Some Key Aspects Do Make VR Games More Immersive than Traditional Video Games

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Abstract

Virtual reality (VR) devices have emerged as promising platforms with the potential to revolutionise the next generation of educational and entertainment applications. This thesis investigated which interactive and visual aspects of VR games contributed to enhanced immersion as compared to traditional video games. This study drew upon some empirical evidence from the literature and the results of two experiments. Experiment One featured collecting subjective feedback by comparing the differences between three different VR scenes. In contrast, Experiment Two compared the experiences of participants in the VR and computer versions of the same game. Both experiments yielded valuable insights, highlighting the benefits of highly detailed virtual environment scenes for enhanced immersion. Additionally, both experiments demonstrated that VR games offered a larger field of view than traditional computer games, and thus enabled an even more immersive three-dimensional interaction for players involved in the game. These findings contributed significantly to the understanding of how VR technology enhances the gaming experience. By examining empirical evidence and experimental results, this research sought to explore the unique features of VR games that offered unrivalled levels of engagement in a virtual environment as opposed to their counterparts. The study emphasised the three dimensions of interaction, field of view and immersion, to showcase the potential of VR in providing superior engagement and immersive experiences that were superior to traditional video games. It was crucial to investigate the potential of VR games to create unrivalled levels of engagement.

Keywords: Virtual Reality, Video game, Interaction, Field of View, Immersion

Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

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Glossary of Terms

AR - Augmented Reality

FOV - Field of View

FPS - First-person shooter

HFOV- Horizontal Field of View

Mesh - Mesh is a collection of vertices, edges, and faces that together form a three-dimensional object.

PC - Personal computer

POV - Point of View

SD - Standard Deviation

VFOV - Vertical Field of View

VR - Virtual Reality

XR - Extended Reality

1 Introduction

As an introverted individual with limited social experiences, it was no surprise that I found solace in the virtual world. There, I delved into numerous sophisticated games and connected with like-minded friends. It was during my university days that I chanced upon a course in virtual reality, which opened a new realm for me. I invested in a suite of VR equipment and began exploring various VR applications and games. During the pandemic, lockdown measures introduced me to VR Chat, a platform that offered unparalleled diversity in online social interactions. Later, I encountered a game that was truly tailor-made for VR: 'Half-life', developed by Valve. The excitement was palpable, and even after completing the game, the thrill lingered. However, my subsequent search for similarly well-crafted VR games proved fruitless. This sparked my initial research question: Despite VR's longstanding history, why hasn't it reached the ubiquity of PC games? What elements were missing from VR games that prevented their widespread adoption? Motivated by these queries, I embarked on a quest to find the answers. Virtual reality (VR) technology came with a long history, yet its adoption and utilization had not reached the same level of pervasiveness as personal computers or smartphones, which were already everywhere in our daily lives. VR might have seemed new to some of us, but its concept was introduced nearly two hundred years ago since its inception. However, thanks to technological advances and increased promotion of multimedia platforms in recent years, VR technology was becoming more and more accepted by the public. The release of Ready Player One (Spielberg, 2018), directed by acclaimed Hollywood director Steve Spielberg, marked the first time that VR had come into the public's life in such a graphic way. In 2021, Mark Zuckerberg, Chief Executive Officer (CEO) of Facebook, announced that he would lead the company into a metaverse and renamed it Meta, which is possibly the best-known and closest virtual world to Ready Player One (Spielberg, 2018). According to information provided by Onion et al., (2022), video games have been in development for more than half a century now, and their history could be divided into three different phases, each characterised by the prominence of the platform (Onion et al., 2022). The first phase was the arcade consoles from 1980 to the present, represented by the well-known Pac-Man (Iwatani, 1980). Then, came console platforms from 1990 to the present, epitomised by Nintendo Switch (Nintendo, 2017), Xbox Series X (Microsoft, 2020), and PlayStation 5 (Sony, 2020). In second phase, from 2000 to the present, we witnessed the dramatic development of games for personal computer platforms, such as Counter-Strike: Global Offensive (Valve, 2012). Finally, the mobile platforms have emerged from 2010 to the present, such as the App Store (Inc, 2008) and Google Play (Google, 2008).

At the moment, we are in the era of mobile gaming, and we have already witnessed the emergence of games like League of Legends: Wild Rift (Riot-Games, 2020). The gaming market for mobile phones is nearing saturation; however, VR has potentially become the subsequent major platform development for video games. This could have marked a turning point for VR, despite not gaining widespread public adoption since its inception. However, now and then, new companies such as Facebook (Zuckerberg et al., 2004) and Sony (Morita & Ibuka, 1946) claimed to further develop VR technology to make it more commercially viable. One of its defining characteristics is VR's capacity to generate a sense of immersion (see Aspect 3: Immersion of VR experience) and presence. The concept of "presence" within the realm of VR pertained to the user's subjective experience of existing within the simulated environment, rather than assuming a passive role as a mere spectator (Schuemie et al., 2001). The increased level of immersion has the potential to result in more meaningful experiences and enhanced outcomes across a range of applications.

VR environments have a unique ability to inspire a greater sense of presence than other forms of media. Schuemie et al. (2001) emphasized the importance of investigating presence in VR, highlighting the role of presence in determining the effects of virtual reality. They conducted a comprehensive survey on the subject, highlighting the various factors that contributed to this phenomenon (Schuemie et al., 2001).

Furthermore, the comprehension of VR has undergone significant development throughout the years. In addition to mere existence, VR facilitates a heightened level of embodiment, when users experience a profound link between their virtual and corporeal identities. Tham et al. (2018) conducted a study to examine the consequences of this phenomenon in professional settings, highlighting the impact of the sense of embodiment experienced in virtual reality on professionals' perception and interaction inside the virtual world. This correlation further underscored the significance of VR in delivering a comprehensive and immersive encounter (Tham et al., 2018).

This study consists of two experiments. In Experiment One, I investigated the factors influencing immersion in VR games by controlling variables within the virtual game environment. In Experiment Two, under the same controlled conditions, I compared the VR version of a similar game to the regular computer version. The objective was to identify the specific factors contributing to an immersive VR game experience compared to traditional computer-based versions. The primary aim of this study was to pinpoint the distinguishing features that set VR games apart from conventional video games. The specific research questions are outlined in the following section.

1.1 Research Question

Within the field of video gaming, the concept of immersion holds significant importance as it exerts a substantial influence on the overall quality of the player's experience. In his seminal work, McMahan (2003) provides a comprehensive analysis of the intricate concepts of immersion, engagement, and presence within the realm of three-dimensional (3D) video games. The author sheds light on the multifaceted nature of players' immersion in these virtual settings, emphasizing the several dimensions involved in this process. According to McMahan, traditional video games provide a multi-faceted immersive experience through their narrative complexity, mechanics, and visual capabilities (Mcmahan, 2003). However, the advent of VR signifies a significant change in this framework. Calleja (2011) presented a development of this idea by introducing the notion of 'incorporation' as a more profound and cohesive kind of player immersion. The shift from mere immersion to incorporation implies that virtual reality (VR) games have the ability to offer a significantly distinct and all-encompassing player experience in comparison to traditional games (Calleja, 2011).

In this context, the core research questions of this study emerged:

What aspects can make VR games more immersive than traditional video games?

In order to answer this question more concretely, I considered further breaking down the three key aspects I mentioned into a series of sub-questions. These sub-questions were as follows:

How does the perspective of a VR game differ from that of a traditional video game, and how does it enhance immersion?

How does the interaction simulation of VR games differ from that of traditional games, and how does it enable players to engage more deeply with the game?

What specific elements of VR technology are key to enhancing immersion?

Virtual Reality (VR) has emerged as a disruptive technology in the field of video gaming, offering a heightened level of immersion and interactivity that surpasses traditional video games. As I embarked on this exploration, three pivotal aspects became central to my inquiry: the unique point of view offered by VR, the unparalleled 3D Interaction Simulation specific to VR, and the depth of immersion that the VR experience itself provided. In order to examine the factors that contribute to the immersive engagement of virtual reality (VR) recreations as compared to conventional video games, it was essential to delve into existing research and scholarly discourse.

1.1.1 Aspect 1: Field of View

VR games have a larger viewing angle than traditional video games. Specifically, the term Field of View (FOV) is used to describe the viewing angle in gaming. In video games, FOV is a command setting in most games that allows players to adjust the range of their viewing angle and thus control how much they can see on the screen (Kenth Ljung, 2015). In other words, in games with a larger viewing angle, the players can see more objects on the screen, but the objects displayed would appear smaller accordingly. Conversely, players could see fewer things on their screens in a game with a smaller viewing angle, but the objects displayed appear larger. This was possible due to the fact that the screen size was constant, so when the players increase the display angle, objects in the game would then be squeezed into the screen due to the size of the game screen, so they appeared smaller to the eye (*Figure 1*).

Similarly, some players of first-person games lower the viewing angle, thus magnifying the size of the visible objects on the screen. As a result, it would be possible for the players to concentrate more on the objects on the screen, with fewer distractions, and therefore enhanced levels of concentration (Denisova & Cairns, 2015).

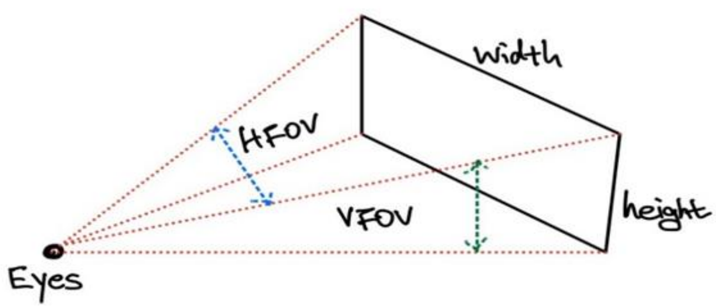

Figure 1: The POV of view of the human eye when viewing the computer screen.

VR headsets can provide a wider FOV than a monitor. For instance, the equipment used in the experimental part of this thesis was an Oculus Quest 2, which had 89-90 degrees of Horizontal FOV (HFOV stands for Horizontal Field of View, which refers to the extent of the observable horizontal area on a screen), and a vertical FOV (VFOV stands for Vertical Field of View, which refers to the extent of the observable vertical area on a screen) of 93 degrees.

1.1.2 Aspect 2: 3D Interaction Simulation in VR

In VR games, users tended to play in a first-person view, as research has shown that a first-person view provides more immersion for the players (Denisova & Cairns, 2015). In virtual display games, VR devices such as headsets and joysticks track the player's head and hand movements, so players' hand, head and even leg movements can be detected by the game and fed back to the game engine. This allows the player to move and interact freely in the virtual environment and to interact with the electronic screen using the keyboard and mouse as well as the physical movements. Also, as the viewing angle of VR is greater than that of a typical computer screen, players can experience the game in a more immersive way. The study conducted by Yang et al. (2019) provided a thorough examination of gesture interaction within the context of virtual reality. The study investigated the utilisation of gestures as a proficient method for engaging with virtual objects and environments. Yang and his research team conducted an investigation into the diverse range of gestures that users could utilise to exert control and manipulate objects within virtual reality (VR). This study aimed to provide insights into the potential of gesture-based interfaces in augmenting user engagement and immersion. The use of gesture interaction in virtual reality (VR) allowed users to engage in natural hand movements for the purpose of interacting with virtual objects, thereby replicating actions that were typically performed in the real world. This methodology obviated the necessity for conventional controllers and augmented the perception of embodiment within the virtual realm (Li et al., 2019). The study conducted by Yang et al. offered significant contributions to the understanding of the design considerations and challenges that arise when implementing gesture-based interaction systems in VR applications.

1.1.3 Aspect 3: Immersion of VR experience

Immersion refers to the state in which an individual is fully absorbed and deeply immersedin a VR environment, usually at a loss for the physical reality around them (Berkman & Akan, 2019). When players play traditional video games, they usually control the movement of the game character through external devices such as joysticks or keyboards and mice, which are only represented on a two-dimensional plane on the screen. In VR games, however, devices such as head-mounted displays and controllers realistically simulate the movement experience in three dimensions. For example, physical movements such as sitting down, standing up, waving an arm, or clenching a fist during VR gaming can be fed back into the VR world in a way that normal video gaming cannot achieve.

Another difference between conventional video games and VR games is the point of view. In traditional video games, players may need to switch between different views or windows to see other scenes in the game. In contrast, in VR games, players are typically limited to playing the game in a first-person view.

2 Literature Review

In this chapter, I provide an overview of previous research on the features of VR games, which I constructed this research question by looking through/exploring existing literature in academic databases such as IEEE Xplore and Google Scholar with targeted keywords 'virtual reality,' 'immersion,' 'video game,' 'sound effect,' and 'simulation' to find relevant and helpful academic journals and articles. This literature review starts with a brief overview of the history of VR and then discusses various older and later definitions of immersion. I then, further explore effective methods to enhance immersion and examine the significance of immersion in VR technology and its applications.

Additionally, I investigate the benefits of increasing the sense of presence in the VR experience. The review also highlights how VR environments can realistically simulate sound and weight. Finally, I delve into the relationship between Augmented Reality (AR) and virtual reality, exploring their distinctions. I then extend the discussion to cover the practical applications of mixed reality.

