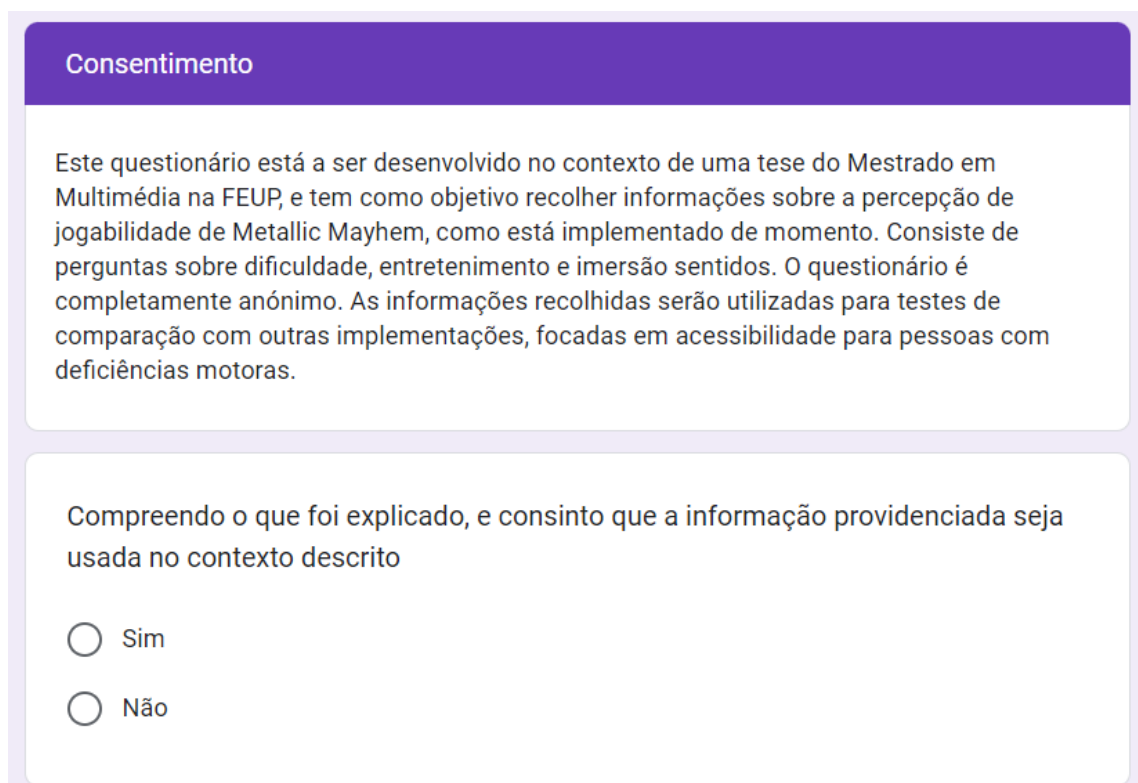
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Appendix A

Questionnaires for first testing



The image shows a digital consent form with a purple header and two white content boxes. The first box contains a paragraph explaining the purpose of the questionnaire. The second box contains a statement of understanding and consent, followed by two radio button options: 'Sim' and 'Não'.

Consentimento

Este questionário está a ser desenvolvido no contexto de uma tese do Mestrado em Multimédia na FEUP, e tem como objetivo recolher informações sobre a percepção de jogabilidade de *Metallic Mayhem*, como está implementado de momento. Consiste de perguntas sobre dificuldade, entretenimento e imersão sentidos. O questionário é completamente anónimo. As informações recolhidas serão utilizadas para testes de comparação com outras implementações, focadas em acessibilidade para pessoas com deficiências motoras.

Compreendo o que foi explicado, e consinto que a informação providenciada seja usada no contexto descrito

☐ Sim

☐ Não

Figure A.1: Consent for original implementation questionnaire

Questionnaires for first testing

Perguntas

Gostou do jogo? *

	1	2	3	4	5	
Não gostei	☐	☐	☐	☐	☐	Gostei muito

Dificuldade sentida durante o jogo *

	1	2	3	4	5	
Nenhuma	☐	☐	☐	☐	☐	Muita

O que causou mais dificuldade *

- ☐ Quantidade de inimigos
- ☐ Controlos de movimento
- ☐ Controlos de shooting
- ☐ Outra: _____

Figure A.2: Original implementation questionnaire Questions, part 1

Questionnaires for first testing

Classifique cada parte em termos de impacto na dificuldade do jogo *

	1	2	3	4	5
Quantidade de inimigos	☐	☐	☐	☐	☐
Controlos de movimento	☐	☐	☐	☐	☐
Controlos de shooting	☐	☐	☐	☐	☐

Quão entretido esteve com o jogo? *

	1	2	3	4	5	
Nada	☐	☐	☐	☐	☐	Muito

Quão imerso se sentiu no jogo? *

	1	2	3	4	5	
Nada	☐	☐	☐	☐	☐	Muito

Figure A.3: Original implementation questionnaire Questions, part 2

Consentimento

Este questionário está a ser desenvolvido no contexto de uma tese do Mestrado em Multimédia na FEUP, e tem como objetivo recolher informações sobre a percepção de jogabilidade de Metallic Mayhem, com técnicas de acessibilidade. Consiste de perguntas sobre dificuldade, entretenimento e imersão sentidos. O questionário é completamente anónimo. As informações recolhidas serão utilizadas para testes de comparação com a implementação base.