2.1 A Brief History of the VR Evolution

VR may seem like the technology of the future, but it has been around for a while. Dom Barnard (Barnard, 2022) and the Virtual Reality Society (Society, 2017) outlined the history of VR technology. It all started in 1838 when Sir Charles Wheatstone first described stereoscopic vision. Two years later, he was awarded the Royal Society Medal for his explanation of binocular vision. This study led to the manufacture of stereoscopic viewing devices (e.g., 3D glasses for 3D movies). Sir Charles Wheatstone invented the stereoscope in the 19th century, which gave images a three-dimensional effect by combining two photographs of the same object taken from different angles. Weinbaum's short story "Pygmalion's Spectacles" (Weinbaum, 1930) described spectacles highly similar to modern VR devices. Sutherland and his student Bob Sproull created the first head-mounted display, the Sword of Damocles 1968. This head- mounted display was connected to a computer and was so primitive that head-mounted display could only display simple virtual wireframe shapes. Thanks to the device's built-in tracking system, these 3D models could change the view as the user moved their head. The device was suspended from the ceiling as it was too heavy for users to wear comfortably. The evolution of VR technology took a significant leap in 1985 with the establishment of VPL Research by Jaron Lanier, who also coined the term "VR". His company was the first to commercialize VR through the sale of head-mounted displays and gloves, offering immersive experiences at a price accessible to the consumer market. However, in 1999, Sun Microsystems

(McNealy & Khosla, 1982) acquired VPL. 1991 witnessed the launch of the first mass-market VR entertainment console by Virtuality Group. Despite offering networked multiplayer gaming through pods equipped with headsets, the console fell into obscurity due to insufficient software support and subpar resolution. The VR landscape transformed with Palmer Luckey's 2012 prototype of the Oculus Rift. Priced competitively, the device heralded an era of affordable and popular VR headsets. Following suit, HTC unveiled the HTC VIVE (HTC, 2016) in 2016, priced at $799. This innovative headset introduced sensor-based tracking, enabling users to navigate within defined spaces, thereby enhancing the immersive experience.

2.2 Definition of Immersion and Presence

Mestre et al. (2006) defined immersion as fully immersed in a virtual environment through multi-sensory stimulation by VR technology. This immersive experience made the user forget about the physical world and became completely immersed in the virtual environment. In this context, immersion referred to the utilisation of technology to induce a sensation of physical presence in a virtual environment, thereby fostering a sense of immersion in said environment (Mestre et al., 2006), while presence referred to the psychological perception experienced by a person immersed in a virtual environment (Mestre et al., 2006). However, Berkman & Akan (2019) offered a different definition of immersion. According to Berkman and Akan (2019), immersion referred to the state in which an individual becomes fully integrated and deeply engaged in a VR environment, oblivious to the reality around them. The concept of presence was a technology-mediated phenomenon focused on the subjective human experience triggered by external stimuli, leading to an inaccurate perception of technological involvement (Berkman & Akan, 2019). These varying definitions highlighted the evolving nature of the concepts of immersion and presence in VR. To ensure accurate interpretation and discussion of research findings in the field of VR, the subtle differences and distinctions among these definitions were carefully examined and studied in this thesis. The definitions of immersion and presence, updated by Berkman & Akan in 2019, were used in subsequent experiments.

Immersion – refers to the state in which an individual becomes fully integrated and deeply engaged in a virtual reality (VR) environment, disregarding the reality around them (Berkman & Akan, 2019).

Presence – presence is a phenomenon mediated by technology that focuses on the subjective human experience triggered by external stimuli, leading to an inaccurate perception of technological involvement (Berkman & Akan, 2019).

2.3 Immersion and Presence in VR

In 2007, Bowman and McMahan (2007) presented their ideas on immersion with Sanchez- Vives and Slater's (2005) definition of immersion, which related to the subjective feedback of a VR experience. According to their argument, immersion referred to the measurable sensory input that VR provided to the user, while presence was related to the subjective perception of the VR encounter (Sanchez-Vives & Slater, 2005). To enhance immersion, Bowman and McMahan (2007) suggested that key factors included improved user display technology and well-developed hardware devices (Bowman & McMahan, 2007). Notably, immersion was not only influenced by the user's VR experience in the moment, but also by external factors. Therefore, they proposed that controllable elements had the potential to enhance the immersive experience of VR, which explained the higher level of immersion provided by VR technology compared to other technologies in the real world (Bowman & McMahan, 2007). This was in line with Bowman's (2007) study suggesting that immersivesimulations and games contributed to knowledge retention (Bowman & McMahan, 2007). Bowman and McMahan's (2007) research underscored the importance of controllable elements in enhancing the immersive experience of VR, supporting the notion that VR technology offered a higher level of immersion compared to other real-world technologies.

According to Nilsson et al. (2016), narrative and challenge-based immersion was characterised by an intense focus on the experience of virtual world events (Nilsson et al., 2016). According to the concept of presence, to experience a sense of presence in a virtual environment, the user has to be fully attentive. In other words, the user has to pay close attention to the virtual world to feel a sense of being there.

Wilkinson et al. (2021) believed that there was a distinction between presence and immersion based on their research; sometimes, the meanings of the words immersion and presence overlap. However, in VR, these two aspects had to be distinguished. As revealed in Wilkinson's study, immersion in VR could be compensated for by external hardware, such as better display cards or gloves with haptic feedback. However, immersion was more reliant on the depiction of the scene, such as the lighting or the level of detail in the model (Wilkinson et al., 2021). Wilkinson et al. (2021) further concluded that the methods of enhancing presence described in their study relied on improving immersion and the user’s experience of VR through technical means, such as using better graphics cards to render 3Dmodels or improving the scene’s lighting. Wilkinson et al. (2021) believed that multisensory feedback, such as adding haptic feedback and allowing users to wear haptic feedback gloves, could enhance the immersive experience.

As VR has rapidly been used to recreate immersive environments and experiences, Slater et al. (1996) argued that immersion describes the technology, whereas presence describes the behavioural and psychological inputs. Presence, as defined by the term "the perceptual illusion of non-mediation" (Witmer & Singer, 1998), was crucial to the effectiveness of VR. In other words, presence refers to the impression of being so immersed to the extent that the medium that conveys the experience is no longer discernible. Witmer and Singer (1998) identified a number of significant factors that influenced the impression of presence.Sensory fidelity, which refers to the accuracy with which virtual environments reproduce sensory information, (e.g., visual, aural, and tactile inputs), has been shown to enhance a user's sense of presence (Lombard & Ditton, 1997). Another critical aspect of presence is its interactivity. Interactivity refers to the extent to which users can interact with and control a virtual environment. Slater and Steed (2000) proposed that increased levels of interactivity could lead to a more immersive experience (Slater & Steed, 2000).

There is another aspect that affects the user's sense of presence, namely the degree of control the users had over their virtual world, with greater control resulting in a more intense sense of presence (Witmer & Singer, 1998). Witmer and Singer (1998) defined the sense of being there in a virtual world as a combination of sensory input, cognitive processing, and emotional response. Both personal characteristics and environmental variables affected sense of presence. Next, they examined the connection between presence and consciousness, concluding that presence was a necessary but not sufficient conditionfor establishing consciousness in virtual contexts (Witmer & Singer, 1998).

Sanchez-Vives and Slater (2005) provided a thorough and insightful analysis of the currentstate of research on presence and consciousness in virtual contexts and highlighted the challenges and opportunities for future research in this rapidly developing field (Sanchez-Vives & Slater, 2005). Wilkinson et al. (2021) argued that enhancing the realism of objectsor characters could give rise to a greater sense of presence by making the user feel less detached from the virtual environment (Wilkinson et al., 2021). Finally, Park and Woo's (2021) research suggested that improving the user's VR environment characteristics, such as lighting, weather, and other features, could allow viewers to experience the same features as the original TV drama and better feel and participate in the story (Park & Woo, 2021). Furthermore, if users could adjust the device, they could view characters and environments from the camera position, leaving them with a more diverse narrative-drivenvirtual world experience.

The above study explored the concepts of presence and immersion in VR and suggested ways to enhance users' sense of presence and immersion in virtual environments. It was found that immersion was influenced by sensory input, scene depiction and hardware device improvements, while presence was closely related to the user's subjective experience and attention. Sensory realism, interactivity and control were critical factors in enhancing the sense of presence. Furthermore, improvements in virtual environment features (e.g., lighting and weather) and the user's ability to adjust their perspective also contributed to an enhanced sense of presence and immersion. These studies contributed tomy understanding of how VR technology could improve the user experience and subsequent research.

2.4 Simulation

Simulation is an indispensable aspect of VR technology. In this section, I present past academic research on sound effects and weight simulation in VR, because these two factors are two variable elements in my subsequent research experiments, demonstrating the significance of these elements in enhancing user experience.

2.4.1 Sound Effects

In the realm of VR, developers and researchers have diligently explored methods to enhance user immersion, as exemplified by the adoption of head-mounted displays (Slater & Sanchez-Vives, 2016). Rogers et al. (2018) determined that sound had a limited impact on users' immersion levels during VR gaming experiences with head-mounted displays (Rogers et al., 2018). Instead, users seemed to place greater emphasis on the visual aspects of the game and the overall aesthetic design. Nevertheless, it is noteworthy that sound localisation accuracy improved significantly when users were provided with visual cues or localisation guidance, as evidenced by the findings of Ahrens et al. (2019).

In general, researchers in the field of VR have been looking for ways to enhance the immersion of the user experience. Sound may not be as significant as visual perception inenhancing immersion. However, for specific environments and user groups, accurate sound positioning can still affect immersion. These findings provided insight into how VR technology affected the user experience and guided future development and research efforts.

2.4.2 Weight Simulation

While the ability of VR to simulate sounds and images has been well attested, exploring the possibilities for other senses, such as weight perception, has just begun. Lim et al.'s (2021) study of weight simulation in VR found that users' priority for weight perception was basedon comfort. If a user wears or uses a heavy device for a prolonged period of time, it caused numbness and, therefore, discomfort in the user's arm (Lim et al., 2021). As such, Lim et al. (2021) used lightweight materials to reduce weight to alleviate this problem. They concluded that there was a need to construct different large-scale specific weight perceptionsimulations as most weight simulations were set up and applied for specific applications (Lim et al., 2021).

In their study, Choi et al. (2017) introduced Grabity, a haptic interface worn by users to augment the perception of grasping and perceiving the weight of virtual objects within a Virtual Reality (VR) setting. This innovative device endeavours to enhance user immersion by effectively replicating tactile, haptic, gravitational, and inertial sensations via precise kinaesthetic feedback. Grabity distinguishes itself with its inventive and cohesive design, skilfully incorporating vibrotactile feedback, unidirectional brakes, and asymmetric skin stretch mechanisms. These elements collectively generate opposing forces between the thumb and index finger, resulting in a realistic perception of inertia and mass for virtual objects.

A prominent obstacle in the VR domain is the limited capability of existing portable devices to replicate intricate sensations like weight and inertia, primarily due to their reliance on mechanically grounded hardware. This limitation often results in a diminished sense of realism and immersion for users. However, Grabity effectively tackles and overcomes these limitations with its unique, ungrounded mechanical configuration. This approach offers a promising solution to replicating perceptions of weight and inertia in VR without necessitating grounded hardware. Furthermore, the device advances the field of asymmetric skin stretch technology, demonstrating its effectiveness as a feasible method for generating haptic forces. This progress is significant in developing more immersive and engaging virtual environment (Choi et al., 2017).

In summary, VR research is progressing in the direction of how to engage the other senses to improve the user experience, including weight perception. For weight simulation, user comfort is an essential consideration. The use of lightweight materials can alleviate the discomfort that users might experience when using heavy objects for extended periods of time. Future research is required to establish specific weight perception simulations based on specific application scenes to enhance the performance of VR technology in the user experience.

2.5 Mixed Reality

In this section, I present AR and mixed reality, along with their real-world applications related to VR technology. I also discuss the distinctions between AR and VR.

2.5.1 Augmented Reality

AR is a technology that enhances the real physical world through some digital elements, such as visual and auditory elements (Farshid et al., 2018). Augmented Reality (AR) blends the physical and digital worlds. Unlike completely digital virtual environments, augmented reality technology layers digital elements such as sight or sound onto existing reality. The goal is to create an enhanced interactive environment where users can seamlessly perceive both real and virtual elements (Craig, 2013a).

Implementing augmented reality requires a combination of technologies. These include the use of sensors and cameras to capture real-world environments to determine the placement of digital elements (Craig, 2013b). As Craig pointed out, integrating the display to present a digital overlay provided a better user experience, and having a powerful processor helped achieve superior digital enhancement and software adaptation (Craig, 2013c). With the popularity of smartphone tablets, AR has become ubiquitous. Games like Pokémon GO have popularised the concept of AR among the general public. Pokémon GO (Niantic, 2016) is a mobile AR game developed by Niantic, Inc. on the Unity platform and released in 2016. This game is so popular that users can download and play the game as long as they have a smartphone. When the game uses actual locations from Google Maps as the game scenes, the presence of Pokémon and the camera scanning the street scene will give users a greater sense of immersion.

2.5.2 Difference Between AR and VR

AR overlays digital content over the real world to provide users with a more exciting real-world experience (Farshid et al., 2018). For example, Pokémon GO (Niantic, 2016) incorporated Google Maps to allow users to catch Pokémon in the real world. Users could use Pokémon GO (Niantic, 2016) to scan the street scene when the camera is switched on, completing the process of scanning the area as well as finding and capturing Pokémon. While AR and VR technologies both offer immersive experiences, they do so in distinct ways. VR allows users to fully immerse themselves in 3D virtual environments (Farshid et al., 2018); examples of VR applications include architects using VR to preview house concepts before physical construction and game designers creating immersive 3D virtual worlds for players. In contrast, AR enhances the user's real-world surroundings with digital information or objects. One popular application of AR is the Pokémon GO game, where players can capture virtual creatures in real-world locations. Unlike VR, which creates entirely virtual environments, AR enriches the user's perception of reality with computer-generated elements.

VR headsets allow users to experience the whole 360-degree gaming experience. The difference between the two is that AR allows users to experience AR through specific media, such as cell phones and tablets, and overlays digital content over the real world. In contrast, VR allows individuals to completely engage with virtual environments, eliminating the requirement for a specific physical reality foundation. The degree of immersion experienced by users can vary depending on the nature of the experience. For example, individuals can engage with VR applications from a seated or reclined position, which can influence the level of immersion achieved. However, the extent of immersion is contingent upon the particular VR application and its design characteristics.

2.5.3 Mixed Reality

Mixed reality technology, which includes augmented and VR, appears to be a promising area of technological development, even though it is not yet fully developed (Punni, 2021). This technology holds the potential for transformative future trends, offering significant advantages such as cost reduction and time efficiency. The future trends of this technology are readily apparent, as it offers significant advantagessuch as the reduction of financial outlay and time consumption. Punni (2021) mentioned that in the future, for example, VR and AR would offer people the possibility to immediately come face-to-face with the person they would like to meet without travelling dozens of hours on planes or spending considerable sums of money (Punni, 2021). Indeed, real-world instances of this potential are already emerging. For instance, in 2018, Walmart made headlines by purchasing 17,000 VR22 headsets as part of a program to train over a million employees for the annual Black Friday shopping event. This example underscores how businesses are actively leveraging mixed reality technology to streamline employee training and other projects, marking an important step in its practical application beyond the realm of speculation.

2.5.4 Point of View

Video games have evolved from their original 2D pixel-based format to the current generation of 3D games, some of which demonstrate the ability to showcase highly realistic environments. According to Chesher (2007), first-person games give the player a vertiginous sense of movement and made them feel like they were in an enhanced visual space. The perception of realism provided by immersive video games relied heavily on the use of an in-game view. Chesher (2007) explored the impact of various views on user experience and performance, reviewing the extensive previous research on the topic of in-game view (Chris Chesher, 2007). The study conducted by Wan and Chiu (2023) examined the user experience in terms of the process of immersive VR gaming. The research team examined the dynamics and mechanics of transformation as participants played the game to study the impact of different views on the user experience. Their research demonstrated the significance of view in gaming and the dynamic evolution of the user experience over the course of the game (Wan & Chiu, 2023). Gorisse et al (2017) explored the presence and representation of first- and third-person views in immersive virtual worlds. They explored how the users' sense of presence in virtual environments was affected by a different point of view and how well they performed in such environments, with the findings indicating that users' sensation of presence and performance might be significantly influenced by the view from which they view the experience (Gorisse et al., 2017). Black's (2016) research investigated players' visual engagement and their level of immersion in a third-person view video game. Black's (2016) study identified the significant impact of visual engagement on the player's feeling of immersion by examining the interactions between the player and the game character from a third-person view, and this allowed the researchers to examine the interactions from the player's view (Black, 2016). Their research offered illuminating perspectives that helped to understand the visual experience of playing video games from a third-person view. As for real driving, POV can be understood through the literature exploring driving experience and functional POV. Research found that participants with driving experience had a broader functional POV when performing driving tasks(Crundall et al., 1999). The findings of their study indicated an increased ability to perceive and process information about their surroundings, including road signs, other vehicles, and pedestrians. In contrast, participants with no driving experience tended to had a narrower functional field of vision, which suggested that they might need to allocate more cognitive resources to effectively process the same amount of information(Crundall et al., 1999).

Overall, these research articles presented in the above literature shed light on the significance of the in-game first-person perspective for immersive VR games and its influence. These studies contributed significantly to identifying the views that should be used when constructing and optimising VR games, as they examined the impact of various perspectives on the user experience, sense of presence, and performance.

3 Research Experiments Design

In this section, I discuss the methodology I used in my thesis. Also, I include a discussion of how I found the participants for my experiments, how I designed Experiment One and Two, and the changes I made to the questionnaire used after the experiments.

3.1 Methodology

In my endeavour to examine the user experience in VR environments, I have identified the mixed-method approach as particularly illuminating. This approach, which combined quantitative methods with qualitative insights, provided a comprehensive understanding of both the objective and subjective facets of the VR user experience. Kim and Rhiu's study, "A comparative study of navigation interfaces in virtual reality environments: A mixed-method approach" (Y. M. Kim & Rhiu, 2021), was a salient example of this methodology in practice. In their work, they not only quantified performance metrics but also gleaned qualitative data to grasp the nuances of user navigation preferences in VR. Drawing inspiration from their methodology, I intended to integrate both statistical analyses and qualitative feedback in my VR experiments, ensuring a holistic understanding of my research findings.

In this study, I compared the differences between VR technology and computer games. I conducted two experiments to explore the immersion of VR games and to compare the differences between the PC and VR versions of a same game. I invited four participants to take part in the experiments. I planned to conduct Experiment One in Room WG906 on campus. Users B and C, however, were scheduled to take the experiment at my house and User D ‘s house, respectively, due to the weather and their schedules. At the same time, Experiment Two was conducted in my living room using a VR device connected to my PC.

Experiment One aimed to explore the factors contributing to immersion in VR games. I created three VR scenes for the experiment and invited four participants to experience gaming in a VR environment. The order of experiments for each participant was from Scene 1 wired - Scene 1 wireless - Scene 2 wired - Scene 2 wireless - Scene 3. Scene 1 and 2 in Experiment One provided a wired connection experience and a wireless connection experience. In contrast, Scene 3 in Experiment One only provided a wired connection experience due the inclusion of many detailed meshes and keeping the frame rate stable while the scenes were running. The focus was on identifying the factors that enhance the immersion of VR games, and as such, I collected the data using quantitative research methods. Participants provided feedback and comments and completed a questionnaire regarding their experience during the gaming process. The collected feedback and survey data were analysed to conclude the factors enhancing VR game immersion.

Experiment Two aimed to compare the PC and VR versions of the game "Superhot." I invited the same participants from Experiment One to play both versions of the game and asked them to provide their opinions and feedback. The objective of this design was to investigate the differences between the PC version and the VR version in terms of game experience, immersion, and user satisfaction. I used quantitative data analysis methods to compare the participants' performance and feedback between the two versions and asked four participant some relevant questions after they had completed the questionnaire. The questions are specified below:

Which version of the game do you prefer? Reason?

What do you think are the strengths and weaknesses of each of these two games?

What improvements do you think the version you dislike has that you could offer?

I recruited four participants from my university social circle for both experiments. I explained to four participants the tasks they needed complete in both VR and desktop environments. I recorded the participants' behaviours and reactions during the experiments and collected key data about the research objectives. I analysed the data using a mixed methods approach, which included qualitative analysis of participants' feedback, comments, and opinions and statistical analysis of questionnaire and game performance data. Based on the collected and analysed data, I had concluded the factors contributing to immersion in VR games and the differences between the PC and VR versions.

After I talked to the four participants prior to the experiment, I realised that they all had different understandings of both 'immersive' and 'presence' and had little knowledge of either concept. I, therefore, explained this to the four participants. I used Berkman & Akan's definitions as a standard criterion for their assessment and feedback in the subsequent questionnaires before the experimental test.

Immersion – referred to the state in which an individual becomes fully integrated and deeply engaged in a virtual reality (VR) environment, disregarding the reality around them (Berkman & Akan, 2019).

Presence – presence was a phenomenon mediated by technology that focused on the subjective human experience triggered by external stimuli, leading to an inaccurate perception of technological involvement (Berkman & Akan, 2019).

3.2 Participants

I recruited four participants from my social circle from the universities, but not all had previous experience on using VR devices. To mitigate any potential ethical concerns, these four participants were all individuals known to me through recommendations and introductions from within my social circle, who met the necessary criteria for the experiment, and with whom I had no prior vested interests or other relationships. I informed each participant of the purpose of the study and obtained their consent prior to their participation. All of these participants had experienced a university education and had graduated. All four participants had heard of VR technology or had some knowledge of it. Two participants (User B and D) had studied related courses at university. Three participants (User A, B and C) were Chinese, and one was from New Zealand (User D).

The decision to recruit only four participants stemmed from several unforeseen challenges encountered during the research process. After inviting the first participant for Experiment One, it became evident that the time required for the experience greatly exceeded our initial expectations. Furthermore, the originally planned experiment venue became unavailable due to unexpected renovations. Subsequent participants faced delays in their scheduled experiment sessions due to external factors like weather conditions and personal scheduling conflicts. This resulted in an extension of the data collection period, causing a delay in the overall project timeline compared to what was originally anticipated. Given that the same participants would be needed for Experiment Two, I decided against recruiting additional individuals. Consequently, data was collected from only four participants for this study.

User A: Male, 26 years old, had nearly ten years of experience playing video games, had heard of VR technology but had not experienced it.

User B: Female, 24 years old, hardly played video games but had a practical understanding of VR technology as she took a relevant course at university.

User C: Male, 24 years old, hardly played video games and had only heard about VR technology through news and other media platforms but had never experienced VR first-hand.

User D: Male, 25 years old, had much experience with video games and had taken a course on VR technology at university, so he had theoretical and practical experience on VR games.

3.3 Experimental Technical Setup

I required four participants to use VR technology in Experiment One and Two. All participants used the same setup. The VR device consisted of an Oculus Quest 2 (Labs, 2020) (borrowed from the university) that linked to my personal computer, which I configured as follows:

System: Windows 10

Processor: AMD Ryzen 7 3700X 8-Core Processor 3.59 GHz Installed memory (RAM): 32 GB

Display adapters: NVIDIA GeForce RTX 3080 Ti

Monitor: ViewSonic VX2882-4KP 28 4K UHD 1ms 150Hz Monitor

3.4 Problems Encountered

In this section, I summarise the major technical issues that affected the design and execution of the experiments. Some of the major technical issues encountered during the experiments included occasional lag and frame rate drops, which affected the smoothness of the VR experience. Additionally, there were instances where the tracking sensors on the Oculus Quest 2 headset failed to accurately capture hand gestures, leading to a less immersive interaction with virtual objects.

The head-mounted display often failed to connect to my PC's Unreal Engine (UE) 4 (computer program). This issue caused delays in the experimentation process as I had to troubleshoot and find alternative solutions. Additionally, there were occasional compatibility issues between the NVIDIA GeForce RTX 3080 Ti and certain software applications, resulting in occasional crashes or performance issues.

The calibration area of the avatar often did not move properly due to system errors. These technical issues hindered the smooth execution of the experiments and impacted the accuracy of the results. Additionally, the frequent failures in connecting the head-mounted display to Unreal Engine 4 caused delays and disrupted the workflow. Moreover, the malfunctioning calibration area of the avatar further complicated the experimental process, leading to inconsistencies in data collection.

The UE4 engine I used to be not the latest version, as the plug-ins supported by the newest version were unstable. Although using an older version of the UE4 engine granted more stability, I could not find an earlier plugin to match it during the experimental period, so that the development phase was much slower, and many extra steps needed to be taken. Additionally, the lack of compatibility between the older version of the UE4 engine and the newer plugins caused frequent crashes and glitches during testing. This further hindered the progress of development and required additional troubleshooting to ensure a smooth experience for users.

When testing virtual scenes, the headset often did not work correctly. After connecting it to the computer, it brought about various system issues, such as screen flickering, crashing, unresponsiveness, among other related problems. However, the packaged Android file had a low frame rate on the headset display, so the lights could not render successfully. Thus, the flashlight in the scene was originally a spotlight, but after it did render properly, it had to replace with a fixed-point light. This change affected the overall visual experience of the virtual scene as the spotlight provided a more dynamic and immersive lighting effect.

Additionally, the low frame rate on the headset displays also impacted the smoothness of the user's interactions within the virtual environment, leading to a less seamless and enjoyable experience.

3.5 VR Scenes for Experiment One

I created three VR scenes for Experiment One using the Unreal game engine. I adopted Oculus Quest 2 (Meta Quest 2) (Labs, 2020) for experiments (Experiment One and Two). When creating the three scenes, I ensured that each scene was different, aiming to provide a different experience in terms of immersion and presence. To ensure that the scenes were comparable but differentiated in terms of immersion and presence, each scene featured the same number of variables (10 tables and a door), but Scene 2 had two extra elements for the second scene (adding texture for the tables and swapping the controller to the mechanical hand palm). For the third scene, I added two bookshelves, one pick-up torch, four pick-up chairs, and two laptops with three books on the tables. Thus, while the first scene was a virtual classroom with no textures and essential virtual interaction, the second scene added textures for all the tables and lighting on the ceilings. I replaced the controller with a hand and added sound effects while I turned on the lights. The third scene added detailed meshes (two bookshelves, one pick-up torch, four pick-up chairs, two laptops and three books on top of the tables), sound effects (light switches), and replaced the hand controller with a more realistic hand.