Compreendo o que foi explicado, e consinto que a informação providenciada seja * usada no contexto descrito

☐ Sim

☐ Não

Figure A.4: Individual implementations questionnaire consent

Implementação jogada

Com qual implementação jogou? *

☐ Movimento por rastreador de nariz + shooting por teclas IJKL

☐ Movimento por rastreador de nariz + shooting automático

☐ Movimento por teclas WASD + shooting por rastreador de olhar

☐ Movimento automático + shooting por rastreador de olhar

Figure A.5: Individual implementations questionnaire - which the user played

Dificuldade shooting por rastreador de olhar

Classifique a dificuldade de uso do shooting por rastreador de olhar *

	1	2	3	4	5	
Muito difícil	☐	☐	☐	☐	☐	Muito fácil

Caso tenha jogado com teclas, classifique a dificuldade de uso do movimento por teclas WASD

	1	2	3	4	5	
Muito difícil	☐	☐	☐	☐	☐	Muito fácil

Figure A.6: Individual implementations questionnaire - difficulty of gaze tracker

Questionnaires for first testing

Dificuldade movimento por rastreador de nariz

Classifique a dificuldade de uso do movimento por rastreador de nariz *

Muito difícil

1

2

3

4

5

Muito fácil

Caso tenha jogado com teclas, classifique a dificuldade de uso do shooting por teclas IJKL

Muito difícil

1

2

3

4

5

Muito fácil

Figure A.7: Individual implementations questionnaire - difficulty of nose tracker

Questionnaires for first testing

Perguntas

Gostou do jogo? *

	1	2	3	4	5	
Não gostei	☐	☐	☐	☐	☐	Gostei muito

Dificuldade sentida durante o jogo *

	1	2	3	4	5	
Nenhuma	☐	☐	☐	☐	☐	Muita

O que causou mais dificuldade *

- ☐ Quantidade de inimigos
- ☐ Controlos de movimento
- ☐ Controlos de shooting
- ☐ Outra: _____

Figure A.8: Individual implementations questionnaire - part 1 of questions

Questionnaires for first testing

Classifique cada parte em termos de impacto na dificuldade do jogo *

	1	2	3	4	5
Quantidade de inimigos	☐	☐	☐	☐	☐
Controlos de movimento	☐	☐	☐	☐	☐
Controlos de shooting	☐	☐	☐	☐	☐

Quão entretido esteve com o jogo? *

	1	2	3	4	5	
Nada	☐	☐	☐	☐	☐	Muito

Quão imerso se sentiu no jogo? *

	1	2	3	4	5	
Nada	☐	☐	☐	☐	☐	Muito

Figure A.9: Individual implementations questionnaire - part 2 of questions

Em comparação com o jogo base, classifique o entretenimento sentido *

	1	2	3	4	5	
Muito menos	☐	☐	☐	☐	☐	Muito mais

Em comparação com o jogo base, classifique a imersão sentido *

	1	2	3	4	5	
Muito menos	☐	☐	☐	☐	☐	Muito mais

Figure A.10: Individual implementations questionnaire - part 3 of questions

Questionnaires for first testing

Appendix B

Questionnaires for final testing

Este questionário está a ser desenvolvido no contexto de uma tese do Mestrado em Multimédia na FEUP, e tem como objetivo recolher informações sobre a percepção de jogabilidade de *Metallic Mayhem*, com técnicas de acessibilidade. Consiste numa avaliação da implementação para acessibilidade desenvolvida durante a tese, e tem como objetivo a comparação da integração de duas tecnologias para acessibilidade com a implementação de só uma tecnologia. É completamente anónimo, sendo as informações recolhidas usadas apenas para a análise da comparação feita.

Figure B.1: Final Questionnaire Consent

Questionnaires for final testing

Dados geo-demográficos

Idade *

☐ 18-24

☐ 25-34

☐ 35-44

☐ 45-54

☐ 55-64

☐ 65+

Género *

☐ Feminino

☐ Masculino

☐ Prefiro não dizer

☐ Outra: _____

Figure B.2: Final GeoDemographical Data part 1

Escolaridade *

☐ Ensino obrigatório

☐ Licenciatura / Bachelorato

☐ Mestrado

☐ Doutoramento

Figure B.3: Final GeoDemographical Data part 2

Questionnaires for final testing

Experiência a jogar

Experiência prévia com vídeo-jogos *

	1	2	3	4	5	
Nenhuma	☐	☐	☐	☐	☐	Muita

Quanto tempo passa a jogar vídeo-jogos por semana? *

☐ Menos de 1h

☐ 1h a 3h

☐ 3h a 5h

☐ Mais de 5h

Já usou alguma ferramenta de acessibilidade para jogar? Se sim, qual? *

A sua resposta _____

Figure B.4: Final Experience with videogames

- 0 = Não de todo
- 1 = Pouco
- 2 = Moderadamente
- 3 = Bastante
- 4 = Extremamente

Figure B.5: Final Questionnaire Number to Meaning

Questionnaires for final testing

Senti-me bem-sucedido *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Senti-me aborrecido *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Achei que o jogo era impressionante *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Figure B.6: Final Questionnaire Questions part 1

Questionnaires for final testing

Ignorei tudo à minha volta enquanto jogava *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Senti-me satisfeito *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Achei o jogo cansativo *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Figure B.7: Final Questionnaire Questions part 2

Questionnaires for final testing

Senti-me frustrado *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Senti-me irritado *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Senti-me habilidoso *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Figure B.8: Final Questionnaire Questions part 3

Questionnaires for final testing

Achei que o jogo era divertido *

	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Estive totalmente absorvido com o jogo *

	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Senti-me desafiado *

	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Figure B.9: Final Questionnaire Questions part 4

Questionnaires for final testing

Senti-me feliz *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Senti-me de mau humor *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Pensei noutras coisas *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Figure B.10: Final Questionnaire Questions part 5

Questionnaires for final testing

Senti-me competente *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Achei que era difícil *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Senti-me bem *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Figure B.11: Final Questionnaire Questions part 6

Questionnaires for final testing

Senti que joguei bem *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Gostei do jogo *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Atingi os objetivos rapidamente *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Figure B.12: Final Questionnaire Questions part 7

Questionnaires for final testing

Senti-me incomodado *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Senti-me sob pressão *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Perdi noção do tempo *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Figure B.13: Final Questionnaire Questions part 8

Questionnaires for final testing

Estive completamente concentrado no jogo *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Foi uma experiência rica *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Perdi conexão com o mundo fora do jogo *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Figure B.14: Final Questionnaire Questions part 9

Questionnaires for final testing

Senti pressão de tempo *

	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Tive que me esforçar muito *

	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Figure B.15: Final Questionnaire Questions part 10

Questionnaires for final testing

Senti-me revivido *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Senti-me mal *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Achei difícil voltar à realidade *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Figure B.16: Final Questionnaire Questions part 11

Questionnaires for final testing

Senti-me culpado *

	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Senti-me vitorioso *

	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Achei que fosse uma perda de tempo *

	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Figure B.17: Final Questionnaire Questions part 12

Questionnaires for final testing

Senti-me energizado *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Senti-me satisfeito *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Senti-me desorientado *						
	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Figure B.18: Final Questionnaire Questions part 13

Questionnaires for final testing

Senti-me exausto *

	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Senti que poderia ter feito algo mais útil *

	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Senti-me poderoso *

	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Figure B.19: Final Questionnaire Questions part 14

Questionnaires for final testing

Senti-me cansado *

	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Senti-me arrependido *

	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Senti-me envergonhado *

	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Figure B.20: Final Questionnaire Questions part 15

Senti-me orgulhoso *

	0	1	2	3	4	
Não de todo	☐	☐	☐	☐	☐	Extremamente

Figure B.21: Final Questionnaire Questions part 16

Appendix C

Raw Data of First Testing Phase

UserID	Compreendo o que foi explicado, e consinto que a informação providenciada seja usada no contexto descrito
1	Sim
2	Sim
3	Sim
4	Sim
5	Sim
6	Sim
7	Sim
8	Sim
9	Sim
10	Sim
11	Sim
12	Sim
13	Sim
14	Sim
15	Sim
16	Sim

Figure C.1: First testing phase, raw data for original implementation, consent

Raw Data of First Testing Phase

UserID	Gostou do jogo?	Dificuldade sentida durante o jogo	O que causou mais dificuldade	Classifique cada parte em termos de impacto na dificuldade do jogo [Quantidade de inimigos]	Classifique cada parte em termos de impacto na dificuldade do jogo [Controlos de movimento]	Classifique cada parte em termos de impacto na dificuldade do jogo [Controlos de shooting]
1		4	3 Controlos de shooting	4	3	4
2		5	1 Quantidade de inimigos	2	1	1
3		5	2 Quantidade de inimigos	5	2	2
4		4	4 Controlos de shooting	1	3	5
5		4	1 Controlos de shooting	2	4	4
6		4	2 Quantidade de inimigos	3	2	1
			Os inimigos que explodem podem ser um bocado complicados de lidar, e alguns mapas são um bocado obstrusivos.			
7		3	2 obstrusivos.	3	1	1
8		4	2 Controlos de shooting	4	5	4
9		5	4 Quantidade de inimigos	5	3	3
10		4	3 Controlos de movimento	1	4	4
11		4	3 Controlos de shooting	5	5	3
12		4	3 Controlos de movimento	2	3	2
13		4	5 Controlos de shooting	1	3	3
14		4	3 Quantidade de inimigos	4	2	2
15		5	3 Controlos de movimento	2	2	3
16		2	4 Quantidade de inimigos	5	4	2

Figure C.2: First testing phase, raw data for individual implementations, part 1

Raw Data of First Testing Phase

UserID	Quão entretido esteve com o jogo?	Quão imerso se sentiu no jogo?
1	4	3
2	5	5
3	5	4
4	3	3
5	4	4
6	4	3
7	3	3
8	4	4
9	5	5
10	4	3
11	5	5
12	4	5
13	4	4
14	4	3
15	4	4
16	3	3

Figure C.3: First testing phase, raw data for original implementation, part 2

Raw Data of First Testing Phase

UserID	Compreendo o que foi explicado, e consinto que a informação providenciada seja usada no contexto descrito
1	Sim
2	Sim
3	Sim
4	Sim
5	Sim
6	Sim
7	Sim
8	Sim
9	Sim
10	Sim
11	Sim
12	Sim
13	Sim
14	Sim
15	Sim
16	Sim

Figure C.4: First testing phase, raw data for original implementation, consent

Raw Data of First Testing Phase

UserID	Com qual implementação jogou?	Classifique a dificuldade de uso do movimento por rastreador de nariz	Caso tenha jogado com teclas, classifique a dificuldade de uso do shooting por teclas IJKL	Classifique a dificuldade de uso do shooting por rastreador de olhar	Caso tenha jogado com teclas, classifique a dificuldade de uso do movimento por teclas WASD
1	Movimento por teclas WASD + shooting por rastreador de olhar			4	5
2	Movimento automático + shooting por rastreador de olhar			3	
3	Movimento por rastreador de nariz + shooting por teclas IJKL	4	3		
4	Movimento por rastreador de nariz + shooting automático	1			
5	Movimento por teclas WASD + shooting por rastreador de olhar			2	5
6	Movimento por rastreador de nariz + shooting automático	4			
7	Movimento automático + shooting por rastreador de olhar			2	
8	Movimento por rastreador de nariz + shooting por teclas IJKL	2	5		
9	Movimento automático + shooting por rastreador de olhar			2	
10	Movimento por teclas WASD + shooting por rastreador de olhar			2	4
11	Movimento por teclas WASD + shooting por rastreador de olhar			3	3
12	Movimento automático + shooting por rastreador de olhar			2	
13	Movimento por rastreador de nariz + shooting por teclas IJKL	1	5		
14	Movimento por rastreador de nariz + shooting automático	2			
15	Movimento por rastreador de nariz + shooting automático	5			
16	Movimento por rastreador de nariz + shooting por teclas IJKL	2	3		

Figure C.5: First testing phase, raw data for individual implementations, part 1

Raw Data of First Testing Phase

UserID	Gostou do jogo?	Dificuldade sentida durante o jogo	O que causou mais dificuldade	Classifique cada parte em termos de impacto na dificuldade do jogo [Quantidade de inimigos]	Classifique cada parte em termos de impacto na dificuldade do jogo [Controlos de movimento]	Classifique cada parte em termos de impacto na dificuldade do jogo [Controlos de shooting]
1	5	4	Controlos de shooting	2	2	3
2	5	3	Controlos de movimento	3	3	1
3	5	3	Controlos de movimento	4	5	3
4	2	5	Controlos de movimento	1	5	1
5	4	4	Controlos de shooting	1	1	4
6	4	3	Quantidade de inimigos	3	2	1
7	3	2	Controlos de shooting	2	1	4
8	4	3	Controlos de movimento	3	4	1
9	5	5	Controlos de movimento	3	4	2
10	4	3	Controlos de movimento	1	3	2
11	5	3	Um pouco de lag	2	3	3
12	5	3	Controlos de shooting	1	1	3
13	3	4	Controlos de movimento	1	5	5
14	4	3	Controlos de movimento	2	3	1
15	5	4	Controlos de movimento	1	2	1
16	2	4	Controlos de movimento	4	5	1