3.5.1 Scene 1

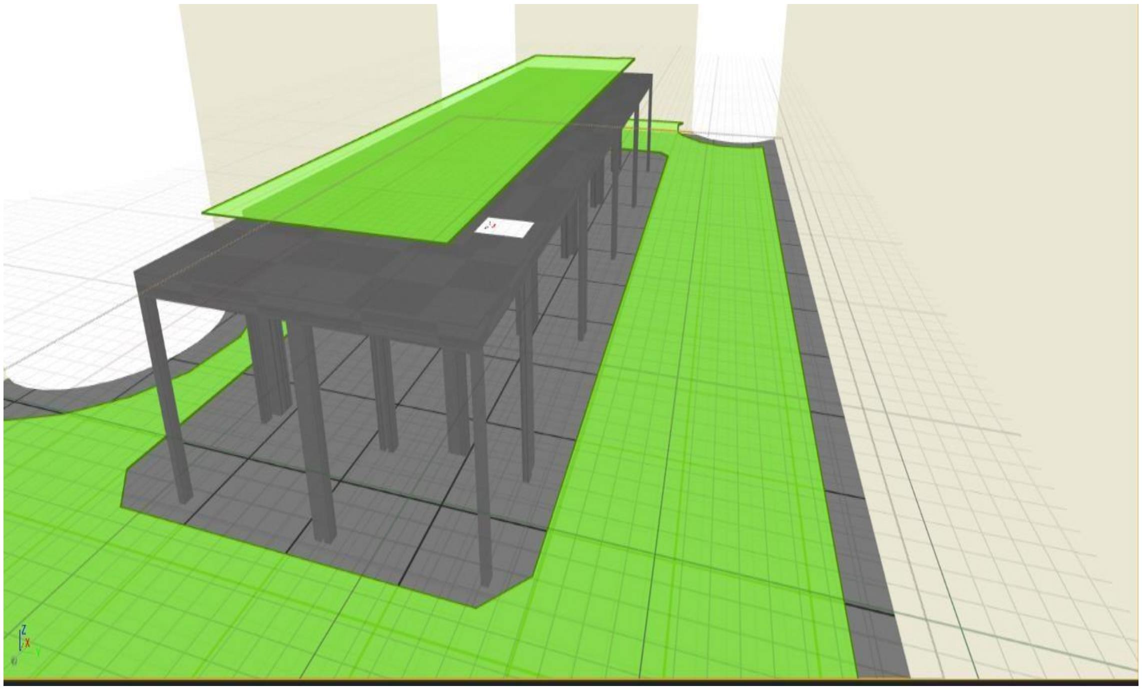

Figure 2: The untextured scene

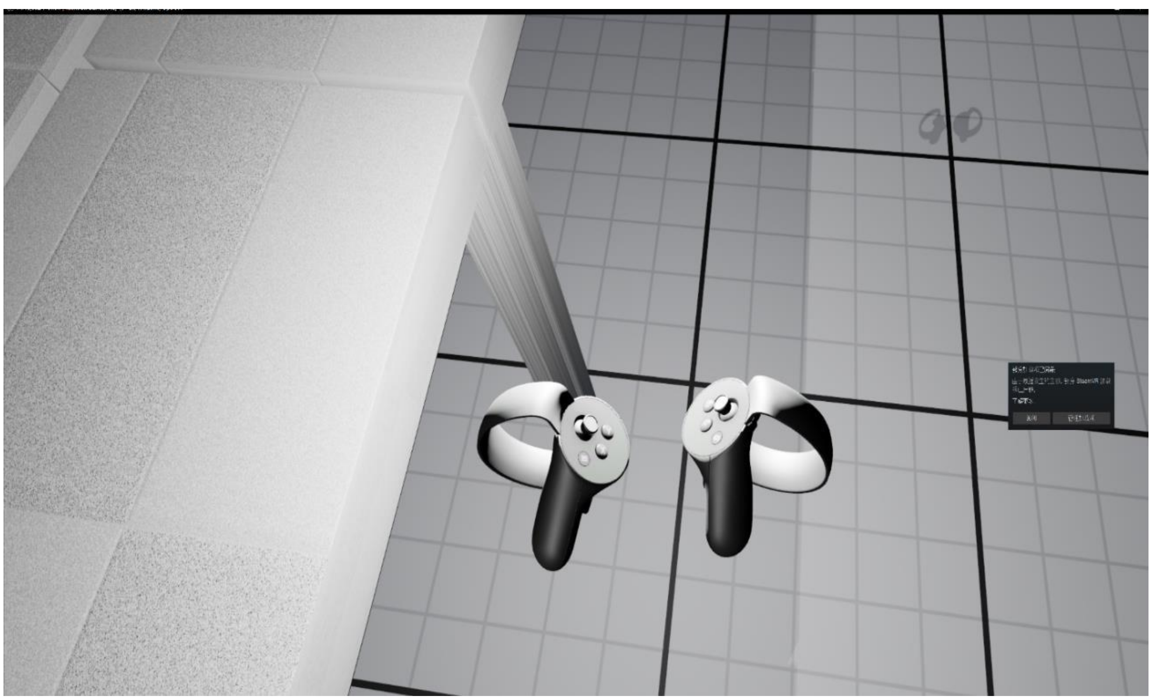

Figure 3：*Original set controller*

Scene 1 was a grey box room (*Figure 2*) with three simple interactions (walking, interacting with the light switch, and the combination lock) available to the user. The controller was the basic VR headset controller (*Figure 3*).

3.5.2 Scene 2

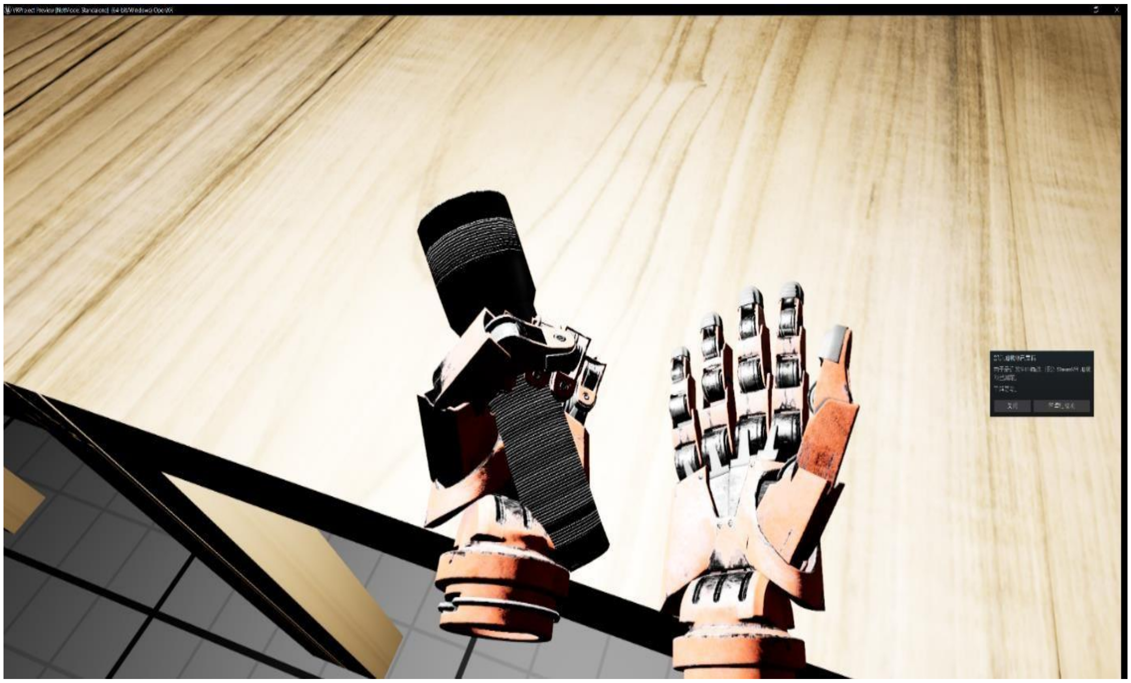

Figure 4: Mechanical hand controls

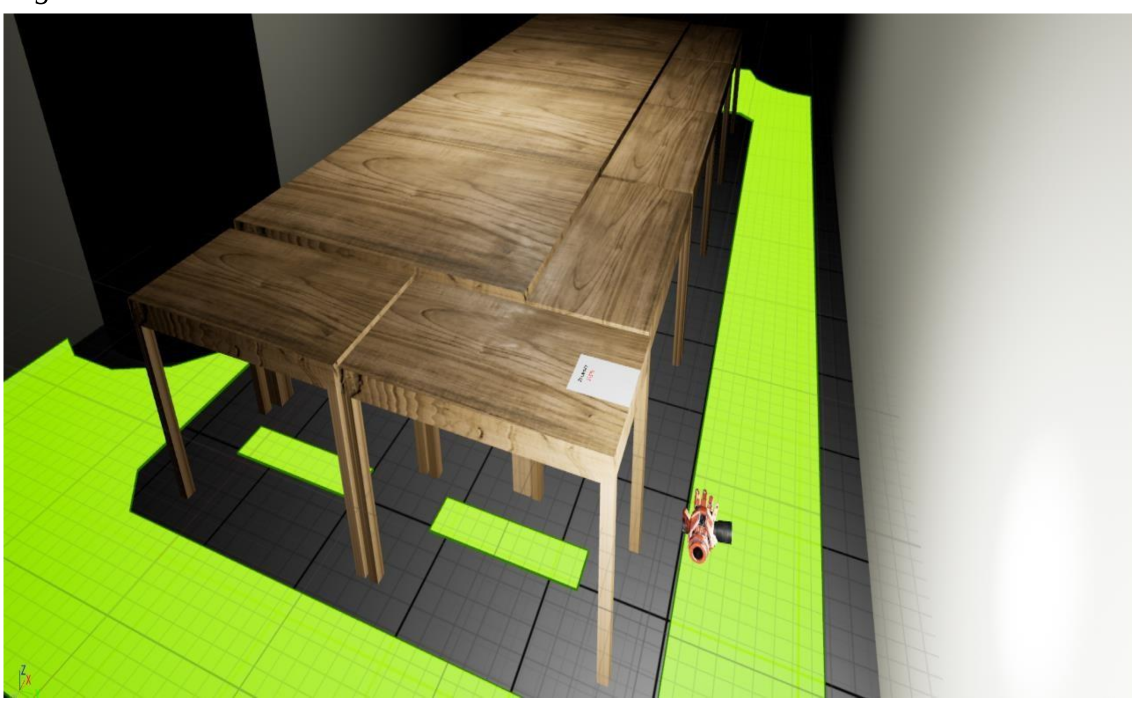

Figure 5: Textured furniture scene

Figure 6: Simple weight simulation by tying a heavy object to player's hand.

Scene 2 was identical to Scene 1 but with more details, such as a hand model (*Figure 4*), some texture in the furniture (*Figure 5*) and more interactions added. I also added sound effects for the light switch. Finally, during the experiment, I attached a counterweight block to the participants' hands to simulate the flashlight (*Figure 6*) to test whether a simple weight simulation could improve the user experience.

3.5.3 Scene 3

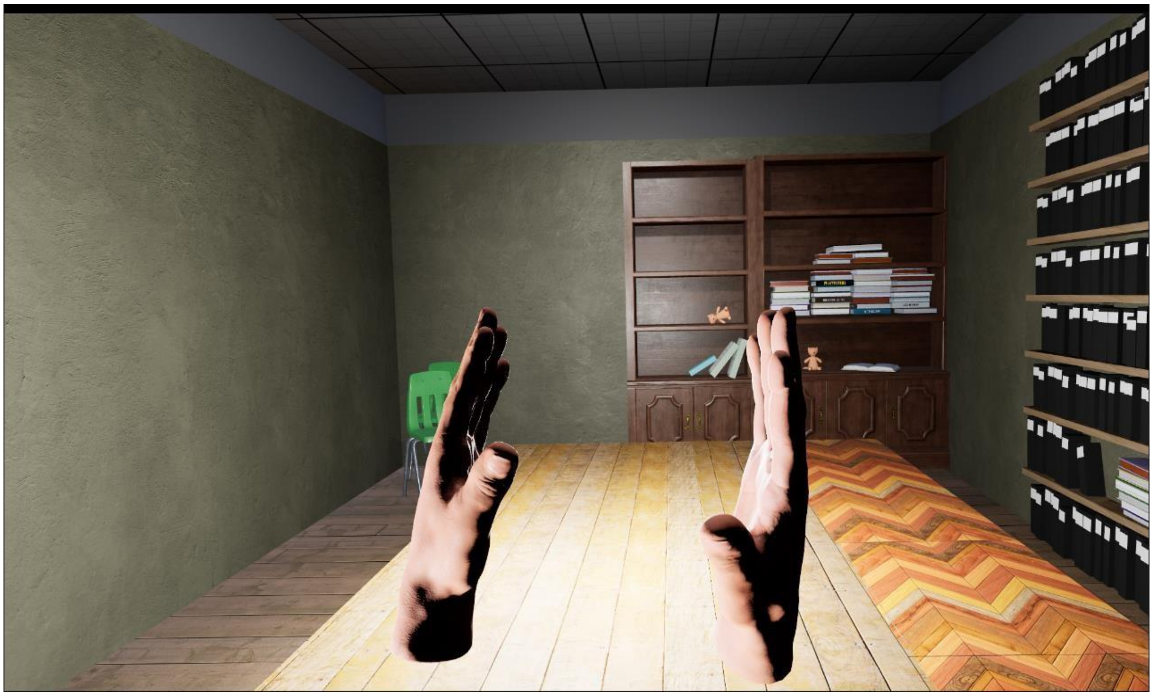

Figure 7: Realistic hand controller

Figure 8: Scenes with fully added textures and objects.

For Scene 3, I aimed to make the experience as realistic and convincing as possible. I provided a realistic hand controller (*Figure 7*) and added multiple meshes (*Figure 8*) (two bookshelves, four chairs, two laptops, as well as two books and a flashlight that participants could pick up), different textures, and realistic interactions (the chairs and flashlight can be picked up and the door can be opened by pushing it) to this scene. In Scene 3, I aimed to explore whether a near-realistic scene with enough detail (texture and realistic interaction) would give the user a more immersive experience.

3.6 Experiment

This section describes the experimental design, the research questions, and how to build, test, redesign, and retest the prototype.

3.6.1 Experiment One Preparation

This study examined the experience of three VR scenes that had the same substrate but different details and whether this would affect the user's experience of immersion or presence with the technology.

The actual area used to construct the virtual scene was Room WG906 (*Figure 9*) at AUT's city campus. Room WG906 was a 9.33 m × 5.42 m × 2.9 m classroom that included three columns with a diameter of 0.63 m, six 1.2 m × 0.6 m × 0.9 m tables, and four 1.8 m × 1.2 m × 0.93 m tables in the centre of the room.

Figure 9: Room WG906

I created a virtual environment for the first scene with the same basic layout as Room WG906 (*Figure 9*) and included the most basic virtual interactions, such as picking up items, opening a door, and moving around the room.

The second scene was created in the same way as Scene 1, but with more details added, such as a hand model, textures for the furniture, and sound effects for the light switch.

In the third scene, I kept the same elements as in the second scene but made some modifications. I removed the combination lock and added more details to the scene, including interaction details (e.g., a realistic sensation of pushing and pulling the door), sound effects (for the light switch), and additional meshes to enhance the environment (two bookshelves, four chairs, two books, two laptops, and a pick-up-able flashlight).

3.6.2 Experiment Design: Experiment One

I added test videos (Experiment One testing: https://youtu.be/MhVLDd5ZGqs) of the three pre-experimental scenes in the appendix. These videos primarily tested the main interactions of the three scenes, including the automatic opening of the door with a combination lock in Scene 1, the automatic door opening of the door with a combination lock and light switch audible feedback in Scene 2, and the interaction of picking up a flashlight, sound feedback of a light switch, and simulating an actual door pushing in Scene 3.