Figure C.6: First testing phase, raw data for individual implementations, part 2

Raw Data of First Testing Phase

UserID	Quão entretido esteve com o jogo?	Quão imerso se sentiu no jogo?	Em comparação com o jogo base, classifique o entretenimento sentido	Em comparação com o jogo base, classifique a imersão sentido
1	5	4	5	4
2	5	5	5	5
3	3	2	2	1
4	2	1	2	2
5	4	4	5	5
6	4	3	3	4
7	2	1	2	1
8	4	4	3	3
9	5	5	4	3
10	4	3	4	4
11	5	5	4	3
12	4	5	5	5
13	3	3	3	3
14	4	4	2	4
15	5	5	5	5
16	3	3	2	4

Figure C.7: First testing phase, raw data for individual implementations, part 3

Raw Data of First Testing Phase

Appendix D

Raw Data for Final Tests

Consinto que os meus dados sejam recolhidos e usados no contexto acima descrito	UserID	Idade	Género	Escolaridade	Experiência prévia com video-jogos	Quanto tempo passa a jogar video-jogos por semana?	Já usou alguma ferramenta de acessibilidade para jogar? Se sim, qual?
Sim	UF1	25-34	Masculino	Ensino obrigatório		5 Mais de 5h	Sim Rato com vários botões de lado
Sim	UF2	18-24	Feminino	Licenciatura / Bachelorato		4 Menos de 1h	Não
Sim	UF3	18-24	Masculino	Licenciatura / Bachelorato		5 1h a 3h	Colorblindness mode
Sim	UF4	18-24	Feminino	Licenciatura / Bachelorato		4 3h a 5h	No
Sim	UF5	18-24	Masculino	Licenciatura / Bachelorato		5 Mais de 5h	Não
Sim	UF6	25-34	Feminino	Mestrado		5 Mais de 5h	nao
Sim	UF7	35-44	Masculino	Licenciatura / Bachelorato		2 Menos de 1h	não
Sim	UF8	18-24	Feminino	Ensino obrigatório		3 1h a 3h	Não
Sim	UF9	25-34	Masculino	Mestrado		4 Menos de 1h	Nao
Sim	UF10	35-44	Feminino	Licenciatura / Bachelorato		1 Menos de 1h	Não
Sim	UF11	35-44	Masculino	Mestrado		3 Menos de 1h	NAO
Sim	UF12	18-24	Feminino	Ensino obrigatório		3 Menos de 1h	não
Sim	UF13	18-24	Masculino	Licenciatura / Bachelorato		4 1h a 3h	Trocar as teclas pré-definidas
Sim	UF14	18-24	Feminino	Ensino obrigatório		3 Menos de 1h	Não

Figure D.1: GeoDemographical results and Previous Experience in video gaming

Consinto que os meus dados sejam recolhidos e usados no contexto acima descrito	UserID
Sim	UF1
Sim	UF2
Sim	UF3
Sim	UF4
Sim	UF5
Sim	UF6
Sim	UF7
Sim	UF8
Sim	UF9
Sim	UF10
Sim	UF11
Sim	UF12
Sim	UF13
Sim	UF14

Figure D.2: Consent for individual nose testing in final implementation

Raw Data for Final Tests

UserID	Senti-me bem-sucedido	Senti-me aborrecido	Achei que o jogo era impressionante	Ignorei tudo à minha volta enquanto jogava	Senti-me satisfeito	Achei o jogo cansativo
UF1	3	0	4	4	4	3
UF2	4	1	1	3	3	2
UF3	3	1	2	3	3	0
UF4	1	0	3	4	3	2
UF5	2	0	3	0	3	0
UF6	0	1	3	3	2	1
UF7	0	2	1	3	2	0
UF8	3	0	4	3	4	0
UF9	3	0	2	1	3	0
UF10	0	2	1	3	0	2
UF11	2	0	3	4	3	0
UF12	0	1	2	1	3	1
UF13	3	0	3	3	3	1
UF14	2	1	2	0	2	1

Figure D.3: Results for individual nose testing in final implementation - part 1

UserID	Senti-me frustrado	Senti-me irritado	Senti-me habilidoso	Achei que o jogo era divertido	Estive totalmente absorvido com o jogo	Senti-me desafiado
UF1	0	0	3	4	4	4
UF2	0	0	2	2	4	3
UF3	0	0	2	2	3	1
UF4	1	0	1	3	4	4
UF5	2	0	1	3	2	4
UF6	2	0	2	4	2	4
UF7	4	1	1	3	4	4
UF8	0	0	3	4	2	3
UF9	1	0	1	3	2	3
UF10	2	0	0	1	3	4
UF11	0	0	1	3	4	4
UF12	0	0	1	3	1	4
UF13	1	1	2	4	2	3
UF14	3	2	1	2	0	4

Figure D.4: Results for individual nose testing in final implementation - part 2

UserID	Senti-me feliz	Senti-me de mau humor	Pensei noutras coisas	Senti-me competente	Achei que era difícil	Senti-me bem
UF1	4	0	0	3	3	4
UF2	4	0	0	2	3	4
UF3	2	0	0	1	2	3
UF4	4	0	0	1	4	2
UF5	3	0	0	1	2	2
UF6	2	1	0	1	4	2
UF7	2	0	0	1	4	3
UF8	4	0	0	3	1	3
UF9	2	0	0	2	2	2
UF10	1	0	0	0	4	2
UF11	3	0	0	1	3	2
UF12	2	0	2	2	3	2
UF13	3	0	1	2	1	3
UF14	1	1	3	1	1	1

Figure D.5: Results for individual nose testing in final implementation - part 3

Raw Data for Final Tests

UserID	Senti que joguei bem	Gostei do jogo	Atingi os objetivos rapidamente	Senti-me incomodado	Senti-me sob pressão	Perdi noção do tempo
UF1	2	4	4	0	0	4
UF2	2	2	0	0	0	4
UF3	0	3	0	0	0	2
UF4	1	4	1	0	1	4
UF5	0	3	0	3	3	2
UF6	1	4	0	0	1	2
UF7	1	1	1	0	3	3
UF8	2	4	2	0	0	1
UF9	1	3	2	0	0	1
UF10	0	2	0	2	0	0
UF11	1	3	0	0	0	4
UF12	0	3	1	1	0	0
UF13	3	3	3	1	1	3
UF14	0	3	1	1	3	0

Figure D.6: Results for individual nose testing in final implementation - part 4

UserID	Estive completamente concentrado no jogo	Foi uma experiência rica	Perdi conexão com o mundo fora do jogo	Senti pressão de tempo	Tive que me esforçar muito
UF1	4	4	4	3	4
UF2	4	4	4	0	3
UF3	3	2	3	0	3
UF4	4	4	4	1	4
UF5	3	1	0	0	3
UF6	4	4	1	0	4
UF7	3	4	0	1	4
UF8	3	3	2	3	0
UF9	3	3	1	0	2
UF10	3	2	3	2	3
UF11	4	3	4	0	4
UF12	2	1	1	0	3
UF13	2	3	1	1	1
UF14	1	2	0	1	1

Figure D.7: Results for individual nose testing in final implementation - part 5

UserID	Senti-me revivido	Senti-me mal	Achei difícil voltar à realidade	Senti-me culpado	Senti-me vitorioso	Achei que fosse uma perda de tempo
UF1	3	0	0	0	4	0
UF2	2	0	0	0	1	2
UF3	0	0	0	0	3	1
UF4	3	0	1	0	2	0
UF5	1	0	2	0	1	0
UF6	0	0	0	0	1	0
UF7	0	0	0	0	1	0
UF8	2	0	0	0	3	0
UF9	2	0	0	0	1	0
UF10	2	0	0	0	0	0
UF11	1	0	0	0	0	0
UF12	1	0	0	0	2	0
UF13	3	0	1	0	3	0
UF14	1	1	0	0	0	0

Figure D.8: Results for individual nose testing in final implementation - part 6

Raw Data for Final Tests

UserID	Senti-me energizado	Senti-me satisfeito	Senti-me desorientado	Senti-me exausto	Senti que poderia ter feito algo mais útil	Senti-me poderoso
UF1	2	3	2	2	3	3
UF2	2	1	2	0	0	1
UF3	0	3	0	0	1	1
UF4	3	3	1	1	0	2
UF5	2	2	3	0	3	2
UF6	0	2	1	2	0	0
UF7	1	4	3	0	0	1
UF8	2	3	0	0	0	2
UF9	2	3	0	0	2	0
UF10	2	1	0	0	1	0
UF11	0	0	0	0	0	0
UF12	3	2	2	0	2	2
UF13	3	3	2	0	0	2
UF14	0	2	2	0	3	0

Figure D.9: Results for individual nose testing in final implementation - part 7

UserID	Senti-me cansado	Senti-me arrependido	Senti-me envergonhado	Senti-me orgulhoso
UF1	0	0	0	4
UF2	0	0	0	2
UF3	0	0	0	2
UF4	0	0	0	2
UF5	0	0	0	1
UF6	2	0	1	1
UF7	0	0	0	1
UF8	0	0	0	3
UF9	0	0	0	2
UF10	0	0	0	0
UF11	0	0	0	0
UF12	0	0	0	2
UF13	0	0	0	2
UF14	0	1	2	0

Figure D.10: Results for individual nose testing in final implementation - part 8

Raw Data for Final Tests

Consinto que os meus dados sejam recolhidos e usados no contexto acima descrito	UserID
Sim	UF1
Sim	UF2
Sim	UF3
Sim	UF4
Sim	UF5
Sim	UF6
Sim	UF7
Sim	UF8
Sim	UF9
Sim	UF10
Sim	UF11
Sim	UF12
Sim	UF13
Sim	UF14

Figure D.11: Consent for individual gaze testing in final implementation

UserID	Senti-me bem-sucedido	Senti-me aborrecido	Achei que o jogo era impressionante	Ignorei tudo à minha volta enquanto jogava	Senti-me satisfeito	Achei o jogo cansativo
UF1	4	0	4	4	4	0
UF2	4	0	2	4	4	3
UF3	3	0	3	3	3	0
UF4	2	0	4	1	3	1
UF5	3	1	3	1	2	0
UF6	1	3	2	0	2	0
UF7	3	0	4	3	3	2
UF8	3	0	4	3	4	0
UF9	2	0	2	1	2	0
UF10	1	1	2	3	1	1
UF11	3	0	3	4	3	0
UF12	4	0	2	3	3	0
UF13	3	0	3	4	3	0
UF14	4	1	3	3	4	0

Figure D.12: Results for individual gaze testing in final implementation - part 1

UserID	Senti-me frustrado	Senti-me irritado	Senti-me habilidoso	Achei que o jogo era divertido	Estive totalmente absorvido com o jogo	Senti-me desafiado
UF1	0	0	4	4	4	4
UF2	0	0	1	3	4	2
UF3	0	0	0	3	3	0
UF4	3	0	1	4	4	4
UF5	0	0	2	3	1	3
UF6	4	3	0	1	0	0
UF7	2	0	3	4	3	3
UF8	0	0	2	4	2	4
UF9	2	0	1	3	3	3
UF10	4	1	0	1	3	2
UF11	1	0	2	3	4	3
UF12	0	1	3	3	2	3
UF13	2	2	3	4	4	4
UF14	0	0	3	3	2	3

Figure D.13: Results for individual gaze testing in final implementation - part 2

Raw Data for Final Tests

UserID	Senti-me feliz	Senti-me de mau humor	Pensei noutras coisas	Senti-me competente	Achei que era difícil	Senti-me bem
UF1	4	0	0	4	0	4
UF2	4	0	0	4	0	4
UF3	3	0	1	2	1	3
UF4	4	0	0	2	2	3
UF5	3	0	1	4	1	3
UF6	0	3	4	0	4	1
UF7	3	0	0	2	3	3
UF8	4	0	0	2	0	3
UF9	3	0	0	2	1	3
UF10	1	0	0	0	3	2
UF11	3	0	0	2	2	2
UF12	3	1	2	3	2	3
UF13	4	0	1	2	3	3
UF14	3	0	1	3	3	3