In Experiment One, I created three VR scenes and invited participants to test them and provide feedback, including gathering their differing opinions about the experience.

The virtual scenes used in Experiment One had the same basic configuration as Room WG906 (*Figure 9*). They featured the most basic virtual interactions, such as picking up items, opening doors, and moving about the room. I introduced the room to the users and explained to them the purpose of the experience. After the experiment I asked participants to evaluate and score each experience at the end on a scale of 1-5, with 1 being poor and 5 being excellent. Before the experience, I told all participants that they could experience each scene for a maximum of 5 minutes before opening the door and escaping the scene, but they could quit the test early if they wished and all the participants were using the same devices to experience the same scenes but in different locations (due to the long period of unavailability of the original experimental site with subsequent renovation.). After all experiences were completed, users were allowed to change the scores but had to explain why. After the participants completed the questionnaires; I interviewed them to ask if they had any comments and questions and collected feedback for subsequent analysis.

In the first scene, I developed a basic VR interaction scene using Room WG906 as a reference. The scene did not include elaborate materials or extensive interactions. The purpose was to provide an equal starting point for all participants to comprehend and familiarise themselves with VR technology. The first scene was more like a trial, allowing the four participants to quickly familiarize themselves with VR operations.

The setting for Scene 2 was modelled on Scene 1, with scene details (interaction details, sounds, etc.) added in response to supervisors feedback. I added textures to all the tables as well as sound effects. Scene 2 served to explore whether changing variables (adding light switch sounds and table textures) would make a difference in the participants' experience. Here, I used the feedback from the supervisors to modify the scene. Moreover, participants were allowed to provide further feedback after the experiment was completed, and they had more time to reflect.

For the third scene, the environment was also based on the original Room WG906. Still, in this scene, I removed the unrealistic interaction (users could enter the correct password to open the door automatically). I used multiple meshes and texture to make the room as real as I could, and I included a more realistic interaction (doors that participants could push and pull).

All four participants experienced Scenes 1 and 2 using both a wired and a wireless connection. However, for Scene 3, they only used a wired connection due to its ability to provide a more stable frame rate. The participants had the same time limit of 5 minutes for all connection methods and scenes.

After completing the three-scene tests and the questionnaire, I interviewed the four participants about their experience. This was designed to further understand if the four participants had anything to add after completing Experiment One and the questionnaire to further refine the analyses.

3.6.3 Experiment Two

I have also included the test videos in Experiment Two (Experiment Two testing: https://youtu.be/JICehtXYcGs) in the Appendix, demonstrating the same game in both the computer and VR versions. These videos showcase tutorial levels and battles against multiple enemies.

I decided to conduct a follow-up comparison experiment to better understand the disparities between VR games and traditional games. I invited the four participants who had previously experienced virtual gaming scenes in Experiment One to participate in this new study. For this experiment, I chose to compare the games "Superhot" (Piotr Iwanicki, 2016)and "SuperhotVR" (Iwanicki, 2016), which Superhot Team developed. These games were released at the beginning of 2016 and the end of the same year.

The rationale behind my selection of these two games for testing was that they shared the same developer and shared identical operational logic, storyline, and graphics. This made them ideal candidates for evaluating the participants' experience. To conduct this experiment, I chose the instructional levels from both games that contained various gameplay aspects such as shooting, punching, dodging, and throwing, culminating in a combined battle. The four participants played through these five instructional levels in both "Superhot" and "SuperhotVR", so I could effectively assess and compare their experiences. This setup could shed light on the differences in gameplay and immersion between traditional games and VR games. In this experiment, I had recorded the time taken by the participants to complete the five levels (and had marked the completion time of each level) and interviewed and collated their impressions of the differences between the two near-identical games as a traditional video game on the computer and as a VR game.

After completing the questionnaire, I interviewed the four participants about their experience and asked them about the interview questions. The reason for this was to find out if the participants had anything to add to the questionnaire after completing Experiment Two to refine the subsequent analysis.

3.6.4 Questionnaire

Experiment One and Experiment Two involved four participants who had experienced the three VR game scenes developed by me, as well as the commercially available games, Superhot and Superhot VR. After experiencing these games, all four participants were asked to complete a modified version of the Immersion Questionnaire (Jennett et al., 2008). The original questionnaire was comprehensive, but some of the questions and wording were not suitable for my research topic and the type of scenes selected in the present study. The original questionnaire was designed to provide participants with a comprehensive gaming experience, including elements such as non-playable characters (NPCs), detailed game plots, and interactive gameplay. However, I excluded the concepts of winning or losing the game world in my experiment. My primary objective was to allow participants to experience a VR scene in Experiment One and subsequently compared the disparities between the computer-based and VR aspects of the same game in Experiment Two. By doing so, I aimed to investigate the impact of different platforms on the gaming experience. Hence, I modified the questionnaire to ensure that it was appropriate for the focus of my thesis.

List of questions removed from the questionnaires:

To what extent did you feel like you were making progress towards the end of thegame?

Were you in suspense about whether or not you would win or lose the game?

How much did you want to "win" the game?

At any point, did you find yourself become so involved that you wanted to speak to thegame directly?

The original questionnaire may had been constructed with a predetermined scoring framework, considering the cumulative impact of all inquiries on the comprehensive measure of immersion. The removal of three questions decreased the maximum attainable score for every participant. This implied that there could be a disparity in the overall potential points when comparing scores between the altered and unaltered versions. The aim of this study was to conduct a comparative analysis of the scores of four users only utilizing the modified version. Hence, although the absolute scores might not had been directly comparable to findings obtained from studies employing the whole questionnaire, the relative disparities and trends seen among the four participants in this investigation remained relevant within the context of the research objectives.

The initial research conducted by Jennett et al. perhaps utilized a particular algorithm or approach to assess the level of immersion by considering the combined feedback from all the inquiries. The formulation would have been derived from the authors' comprehension and delineation of immersion, presumably considering the interaction among many aspects of the phenomenon. The exclusion of items had the potential to modify the subtleties of the constructs that the questionnaire assessed. Nevertheless, it was important to acknowledge that the main objective of this study was not to replicate the precise measurement of immersion as specified by Jennett et al. (2008), but rather to utilize the instrument for comparative purposes across users.

Selected and modified version of the questionnaire

Legend for modifications (highlighted in blue)

1) To what extent did the game hold your attention?
2) To what extent did you feel you were focused on the game?
3) How much effort did you put into playing the game?
4) Did you feel that you were trying your best?
5) To what extent did you lose track of time?
6) To what extent did you feel consciously aware of being in the real world whilst playing?
7) To what extent did you forget about your everyday concerns?
8) To what extent were you aware of yourself in your surroundings?
9) To what extent did you notice events taking place around you?
10) Did you feel the urge at any point to stop playing and see what was happening around you?
11) To what extent did you feel that you were interacting with the game environment?
12) To what extent did you feel as though you were separated from your real-world environment?
13) To what extent did you feel that the game was something you were experiencing rather than something you were just doing?
14) To what extent was your sense of being in the game environment stronger than your sense of being in the real world?
15) At any point, did you find yourself become so involved that you were unaware you were even using a controller?
16) To what extent did you feel as though you were moving through the game according to your own will?
17) To what extent did you find the game challenging?

18) Were there any times during the game in which you just wanted to give up?

19) To what extent did you feel motivated while playing?

20) To what extent did you find the game easy?

21) How well do you think you performed in the game?

22) To what extent did you feel emotionally attached to the game?

23) To what extent were you interested in seeing how the game's events would progress?

24) To what extent did you enjoy the graphics and the imagery?

25) How much would you say you enjoyed playing the game?

26) When interrupted, were you disappointed that the game was over?

27) Would you like to play the game again?

4 Experiment Data

In this section, I present the questionnaire scores of the four participants after they had completed Experiment One and Experiment Two in the form of tables. These tables included each participant's total questionnaire score for each scene of the two experiments so that I could assess the level of immersion experienced in different scenes. Additionally, by considering the standard deviation of the data, I was able to analyse the questions in the questionnaire where the score change was not significant after adjusting for variables.

This analysis allowed me to identify which scenes elicited a higher level of immersion from participants and helped me understand which aspects of the experiments were more engaging. Furthermore, through identification of problems with less fluctuations, I could also identify stabilising factors that were not much affected by variable adjustments.

4.1 Experiment One:

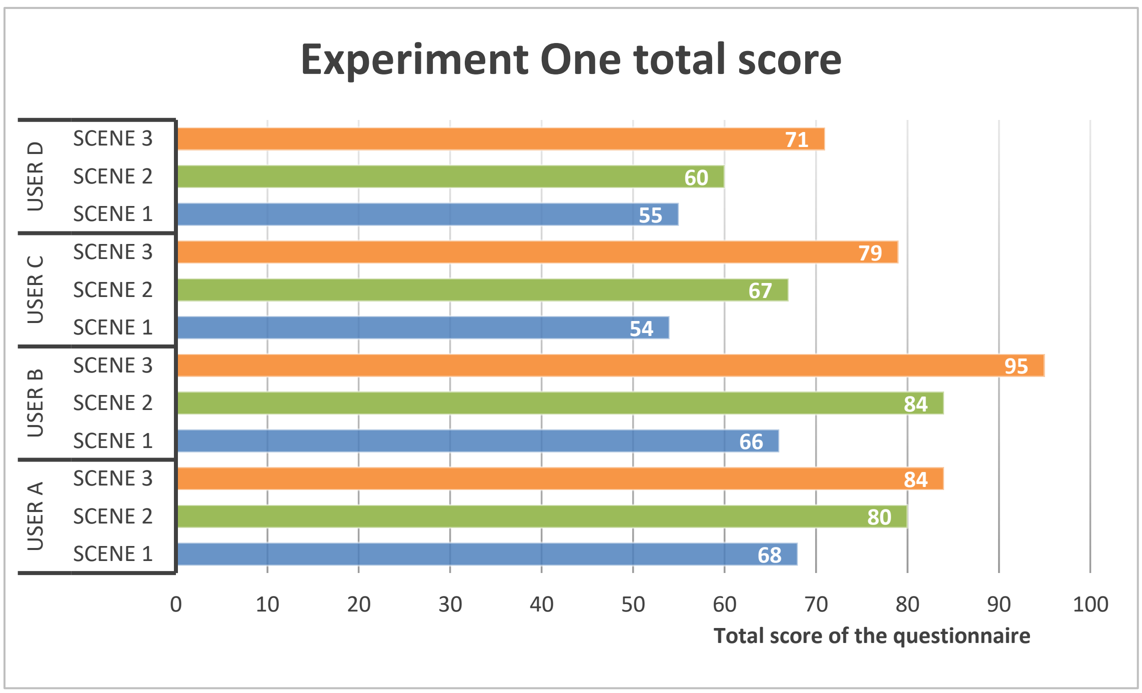

Figure 10: Total questionnaire score for Experiment One for the four participants

As shown in *Figure 10*, that each participant scored higher in Scene 3 than Scene 2 and higher in Scene 2 than Scene 1. This demonstrated that scene 3 afforded the most immersive experience out of the three scenes. This suggested that the participants' perception of immersion increased as they progressed through the scenes. The consistent pattern of higher scores in each subsequent scene indicated a positive correlation between the immersive qualities of the scenes and the participants' overall experience.

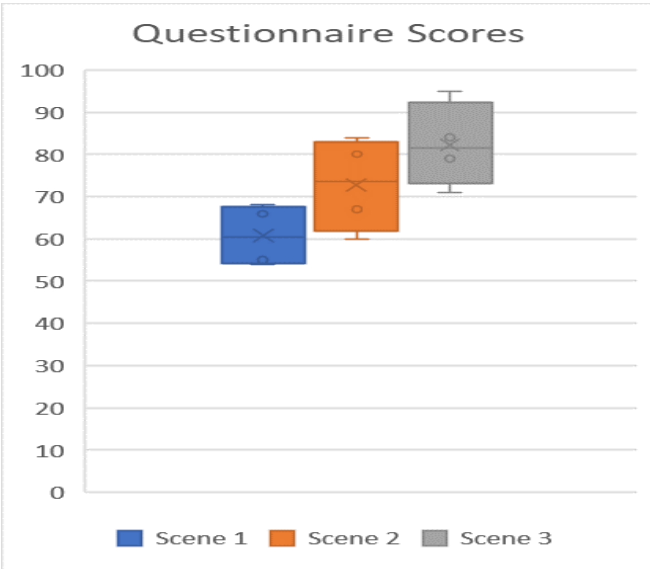

Figure 11: Box plot representation of scores for three scenes

Observations from (*Figure 11*) the four participants indicated that the scores for Scene 3 are typically higher than those for Scene 2, and scores for Scene 2 are higher than those for Scene 1. The average scores for each scene were ranked as follows: Scene 1 (60.75) < Scene 2 (72.75) < Scene 3 (82.25). Upon using a one-way ANOVA analysis, the p-value was 0.034, which was less than 0.05, suggesting that there were significant differences in the scores among the three scenes. Further pairwise comparisons also showed statistically significant differences in scores between all scenes. Therefore, based on the presented data, Scene 3 received the highest ratings, while Scene 1 received the lowest. The differences in ratings between all scenes were statistically significant.

4.1.1 Experience time in each scene for four participants

Here, I present the wired connections of each participant in Experiment One for Scene 1, Scene 2, and Scene 3. Additionally, I provide the exit times for the wireless connections in Scene 1 and Scene 2, the duration from entering the VR scene to completing the experience. I provide statistical tables (*Figure 12*) of the experimental experience time for four participants in different scenes in Experiment One.