Figure D.14: Results for individual gaze testing in final implementation - part 3

UserID	Senti que joguei bem	Gostei do jogo	Atingi os objetivos rapidamente	Senti-me incomodado	Senti-me sob pressão	Perdi noção do tempo
UF1	4	4	4	0	0	4
UF2	3	4	2	0	0	2
UF3	2	3	2	0	0	3
UF4	2	4	2	0	3	4
UF5	2	3	4	1	0	3
UF6	0	3	0	2	0	0
UF7	3	3	3	0	0	2
UF8	3	3	1	0	0	0
UF9	0	3	1	0	0	1
UF10	0	2	0	0	0	0
UF11	2	3	2	0	0	3
UF12	3	3	4	0	0	4
UF13	2	4	2	1	3	3
UF14	3	3	3	1	0	1

Figure D.15: Results for individual gaze testing in final implementation - part 4

UserID	Estive completamente concentrado no jogo	Foi uma experiência rica	Perdi conexão com o mundo fora do jogo	Senti pressão de tempo	Tive que me esforçar muito
UF1	4	4	4	0	0
UF2	4	4	4	0	0
UF3	3	2	3	0	0
UF4	4	4	4	3	1
UF5	3	3	1	0	2
UF6	2	4	0	0	4
UF7	3	4	0	0	2
UF8	3	3	0	0	0
UF9	4	4	2	1	1
UF10	3	1	1	0	2
UF11	4	3	4	0	3
UF12	3	2	1	0	2
UF13	4	4	1	3	1
UF14	3	2	2	0	2

Figure D.16: Results for individual gaze testing in final implementation - part 5

Raw Data for Final Tests

UserID	Senti-me revivido	Senti-me mal	Achei difícil voltar à realidade	Senti-me culpado	Senti-me vitorioso	Achei que fosse uma perda de tempo
UF1	4	0	0	0	4	0
UF2	2	0	2	0	4	0
UF3	0	0	0	0	0	0
UF4	3	0	1	0	2	0
UF5	2	0	0	0	2	0
UF6	0	2	1	4	0	3
UF7	2	0	0	0	3	0
UF8	2	0	0	0	3	0
UF9	1	2	0	0	0	0
UF10	1	0	0	0	1	1
UF11	3	0	0	0	3	0
UF12	1	0	1	0	4	0
UF13	3	0	0	0	3	0
UF14	0	0	0	0	4	1

Figure D.17: Results for individual gaze testing in final implementation - part 6

UserID	Senti-me energizado	Senti-me satisfeito	Senti-me desorientado	Senti-me exausto	Senti que poderia ter feito algo mais útil	Senti-me poderoso
UF1	4	4	0	0	4	4
UF2	2	4	0	0	2	3
UF3	1	3	0	0	1	1
UF4	2	3	1	3	0	1
UF5	1	2	1	0	2	3
UF6	0	0	0	0	1	0
UF7	2	4	2	0	0	2
UF8	3	3	0	0	0	2
UF9	3	3	0	0	2	1
UF10	1	1	0	0	2	0
UF11	0	3	0	0	0	1
UF12	3	3	1	0	2	3
UF13	3	3	0	0	0	2
UF14	1	3	0	0	1	3

Figure D.18: Results for individual gaze testing in final implementation - part 7

UserID	Senti-me cansado	Senti-me arrependido	Senti-me envergonhado	Senti-me orgulhoso
UF1	0	0	0	4
UF2	0	0	0	3
UF3	0	0	0	3
UF4	2	0	0	3
UF5	0	0	0	2
UF6	0	0	0	0
UF7	0	0	0	2
UF8	0	0	0	3
UF9	0	0	1	1
UF10	0	0	0	1
UF11	0	0	0	2
UF12	1	0	0	2
UF13	0	0	0	2
UF14	0	0	1	4

Figure D.19: Results for individual gaze testing in final implementation - part 8

Raw Data for Final Tests

Consinto que os meus dados sejam recolhidos e usados no contexto acima descrito	UserID
Sim	UF1
Sim	UF2
Sim	UF3
Sim	UF4
Sim	UF5
Sim	UF6
Sim	UF7
Sim	UF8
Sim	UF9
Sim	UF10
Sim	UF11
Sim	UF12
Sim	UF13
Sim	UF14

Figure D.20: Consent for integration testing in final implementation

UserID	Senti-me bem-sucedido	Senti-me aborrecido	Achei que o jogo era impressionante	Ignorei tudo à minha volta enquanto jogava	Senti-me satisfeito	Achei o jogo cansativo
UF1	2	0	4	0	4	0
UF2	1	3	1	1	1	3
UF3	0	4	2	3	1	2
UF4	3	0	4	4	4	1
UF5	3	0	4	4	3	0
UF6	1	4	0	3	0	2
UF7	0	2	0	0	0	2
UF8	3	0	4	4	4	0
UF9	3	0	2	0	2	1
UF10	2	0	2	4	3	0
UF11	1	1	2	4	3	0
UF12	3	0	2	4	3	1
UF13	1	1	3	2	2	1
UF14	2	1	3	2	2	1

Figure D.21: Results for integration testing in final implementation - part 1

UserID	Senti-me frustrado	Senti-me irritado	Senti-me habilidoso	Achei que o jogo era divertido	Estive totalmente absorvido com o jogo	Senti-me desafiado
UF1	0	1	2	3	4	4
UF2	2	0	0	0	0	0
UF3	2	3	1	1	3	0
UF4	0	0	3	4	4	4
UF5	1	0	3	4	4	3
UF6	4	3	0	0	0	0
UF7	4	2	0	0	2	4
UF8	0	0	3	4	3	4
UF9	2	0	0	3	3	3
UF10	1	1	0	4	4	4
UF11	2	0	0	3	4	3
UF12	2	2	0	2	2	3
UF13	3	2	1	3	3	3
UF14	1	0	1	1	1	3

Figure D.22: Results for integration testing in final implementation - part 2

Raw Data for Final Tests

UserID	Senti-me feliz	Senti-me de mau humor	Pensei noutras coisas	Senti-me competente	Achei que era difícil	Senti-me bem
UF1	4	0	0	2	4	3
UF2	4	0	0	1	4	2
UF3	1	2	1	0	2	1
UF4	4	0	0	3	2	3
UF5	3	0	0	3	3	2
UF6	0	4	2	0	2	1
UF7	1	2	0	0	4	1
UF8	4	0	0	3	2	3
UF9	3	0	0	2	3	2
UF10	3	0	0	0	1	3
UF11	3	0	0	0	4	3
UF12	3	1	2	2	2	3
UF13	3	1	1	1	3	3
UF14	2	0	2	1	2	1

Figure D.23: Results for integration testing in final implementation - part 3

UserID	Senti que joguei bem	Gostei do jogo	Atingi os objetivos rapidamente	Senti-me incomodado	Senti-me sob pressão	Perdi noção do tempo
UF1	3	4	2	1	0	0
UF2	0	0	0	1	0	1
UF3	1	2	0	2	2	1
UF4	3	4	2	0	1	4
UF5	3	4	1	0	3	3
UF6	0	2	0	0	0	0
UF7	0	0	1	3	0	0
UF8	2	4	2	0	0	0
UF9	2	3	1	0	1	0
UF10	0	4	0	0	1	2
UF11	0	3	0	0	0	0
UF12	0	3	1	1	0	4
UF13	2	3	2	2	2	1
UF14	2	2	0	0	2	0

Figure D.24: Results for integration testing in final implementation - part 4

UserID	Estive completamente concentrado no jogo	Foi uma experiência rica	Perdi conexão com o mundo fora do jogo	Senti pressão de tempo	Tive que me esforçar muito
UF1	4	4	2	2	4
UF2	3	2	3	0	4
UF3	1	0	0	2	1
UF4	4	4	4	1	3
UF5	4	3	4	1	3
UF6	1	3	0	0	4
UF7	2	1	0	0	4
UF8	3	3	0	2	0
UF9	0	3	0	0	3
UF10	3	2	3	2	1
UF11	4	2	3	0	4
UF12	2	2	2	0	2
UF13	3	3	1	2	1
UF14	1	0	0	1	3

Figure D.25: Results for integration testing in final implementation - part 5

Raw Data for Final Tests

UserID	Senti-me revivido	Senti-me mal	Achei difícil voltar à realidade	Senti-me culpado	Senti-me vitorioso	Achei que fosse uma perda de tempo
UF1	3	1	0	0	3	0
UF2	2	0	0	0	0	1
UF3	1	2	0	0	0	2
UF4	3	0	1	0	3	0
UF5	3	0	1	0	3	0
UF6	2	4	0	4	0	0
UF7	1	0	0	0	0	2
UF8	2	0	0	0	3	0
UF9	2	0	0	0	2	0
UF10	2	0	0	0	1	0
UF11	0	0	0	0	0	0
UF12	1	1	1	0	1	1
UF13	3	1	0	0	2	0
UF14	0	0	0	0	2	1

Figure D.26: Results for integration testing in final implementation - part 6

UserID	Senti-me energizado	Senti-me satisfeito	Senti-me desorientado	Senti-me exausto	Senti que poderia ter feito algo mais útil	Senti-me poderoso
UF1	3	3	3	0	2	2
UF2	2	2	0	0	0	2
UF3	0	1	0	0	3	2
UF4	3	3	1	1	0	2
UF5	4	3	3	0	1	3
UF6	0	0	1	0	2	0
UF7	1	1	3	0	0	1
UF8	2	3	0	0	0	2
UF9	2	3	2	0	1	1
UF10	1	2	0	0	0	1
UF11	0	0	2	0	0	0
UF12	2	3	1	0	3	2
UF13	3	2	2	0	0	2
UF14	0	2	3	0	1	2

Figure D.27: Results for integration testing in final implementation - part 7

UserID	Senti-me cansado	Senti-me arrependido	Senti-me envergonhado	Senti-me orgulhoso
UF1	0	0	0	2
UF2	0	0	0	2
UF3	2	0	0	1
UF4	1	0	0	2
UF5	0	0	0	3
UF6	0	0	0	0
UF7	0	0	0	1
UF8	0	0	0	3
UF9	0	0	0	1
UF10	0	0	0	1
UF11	0	0	0	0
UF12	0	0	0	2
UF13	0	0	0	2
UF14	0	1	0	3

Figure D.28: Results for integration testing in final implementation - part 8

Appendix E

Tables of results

	Skillful	Competent	Good at it	Successful	Goal speed
Average	1.5	1.5	1	1.86	1.07
Mode	1	1	0	3	0
Median	1	1	1	2	1

Table E.1: Competence metrics and their score for individual nose tracker implementation

Tables of results

	Game impressive	Rich experience
Average	2.43	2.86
Mode	3	4
Median	2.5	3

Table E.2: Immersion metrics and their score for individual nose tracker implementation

	Fully occupied	Surroundings	Track of time	Deep Focus	Outside World
Average	2.64	2.5	2.14	3.07	2
Mode	4	3	4	3	4
Median	2.5	3	2	3	1.5

Table E.3: Flow metrics and their score for individual nose tracker implementation

	Annoyed	Irritable	Frustrated
Average	0.57	0.29	1.14
Mode	0	0	0
Median	0	0	1

Table E.4: Tension metrics and their score for individual nose tracker implementation

	It was hard	Pressure	Challenge	Time Pressure	Effort
Average	2.64	0.86	3.5	0.86	2.79
Mode	3	0	4	0	4
Median	3	0	4	0.5	3

Table E.5: Challenge metrics and their score for individual nose tracker implementation

	Bad Humour	Thought of other	Tiresome	Bored
Average	0.14	0.43	0.93	0.64
Mode	0	0	0	0
Median	0	0	1	0.5

Table E.6: Negative Aspects metrics and their score for individual nose tracker implementation

	Satisfied	Fun	Happy	Good	Liked the game
Average	2.71	2.93	2.64	2.5	3
Mode	3	3	2	2	3
Median	3	3	2.5	2	3