U ser A

Scene 1 wired. Time 4 mins 48 seconds

Scene 1 wireless. 2 mins 35s seconds

Scene 2 wired. 4 mins 43 seconds

Scene 2 wireless. 2 mins 21 seconds

Scene 3 wired. 5 mins

User B

Scene 1 wired. 5mins

Scene 1 wireless. 2mins 24seconds

Scene 2 wired. 3 min 49 seconds

Scene 2 wireless. 2 min 12 seconds

Scene 3 wired. 5 mins

User C

Scene 1 wired. 4 mins 57 seconds

Scene 1 wireless. 2 2mins 21 seconds

Scene 2 wired. 2 4mins 3 seconds

Scene 2 wireless. 2 mins 11 seconds

Scene 3 wired. 5 mins

User D

Scene 1 wired. 4mins 42 seconds

Scene 1 wireless. 1 min 56 seconds

Scene 2 wired. 3 min 44 seconds

Scene 2 wireless. 2 min 08 seconds

Scene 3 wired. 5 4mins 49 seconds

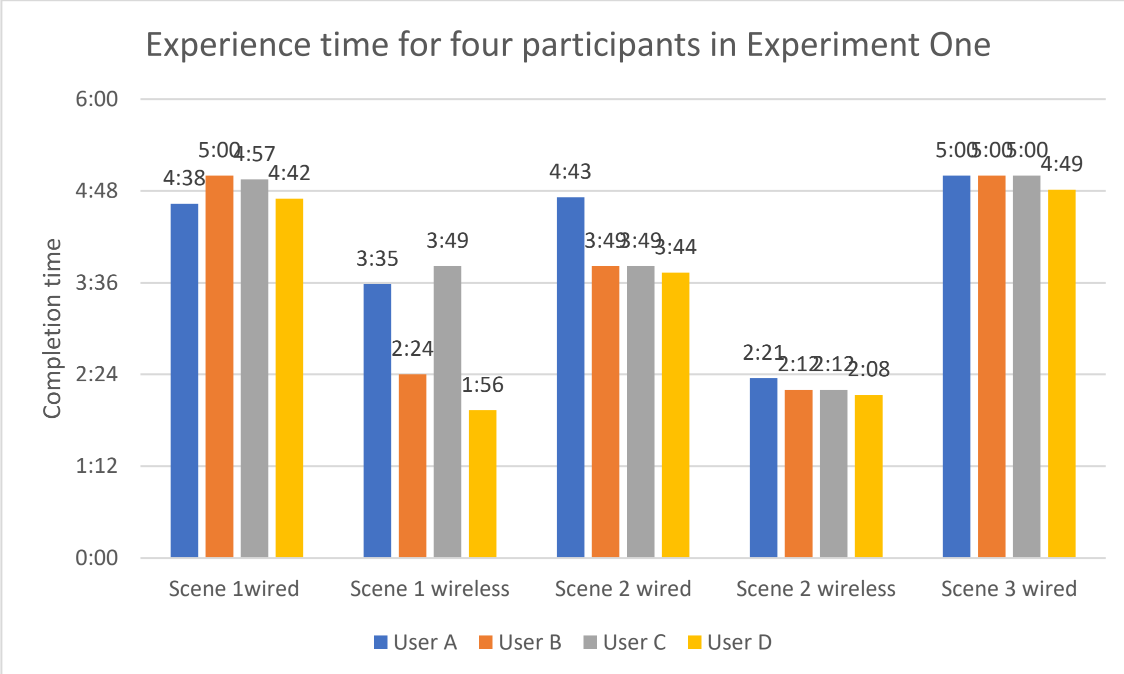

Figure 12: An experimental experience of four participants in various scenes in different situationsof Experiment One

4.1.2 Interview Feedback

In this section, I briefly outline the prerequisites for each participant prior to experiencing the scenes. Following that, I outline each participant's feedback in the interview after completing each scene consecutively. The prerequisites for each included participant were that they had prior experience with both wireless and wired setups, as well as familiarity with the equipment used in the experiment.

User A

The premise: I brought User A into Room WG906 and asked him to put on Oculus 2 to experience Scene 1 and Scene 2, which had the same basics but different details. I explained to him the basic information about the room and the purpose of my experiment.

Scene 1: The user's visible hand was the controller's handle, and most of the objects in the room had no materials added to them.

Feedback: The first experience of the first scene felt okay at first, but the scene was not detailed enough. The lack of cables slightly enhanced the wireless experience, and I could walk freely, but not a lot, so it was an OK VR experience. The VR experience was in first person as opposed to traditional gaming scenes, which was a plus because the user thought the first-person perspective was a very effective point of enhanced immersion. However, the scenes lack a great deal of material detail, and in the user's opinion, it was more of a demonstration or simulation.

Scene 2: The hand of the participant operating in the scene was a mechanical hand, and the meshes in the room had added materials.

Feedback: The controller in Scene 1 was replaced with the user's favourite robot, and the objects in the scene were carefully detailed to enhance the gameplay experience. In Scene 2, the textures and details of the objects were increased compared to the first scene. The controller was switched to a mechanical palm, so that the immersion of the game was boosted. Basic movements were supported, and lighting effects were added to enrich the overall look and feel of the scene."

Scene 3: I replaced the controllers with realistic palms and added details of bookcases, tables, chairs, books, and computers to the scene to make it more realistic.

Feedback: The controllers had been replaced with realistic hands, much better than the first two scenes, and detailed bookcases, tables, and chairs, as well as books and computers, had been added to the scene to bring it closer to reality. Scene 3 was much more realistic than the first two scenes. The richness of the objects, the very anthropomorphic controller, and the door-opening interactions were a bit clunky but much better than the automatic door opening in the first two scenes. The user wanted to spend more time appreciating the details of this scene.

User B

The premise: Due to the extreme weather, User B could not drive to the experiment location (Room WG906). The experiment could only be conducted indoors in the bedroom and not in Room WG 906. Before the experiment, I introduced the basic information of Room WG906 through images (*Figure 9*) and the purpose of my experiment.

Scene 1: The user's visible hand was the controller handle, and most objects in the room had no material added. Feedback: The overall experience was okay, but the movement made the user feel dizzy. Although the scene could be seen as a classroom, it was missing many elements such as textures and lighting compared to a traditional game scene."

Scene 2: The hand of the participant operating in the scene was a mechanical hand, and the meshes in the room had added materials.

Feedback: Scene 2 was a much better experience than Scene 1, despite adding textures and replacing the controller model. Replacing the hand controller model in the second scene provided a huge immersion boost for a first-person virtual experience, and some hand interactions enhanced the overall experience. However, there was still a slightly monotonous look to the scene due to the lack of some furniture or objects.

Scene 3: I replaced the controllers with realistic palms and added details of bookcases, tables, chairs, books, and computers to the scene to make it more realistic.

Feedback: This scene was much better than Scene 1 and 2. The third scene was rich in detail, with the controller becoming more like a real person's hand and interacting with the door more realistically. The richness of the objects and the attention to detail made it a pleasure to explore the scenes up close. Thanks to the excellent structural and room detail, users were left in no doubt that this was a real-life gaming scene, but to her regret, this experiment was not a wireless experience.

User C

The premise: For reasons of unreliability, I did not bring User C to Room WG906 to complete the experience but rather had him do it in an open area. As with the first two users, he tested the wired and wireless headsets.

Scene 1: The user's visible hand was the controller handle, and most objects in the room had no material added.

Feedback: While the experience of using a wireless device improved over the wired one, the lack of scene depiction was not compensated by the wireless experience. The first scene was more of a VR experience than a game because of the lack of items in the scene, so the user claimed that the scene was immersive or experiential.

Scene 2: The hand of the participant operating in the scene was a mechanical hand, and the meshes in the room had added materials.

Feedback: The change of the controller to a robot really improved the game experience significantly as compared to the controller in Scene 1, and the objects had materials that made the scenes less boring. Scene 2 was more complete than Scene 1, but the details added to Scene 1 did not feel original to the user.

Scene 3: I replaced the controllers with realistic palms and added details of bookcases, tables, chairs, books, and computers to the scene to make it more realistic.

Feedback: Scene 3 was arguably better in every way than Scenes 1 and 2. Scene 3 was more of a finished product with very detailed scenes, items in each scene that the user wanted to pick up and look at, and a very experiential interaction with the door at the end. While a little awkward to operate, it did not detract from my enjoyment of the scene.

User D

The premise: Since User D was not in Auckland during the experience phase, I had sent the user the test file, and the user used his device, the Oculus Quest 2, to test the experience.

Scene 1: The user's visible hand was the controller handle, and most objects in the room had no material added.

Feedback: There was no way to had enhanced the experience with the lack of scenery with a wireless experience. Scene 1 was so lacking in content that experience could not be called a game, nor could it be compared to a traditional game; this experience could only be considered a demo of a VR experience.

Scene 2: The hand of the participant operating in the scene was a mechanical hand, and the meshes in the room had added materials.

Feedback: Scene 2 was a step up from Scene 1, where the controller becomes a palm, but the scenes were still lacking. Palm lifts would have further enhanced the immersion, and adding home materials would had been a good thing, but these scenes still left the user feeling unfinished or lacking.

Scene 3: I replaced the controllers with realistic palms and added details of bookcases, tables, chairs, books, and computers to the scene to make it more realistic.

Feedback: Scene 3 was a complete upgrade compared to the previous two scenes. Scene 3 had more details, bookcases, stationery furniture etc. These additions made the scene more convincing, and the change in the hand controller gave the user a sense of being there.

In the provided experimental feedback, the participants, referred to as Users A through D, interacted with three separate virtual reality (VR) environments. All participants possessed prior experience in working with both wireless and wired setups, as well as a level of familiarity with the equipment employed in the study. Participants were sequentially exposed to Scenes 1, 2, and 3, and subsequently provided feedback following the experiential exposure.

Scene 1 had consistently received criticism for its dearth of intricate elements, with users characterising it as a rudimentary or prototype-level VR encounter. While acknowledging the freedom provided by the wireless setup, it is important to note that the overall impact of this setup was limited due to the simplicity of the scene. It is noteworthy that users had expressed their appreciation for the utilisation of a first-person perspective in Scene 1, deeming it a substantial catalyst for immersion enhancement when juxtaposed with conventional gaming scenes. Nevertheless, it was consistently noted that the scene lacked detailed materials, resulting in a more demonstrative experience rather than an immersive or engaging one.

Scene 2, which featured a more intricate array of objects and a mechanical hand as a replacement for the original controller, garnered a generally favourable response. Users had recognised the improvements made in texture and object detailing as significant advancements compared to Scene 1. The advent of the mechanical hand controller was widely acclaimed for its significant contribution to enhancing the level of immersion, as it meticulously addressed the aspects of texture and intricate details, thereby enriching the overall gaming experience. However, the feedback received indicated that despite the enhancements, it would be advantageous to incorporate supplementary elements and details into the scene in order to prevent any potential visual monotony.

Scene 3 received widespread acclaim for its meticulous depiction of a realistic environment, featuring elaborately designed bookcases, tables, chairs, books, computers, and a substitution of controllers with lifelike hands. The scene's fidelity to reality and its meticulous rendering of objects were highly commended. The anthropomorphic controllers and increased interactivity, such as the inclusion of manual door opening, were well-received by users, despite some minor operational issues. The users expressed a strong interest in further exploration of the scene due to its compelling and realistic design, which was characterised by its detailed richness and interactive features.

In general, the feedback indicated a gradual enhancement from Scene 1 to Scene 3, wherein each scene improvement contributed positively to the user's experience and level of immersion. The reception of the transition from a rudimentary, illustrative virtual reality (VR) scene to a highly detailed, immersive environment was favourable, underscoring the significance of meticulous scene rendering and the development of interactive, lifelike controller design in the creation of captivating VR experiences.

4.2 Experiment Two:

Experiment Two had been conducted with four participants from a previous study to understand disparities between VR and traditional game. "Superhot" and "SuperhotVR", developed by Superhot Team in 2016, were selected for their identical logic, storyline, and graphics. Participants had played through five instructional levels from both games featuring gameplay elements like shooting, dodging, and throwing. The experiment had aimed to assess and compare participant experience, recording time taken to complete each level and gathering impressions about the differences between the traditional and VR versions of the game.

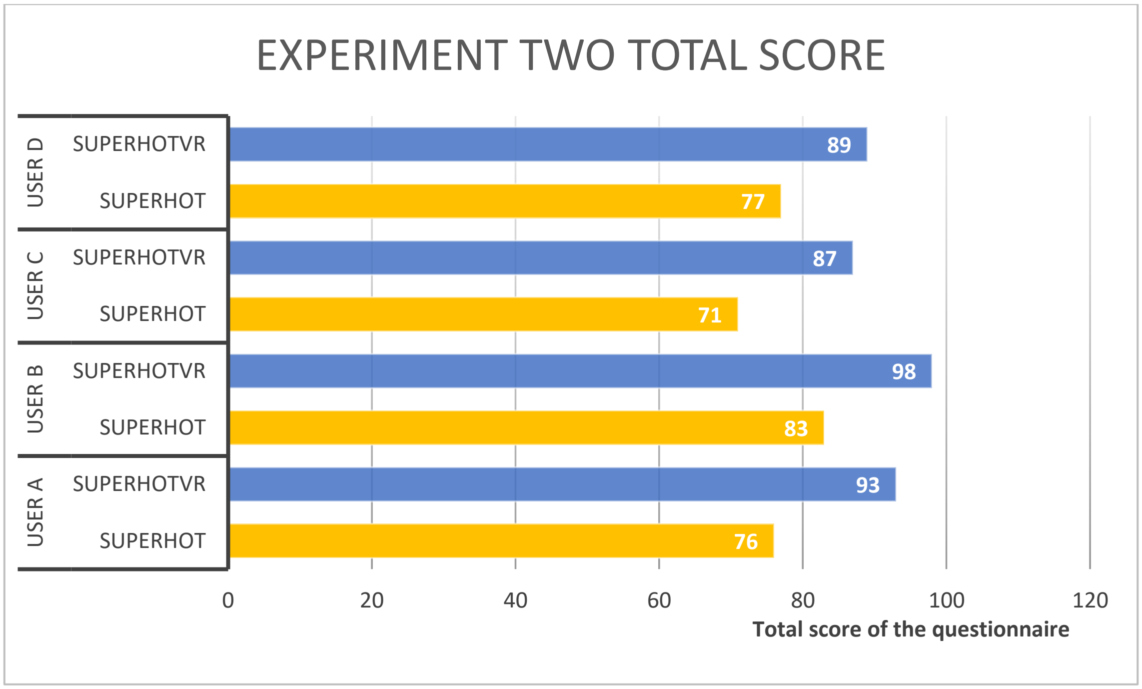

Figure 13: Total questionnaire score for Experiment Two for the four participants

As shown in *Figure 13*, the sum of the questionnaire scores for the four participants after they had experienced the two game versions in Experiment Two is displayed. It was evident that each participant reported higher scores in the Superhot VR version, and this also suggested that the four participants preferred the VR version.