Table E.7: Positive Aspects metrics and their score for individual nose tracker implementation

	Revived	Victorious	Energized	Satisfied	Powerful	Proud
Average	1.5	1.57	1.57	2.29	1.14	1.57
Mode	2	1	2	3	2	2
Median	1.5	1	2	2.5	1	2

Table E.8: Positive Experience metrics and their score for individual nose tracker implementation

Tables of results

	Bad	Guilty	Waste of time	Useless	Regret	Shame
Average	0.07	0	0.21	1.07	0.07	0.21
Mode	0	0	0	0	0	0
Median	0	0	0	0.5	0	0

Table E.9: Negative Experience metrics and their score for individual nose tracker implementation

	Exhausted	Tired
Average	0.36	0.14
Mode	0	0
Median	0	0

Table E.10: Tiredness metrics and their score for individual nose tracker implementation

	Hard to get back	Disoriented
Average	0.29	1.29
Mode	0	2
Median	0	1.5

Table E.11: Returning to reality metrics and their score for individual nose tracker implementation

	Skillful	Competent	Good at it	Successful	Goal speed
Average	1.79	2.29	2.07	2.86	2.14
Mode	3	2	3	3	2
Median	2	2	2	3	2

Table E.12: Competence metrics and their score for individual gaze tracker implementation

	Game impressive	Rich experience
Average	2.93	3.14
Mode	2	4
Median	3	3.5

Table E.13: Immersion metrics and their score for individual gaze tracker implementation

	Fully occupied	Surroundings	Track of time	Deep Focus	Outside World
Average	2.79	2.64	2.14	3.36	1.93
Mode	4	3	3	3	4
Median	3	3	2.5	3	1.5

Table E.14: Flow metrics and their score for individual gaze tracker implementation

	Annoyed	Irritable	Frustrated
Average	0.36	0.5	1.29
Mode	0	0	0
Median	0	0	0.5

Table E.15: Tension metrics and their score for individual gaze tracker implementation

Tables of results

	It was hard	Pressure	Challenge	Time Pressure	Effort
Average	1.79	0.43	2.71	0.5	1.43
Mode	3	0	3	0	2
Median	2	0	3	0	1.5

Table E.16: Challenge metrics and their score for individual gaze tracker implementation

	Bad Humour	Thought of other	Tiresome	Bored
Average	0.29	0.71	0.5	0.43
Mode	0	0	0	0
Median	0	0	0	0

Table E.17: Negative Aspects metrics and their score for individual gaze tracker implementation

	Satisfied	Fun	Happy	Good	Liked the game
Average	2.93	3.07	3	2.86	3.21
Mode	3	3	3	3	3
Median	3	3	3	3	3

Table E.18: Positive Aspects metrics and their score for individual gaze tracker implementation

	Revived	Victorious	Energized	Satisfied	Powerful	Proud
Average	1.71	2.36	1.86	2.79	1.86	2.29
Mode	2	4	1	3	3	2
Median	2	3	2	3	2	2

Table E.19: Positive Experience metrics and their score for individual gaze tracker implementation

	Bad	Guilty	Waste of time	Useless	Regret	Shame
Average	0.29	0.29	0.36	1.21	0	0.14
Mode	0	0	0	2	0	0
Median	0	0	0	1	0	0

Table E.20: Negative Experience metrics and their score for individual gaze tracker implementation

	Exhausted	Tired
Average	0.21	0.21
Mode	0	0
Median	0	0

Table E.21: Tiredness metrics and their score for individual gaze tracker implementation

	Hard to get back	Disoriented
Average	0.36	0.36
Mode	0	0
Median	0	0

Table E.22: Returning to reality metrics and their score for individual gaze tracker implementation

Tables of results

	Skillful	Competent	Good at it	Successful	Goal speed
Average	1	1.29	1.29	1.79	0.86
Mode	0	0	0	3	0
Median	0.5	1	1.5	2	1

Table E.23: Competence metrics and their score for integration implementation

	Game impressive	Rich experience
Average	2.36	2.29
Mode	2	3
Median	2	2.5

Table E.24: Immersion metrics and their score for integration implementation

	Fully occupied	Surroundings	Track of time	Deep Focus	Outside World
Average	2.64	2.5	1.14	2.5	1.57
Mode	4	4	0	4	0
Median	3	3	0.5	3	1.5

Table E.25: Flow metrics and their score for integration implementation

	Annoyed	Irritable	Frustrated
Average	0.71	1	1.71
Mode	0	0	2
Median	0	0.5	2

Table E.26: Tension metrics and their score for integration implementation

	It was hard	Pressure	Challenge	Time Pressure	Effort
Average	2.71	0.86	2.71	0.93	2.64
Mode	2	0	3	0	3
Median	2.5	0.5	3	1	3

Table E.27: Challenge metrics and their score for integration implementation

	Bad Humour	Thought of other	Tiresome	Bored
Average	0.71	0.57	1	1.14
Mode	0	0	0	0
Median	0	0	1	0.5

Table E.28: Negative Aspects metrics and their score for integration implementation

	Satisfied	Fun	Happy	Good	Liked the game
Average	2.29	2.29	2.71	2.21	2.71
Mode	3	3	3	3	4
Median	2.5	3	3	2.5	3

Table E.29: Positive Aspects metrics and their score for integration implementation

Tables of results

	Revived	Victorious	Energized	Satisfied	Powerful	Proud
Average	1.79	1.43	1.64	2	1.57	1.64
Mode	2	0	2	3	2	2
Median	2	1.5	2	2	2	2

Table E.30: Positive Experience metrics and their score for integration implementation

	Bad	Guilty	Waste of time	Useless	Regret	Shame
Average	0.64	0.29	0.5	0.93	0.07	0
Mode	0	0	0	0	0	0
Median	0	0	0	0.5	0	0

Table E.31: Negative Experience metrics and their score for integration implementation

	Exhausted	Tired
Average	0.07	0.21
Mode	0	0
Median	0	0

Table E.32: Tiredness metrics and their score for integration implementation

	Hard to get back	Disoriented
Average	0.21	1.50
Mode	0	3
Median	0	1.5

Table E.33: Returning to reality metrics and their score for integration implementation