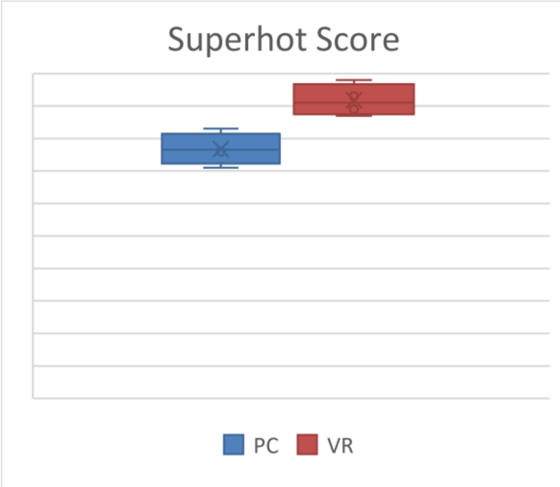

Figure 14: Box plot representation of scores for two versions of "Superhot"

From *Figure 14*, it could be seen that, among the four users, the experience rating for "Superhot" was consistently higher for the VR version compared to the PC version. The average score for the PC version was 76.75, while for the VR version, it was 91.75, indicating a clear preference difference. Using a one-tailed t-test, the p-value was less than 0.001, suggesting that "Superhot" received notably higher ratings on the VR platform compared to the PC platform, and this difference was statistically significant.

4.2.1 Interview feedback:

In this section, I outline the feedback from each participant during the interview after they had consecutively completed each game.

User A

"I preferred the PC version from my experience with both games. One reason was that the computer screen was smaller than VR, so my visual focus was confined to the screen, allowing me to concentrate more on the game. The second reason was that I preferred using the mouse for aiming, as it felt more accurate compared to VR controls. The third reason was the discomfort of wearing a VR headset. It is heavy, which caused me to sweat a lot during the game. This led to the VR display lens fogging up and obstructing my vision. For this VR game specifically, I would recommend adding scopes or infrared aids to improve the accuracy of firearm aiming. Reducing the number of enemies in each scene would also be beneficial or concentrating them more in the centre of the POV rather than on the periphery. Additionally, providing more assistive features such as adjustable viewing angles or the ability to modify the number of enemies would enhance the gameplay experience."

User B

"Of the two games, I preferred the VR version. One reason was that the VR version offered a deeper sense of immersion, allowing me to feel like I was in the game world. By turning my head or moving in various ways, I could interact with the virtual environment in a manner that traditional video games could not replicate. The second reason was that the VR version felt more intuitive and realistic regarding movement within the virtual world. For instance, I could physically step back or make other bodily movements, which translated into actions in the game. This added physical feedback that traditional video games could not provide. Thirdly, VR offered more realistic feedback and interactions than traditional video games. In the traditional version, pressing a button gave the user result in feedback from the computer, whereas in VR, I could use my head or body movements to provide physical feedback to the game. This immersive level of interaction was something that traditional video games could not deliver. As someone who was not an experienced gamer, I could not provide extensive feedback on specific game changes. However, one aspect that I believe could improve was adding a crosshair or more effect when enemies getting hit (User B preferred the VR version but User B apparently had found the PC version easier to aim and gives better feedback on shots than VR). This would further enhance the immersive experience in the game."

User C

"Of the two games, I preferred the VR version. The reason for this was that, while the PC version of the game was also great, I enjoyed the more immersive gameplay offered by the VR version. Had a wider POV in VR allowed me to fully experience and engage in the addictive actions of the game. Additionally, the physical instinctive control and manipulation of the character in VR added to the immersive experience. There were a few factors that influenced my preference. One was the issue of the headset causing the mirrors to sweat and fog up when worn for extended periods of time. This necessitated occasional interruptions during testing to remove the headset, wipe the mirrors, and readjust before continuing. Additionally, the headset's weight could become noticeable over time, requiring occasional adjustments for comfort. Despite these minor drawbacks, I found the VR version of the game to be more captivating and immersive compared to the PC version with its keyboard and mice controls."

User D

"I preferred the PC version to both games because the graphics were more detailed than the VR version. Additionally, the actions required by the characters in the PC version could be executed quickly and precisely using the keyboard and mice controls. The PC version provided a focal point (crosshair) that allowed me to aim at enemies and make quick judgments. In contrast, the VR version relied mostly on my senses, and due to the wide POV, I sometimes found it challenging to react as swiftly as I would have liked upon encountering an enemy. As a result, I currently prefer the PC version. However, the VR version offered a much more immersive experience, allowing me to physically move and interact with the virtual environment. The sense of presence and realism in the VR version was unparalleled, making it feel like I was truly inside the game. Despite the slight disadvantage in reaction time, the VR version provided a unique level of immersion that made it an unforgettable gaming experience."

Based on the feedback there appears to be a 50-50 split between the participants on which medium they preferred. The reasons for this might be attributed to the extensive prior experience of Users A and D with traditional computer games, which has led them to had certain expectations for both traditional computer games and VR games. Therefore, in their eyes, for the same game, they would lean more towards the computer version because it can provide them with a more stable frame rate and a relatively familiar and easy-to-learn control scheme. On the other hand, Users B and C, lacking similar past experiences as the other two participants, might have preferred the VR version because they found it more novel and exciting. Consequently, they were more inclined towards a completely new gaming experience, unlike Users A and D, who had higher demands for certain details in games.

4.2.2 Completion times for the four participants in Experiment Two

Here, I present the clearance times for each participant in Experiment Two for each level in Superhot (Piotr Iwanicki, 2016) and Superhot VR (Iwanicki, 2016).

User A
PC version
Level 1 – shooting –0: 43
Level 2 – punching – 1:09
Level 3 – dodging – 1:15
Level 4 – throwing - 4:30
Level 5 – comprehensive battle- 6:11
VR version
Level 1 – shooting –0: 16
Level 2 – punching – 0:27
Level 3 – dodging – 0:50
Level 4 – throwing – 1:17

Level 5 – comprehensive battle- 6:25

User B

PC version

Level 1 – shooting –1: 27

Level 2 – punching – 1:58

Level 3 – dodging – 2:43

Level 4 – throwing – 3: 37.

Level 5 – comprehensive battle- 7:21

VR version

Level 1 – shooting –0: 21

Level 2 – punching – 0:37

Level 3 – dodging – 1:47

Level 4 – throwing – 3:57

Level 5 – comprehensive battle- 8:24

User C

PC version

Level 1 – shooting –1: 58

Level 2 – punching – 2:47

Level 3 – dodging – 4:53

Level 4 – throwing – 6: 33.

Level 5 – comprehensive battle- 10:28

VR version

Level 1 – shooting –2: 31

Level 2 – punching – 4:24

Level 3 – dodging – 6:57

Level 4 – throwing – 10:36

Level 5 – comprehensive battle- 15:48

User D

PC version

Level 1 – shooting –0: 38

Level 2 – punching – 1:23

Level 3 – dodging – 2:40

Level 4 – throwing – 3: 43.

Level 5 – comprehensive battle- 5:28

VR version

Level 1 – shooting –1: 13

Level 2 – punching – 2:36

Level 3 – dodging – 3:59

Level 4 – throwing – 4:14

Level 5 – comprehensive battle- 5:21

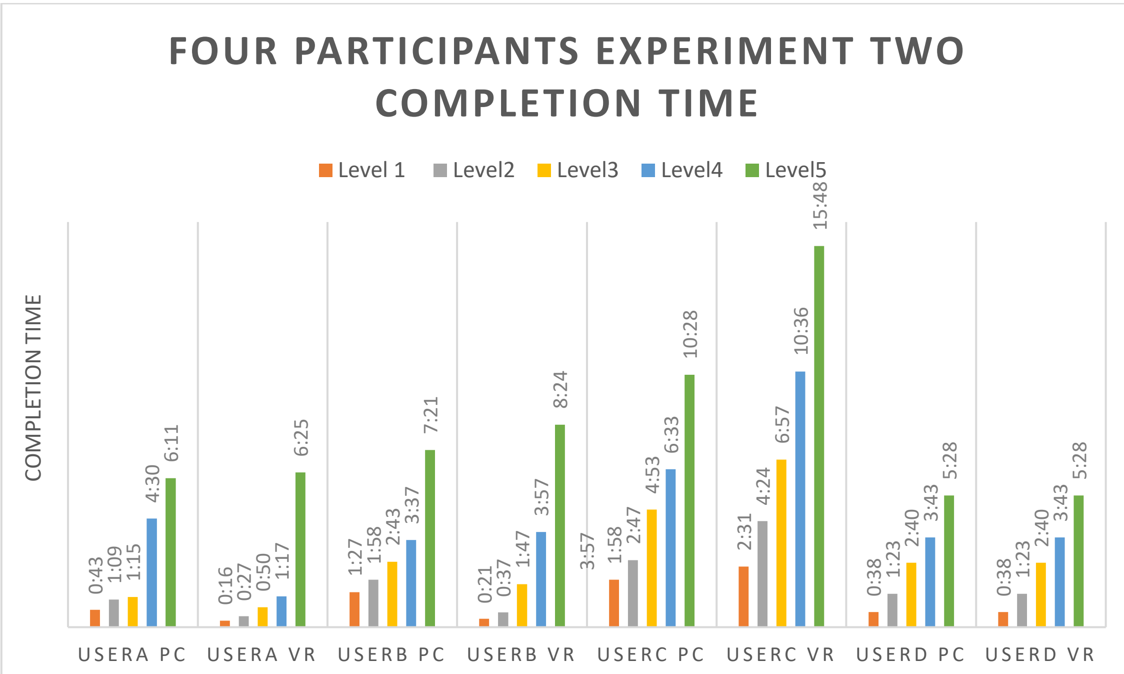

Figure 15: Four participants' completion times for Superhot as well as Superhot VR in Experiment Two

4.3 Point Of Rational

Experiment One

During the VR experience, I observed the behavior of four participants. User A showed signs of excitement before the experiment. However, when User A experienced Scenes 1 and 2, User A did not display much facial expression or emotion. In Scene 3, User A exhibited surprise and admiration. User B also showed signs of excitement. This was because User B had never experienced VR before. During the experiment, User B demonstrated some clumsy operations at the beginning. However, once User B got used to it, everything went smoothly. User B then began to spend more time observing the details of the scenes, especially in Scene 3. User B tried to get as close as possible to see every detail in the scenes. Every now and then, User B gasped in surprise, noting that some elements looked incredibly real. User C, on the other hand, used the VR device for the first time.

Throughout the three scenes, User C expressed amazement and praise, especially in Scenes 1 and 3. This was likely because Scene 1 was their first experience, and Scene 3 was the most beautifully designed. In contrast, User D remained relatively calm. In Scene 1, User D pointed out the lack of details and made similar observations in Scene 2. It was not until Scene 3 that User D began to closely observe the scene's details and expressed admiration.

Experiment Two

In Experiment 2, User A, who had considerable computer gaming experience, completed the PC version quickly and easily at the outset. User A's gaming experience laid the foundation for the subsequent VR version of the test, leading to User A's commendable performance in the basic levels before the final comprehensive level. In the PC version, User B took time to familiarize himself with the controls due to her lack of prior PC gaming experience. However, she adapted quickly. Despite this, she took longer to finish the final comprehensive level, likely due to this inexperience. In the VR version, User B's lack of game experience and difficulty adjusting to the new control method resulted in a longer completion time. User C, inexperienced in both PC and VR gaming, took a considerable amount of time to adapt and finish levels in both formats. Nevertheless, User C remained undeterred and genuinely enjoyed the testing process. User D, with extensive experience in both PC and VR gaming, completed the levels efficiently and easily. However, User D did not display any signs of enjoyment or other emotions.

5 Data Analysis

Based on the data collected above (*Figure 15*), User A completed the PC version of the game slightly faster than the VR version. Both versions of the game were relatively simple until the final combined battle. However, it took User A significantly longer to get through the PC version of the game. On the other hand, User A found it challenging to adapt and get through the combined battle in the VR version. User A felt that there were too many factors to consider in the final battles of the VR version. Additionally, there were so many enemies that User A often forgot what he had learnt in the previous training levels. Moreover, the lack of focus on aiming in the VR version led to a significant loss of accuracy when facing multiplayer battles.

In the PC version of the game, User B spent a relatively longer time completing the games compared to User A. This was attributable to the fact that User B did not have much prior experience with video games. User B spent a longer time on the shooting, punching and dodging levels and a slightly shorter time on the throwing levels. In the full combat level, it took User B longer due to the complexity and challenge of the level. User B's less experience in traditional gaming led to taking long to complete the challenge. User B had a relatively short passage time in the VR version of the game. User B performed relatively quickly in the shooting and boxing levels as in the PC version of the game. User B spent a longer time in the dodging level and slightly less time in the throwing level. In the total combat level, User B spent a relatively long completing the comprehensive battle than the PC version due to the need to deal with more missions and enemies in the VR environment and the adjustment of the head-mounted display.

Overall, there were differences in the time it took User A and User B to complete the different game versions. User A performed better in the PC version of the game, especially in the shooting and boxing levels, while User B performed better in the VR version of the game. Based on the data presented in *Figure 12* and the users' responses, there were differences between User A and User B in terms of their preferences for the PC and VR versions of the game. User A preferred the PC version of the game mainly because of the smaller computer screen, which helped the user to focus and the more accurate way of controlling the mouse, especially in terms of aiming. At the same time, the VR headset was unsatisfactory in terms of comfort; prolonged wearing of the VR headset resulted in sweating and fogging of the lenses, which affected the line of sight.

However, User B preferred the VR version of the game because it offered a deeper immersion and a more realistic interactive experience. The VR version of the game allowed the user to freely rotate their head and body in the game world; thus, gaining an immersive feel that traditional video games could not provide. User B also noted that the VR version of the game was more intuitive, so that users could bring physical feedback to the game through body movements and become more interactive with the game world. This sense of realism and interactivity went beyond traditional video games, as users could bring actual feedback to the game by bobbing their heads or body around rather than simply pressing buttons and waiting for feedback from the computer.

User C had barely played the game before and had little to no experience with VR gaming, so it took him longer to complete Superhot in both the PC and VR versions than the other three users, with User C performing slightly better in the PC version than in the VR version. Although User C did not perform well in the VR version, he stated that he preferred the VR version over the PC version as he preferred the instinctive virtual interaction in the VR version even though the PC version was more intuitive. For example, in the PC version, the WASD button was applied to move and dodge the character, but in the VR version, dodging could be done by tapping the joystick or crouching the body or physically moving your head, which User C found this could not be done in traditional PC games.

User D scored the highest of all participants in both the PC and VR versions due to his extensive experience with traditional video games and some experience with VR games. User D found both games easy to pick up, but he found the VR version's shooting and throwing challenging at first because of the lack of aiming support, such as the crosshairs in traditional first-person shooting games. User D said that although the VR version gave a more innovative gaming experience, he preferred the PC version. The main reason for this preference was that the PC version of the game provided him with a more comfortable playing experience. In contrast, the VR version had a larger viewing area, and he often could not see enemies accurately, and more importantly, wearing the headset for long periods of time made him feel uncomfortable.

Regarding the improvement of the gameplay of the VR version of the game, User A and User D put forward the following suggestions for the VR version of the game, to add a scope or infrared assistive device when aiming the gun to improve the accuracy of the shooting; to reduce the number of enemies or concentrate the enemies in the centre of the POV to enhance the gameplay experience; and to add assistive functions such as adjusting the angle of the POV or adjusting the number of enemies. User B and User C, who were less familiar with the game and made fewer suggestions, but agreed that the immersion of the game could be enhanced by adding more realistic character feedback, such as sound effects or blood effects after being hit.

To summarise, User A and User D preferred the PC version of the game and considered its handling experience and comfort to be superior to the VR version of the game. At the same time, User B and User C preferred the VR version of the game as it provided a deeper immersion and a more realistic interaction experience. User A and User D suggested some improvements. They thought that more assistive features should be provided to make users adapt faster. At the same time, User B and User C felt that the immersion of the game could be improved by adding more realistic character feedback. These ideas and suggestions can provide valuable references for game developers to improve user experience and game integrity.

6 Findings

In this section, I used the data that I collected from Experiment One and Experiment Two, including the questionnaire scores, participants' feedback, and the time they spent during the experiments. I then separated that information into several parts to discuss my findings in these two experiments.

6.1 Participant Performance and Scene Analysis for Experiment One

The total questionnaire score of the four participants' experience of the three scenes in Experiment One showed an upward trend. The total scores of the four players for Scene 3 were higher than that of Scene 2, and the total scores for Scene 2 were higher than those for Scene 1. Meanwhile, the interview responses of the four participants showed that their satisfaction with the three scenes increased gradually, and the average scores also increased gradually. Considering the time taken by the participants to complete the different scenes recorded in *Figure 13* above, I saw that User A exhibited the slowest completion times across all three VR scenes in the Wired Condition: 4 minutes and 49 seconds for Scene 1, 4 minutes and 43 seconds for Scene 2, and 5 minutes for Scene 3. However, in the Wireless Condition, User A's completion time improved significantly to 2 minutes and 35 seconds for Scene 1 and 2 minutes and 21 seconds for Scene 2. I saw that User A initially spent time familiarising himself with the operations in the first scene, even after accepting instructions. In Scene 3, User A spent a considerable amount of time exploring the objects present. User A stated that the wireless setup did not directly contribute to reduced time; instead, familiarity with the operations allowed for faster completion of Scenes 1 and 2.

Similar patterns were observed in the data collected from Users B, C, and D, albeit in different test environments. Users B, C, and D reported that the speed of completing the scenes was not significantly affected by wired or wireless connectivity. However, after completing the wired scene, they believed they became more familiar with the sights and interactions in the wireless scene, resulting in significantly shorter completion times.

Interestingly, while all participants aimed to complete the experience within five minutes, Users A, B, and C wanted to spend more time investigating the objects in Scene 3. User D was more task orientated and focused on interacting with specific elements before concluding the experience. These findings highlighted the importance of striking a balance between user exploration and overall efficiency within the game.

6.2 User Satisfaction and Experience on Experiment One

In Experiment One, four participants with varying levels of gaming and VR experience were asked to experience three VR scenes and complete a questionnaire. User A expressed overall satisfaction with the game and immersive experience; however, they felt discomfort and dissatisfaction during the test due to the heavy equipment. The overall satisfaction and immersion satisfaction of User B was slightly lower as compared to User A. Their presence satisfaction was also lower due to limited space and discomfort at home. As a newcomer to VR, User C had high expectations for his first experience. After User C completed the first scene of Experiment One, he found the overall experience to be good, if not quite what he expected; therefore, after experiencing three consecutive scenes from Experiment One, User C's psychological threshold for the virtual scenes became higher and higher. Initially, User C did not find Scene 1 bad. However, compared to Scenes 2 and 3, Scene 1 appeared unrealistic and boring due to the lack of details. As a result, User C was less satisfied compared to Users A, and B. User D had the lowest overall immersion satisfaction, which might had been influenced by their critical mindset and high expectations from prior VR experiences. Notably, presence satisfaction was consistently lower than immersion satisfaction across all participants and scenes.

6.3 Insights from User Feedback and Interviews

Participants' differences in the game situation, the location of the experiment, and the time required to complete the different scenes led to different experiences of the scenes, which were reflected in the feedback they provided. The feedback sessions, conducted after the questionnaires, revealed additional insights that were not captured by the questionnaire. The participants' overall experience was more positive due to the freedom of movement and lack of physical constraints in the wireless condition. The original intention was to provide a VR experience closely resembling reality. However, the experiment was scheduled to take place at the end of January, but due to heavy rain in the centre of Auckland at that time, User B and User C, who did not have a private car, could not reach the scheduled location. Additionally, User D's flight was cancelled, and he failed to return to New Zealand.

Furthermore, Room WG906, which was originally planned for Experiment One, was under renovation and could not provide enough space for this experiment. As a result, Users B, C, and D were scheduled to complete the experiment at different times and locations, with two participants (User B and C) had to conduct the experiment at another location and the other completed the experiment at his (User D) residence. User A, a student at AUT, was able to visit the primary location (WG906) with a simple explanation, as he was familiar with the school layout. User A did not exhibit significant surprise upon experiencing the first scene, recognising the non-reality of the environment, particularly due to the absence of additional materials and the virtual controller resembling the original VR. However, in Scene 2, when materials were introduced, perception changed, and the human hand replaced the virtual controller. User A reported a high level of immersion and presence, indicating that Scene 2 was highly similar to reality. This observation suggests that incorporating physical principles into VR experiences presented the potential to enhance familiarity and immersion. User B had a similar experience to User A, albeit in a different context. Due to the weather, User B was confined to her residential area, and although he found Scene 2 to be more realistic, he found the VR experience to be incomplete and lacking in true immersion. It became evident that immersion could be improved through software or hardware upgrades and scene enhancements. Additionally, User B experienced discomfort and occasionally removed the headset during the VR experience due to its weight, impacting her overall experience and feedback.

In the Scene 2 experience, it was found that the weight simulation through the counterweight fixed to the left controller was not as effective as the weight simulation through the counterweight fixed to the strut in front of the controller. The weight simulation surprised all four users, but Users A, B, and C expressed dissatisfaction that the weight simulation was unwieldy and resulted in an unstable centre of gravity. Nonetheless, all four users reported an immersive experience, but none of them were satisfied.

Participants experienced both wired and wireless connections during the study, and their responses to the different modes were consistent. After collecting feedback from four participants, a consensus was reached; the wired experience provided better visual quality and stability, whereas the wireless experience offered greater freedom. However, participants, including Users A and B, experienced inconvenience, and disruption from the connection cable, despite the cable being only 2.5 metres long. Users C and A required assistance during the wired experience due to cable tangles caused by frequent 360-degree rotations. User feedback indicated that the wireless experience was satisfactory in Scene 1. Still, system errors and loading issues negatively affected Scene 2, reducing picture quality and stability as compared to the wired experience.

In Scene 3, the wireless version was unavailable due to the large number of meshes and textures used, which resulted in significant frame loss during testing. Therefore, the wired version was exclusively used for Scene 3. Surprisingly, all four participants unanimously agreed that Scene 3 offered the best experience for them. The intricacy of the scene and the opportunity for further exploration was cited as reasons for their positive perception. Users A, B, and C reported spending the longest time in this scene.

6.4 Enhancing Immersion and User Experience

By analysing users' feedback, we could observe that software and hardware upgrades were required to enhance immersion. This could involve improvements in modelling, creating intricate scenes, increasing virtual interactions, and utilising higher-resolution head- mounted displays. Users A and C agreed that enhanced immersion would heighten the sense of presence. At the same time, User D emphasised the importance of an immersive experience that would make users forget they were in a virtual environment, suggesting that virtual scenes should be remarkably similar to the real world.

Considering the user feedback, it was important to strike a balance between the need to allow users to explore and maintain overall game efficiency. Additionally, addressing factors such as comfort, weight, cable management, and system stability would contribute to a more satisfactory VR experience.

6.5 Participants Performance and Analysis for Experiment Two

User A reported that it took some time to adjust the head-mounted display during the game. And based on the completion time data presented in *Figure 15*, we can see that User A had relatively short completion times in the PC version of the game. His performance at the shooting and boxing levels was good, and he spent less time on them. However, User A also spent a longer time completing the full combat level because there were more tasks and challenges involved, and he spent a longer time on the dodging and throwing levels.

In the VR version of the game, User A spent a long time getting through the game and spent less time completing the shooting and boxing levels, which was the same as in the PC version. However, it took him longer to complete the dodging and throwing levels. He spent less time completing all the combat levels.

Figure 16: Game- Superhot- PC version

Figure 17: The VR version of Superhot, as described by participants, VR had a larger viewer areathan the PC version.

In the PC version of the game, User B spent a relatively long time completing the game. She spent more time on the shooting, boxing, and dodging levels and slightly less time on the throwing levels. Due to the complexity of the combat levels and her limited experience with traditional games, it took her longer to complete the entire combat level. In contrast, in the VR version of the game, User B completed the shooting and boxing levels very quickly. It took her longer to complete the entire combat level due to the need to deal with more tasks and enemies in an immersive VR environment, but also the difficulty User B had adjusting to the head-mounted display. Overall, there was a difference in completion time it took User A and User B to complete the different versions of the game. User A performed better in the PC version, while User B performed better in the VR version.

Additionally, on the provided data and user responses, there were differences in preferences for the PC and VR versions of the game between User A, and User B. User A preferred the PC version primarily because he found that the smaller computer screen helped him to concentrate and because the mouse control was more accurate for greater accuracy, particularly for aiming. User A found the VR headset too heavy, and his vision was impeded by foggy and sweaty lenses, thus making it uncomfortable. In addition, User B preferred the VR version of the game for its deeper immersion and more realistic interactive experience. The VR version allowed users to freely rotate their heads and body in the game world, providing an immersive feeling that traditional video games could not possibly offer. User B also noted that the VR version was more intuitive and allowed for physical feedback through body movements, creating a more interactive game world. This sense of realism and interactivity went beyond traditional video games, as users could physically respond to the game by bobbing their heads or body rather than pressing buttons and waiting for computer feedback.

Notably, User C, who had little to no gaming experience and very little exposure to VR games compared to the other three users, devoted more time to familiarising himself with the PC and VR versions of Superhot. In the PC version, User C performed slightly better than in the VR version and expressed a clear preference for the VR version due to the instinctive virtual interaction it provided. For instance, while the PC version required using the WASD keys for character movement and dodging, the VR version allowed dodging through a nudge of the joystick, crouching, or head movements. Notably, User C perceived that the VR version offered a higher level of interaction compared to the PC version, which he found lacking in this aspect.

Of all the participants, User D achieved the best scores in both the PC and VR versions, thanks to his extensive experience with traditional video games and some exposure to VR gaming. User D mentioned that both versions were simple but found the shooting or throwing in the VR version challenging because of the lack of precise aiming assistance when playing VR games. The larger POV (*Figure 17*) in the VR version often made it difficult to spot the enemies, and the discomfort of wearing a head-mounted display for long periods of time made User D question whether he would continue to play games using a VR device. User D believed there was not enough incentive for him to buy or play VR devices or games at this stage, and he preferred the PC version, which he found was more comfortable to play.

User A and User D suggested adding scopes or crosshairs to the game to improve shooting accuracy and reduce the number of enemies, along with gameplay enhancements in the VR version of the game or focusing them on the centre of the POV to enhance the gameplay experience. They also recommended introducing assistive features such as adjusting the POV angle or the number of enemies. User B made fewer suggestions but mentioned that immersion could be enhanced by adding more realistic character feedback, such as sound effects or blood stains when being hit. User C suggested adding more interactive elements to the game. The comments and suggestions made by the four users were as above, all of which could provide valuable references for game developers to improve user experience and game integrity.

After analysing and summarising the data and responses from Users A, B, C and D, the following conclusions, and analyses were drawn User A preferred the PC version of the game because it was easier to concentrate on a smaller computer screen. User A also valued the increased accuracy provided by the mice as a controller, particularly for shooting.

However, The VR headset caused User A to sweat and the lenses to fog up, which could affect vision. Despite these problems, User A performed better and finished the levels faster on the PC version. While User B liked the VR version of the game because it offered a more immersive and realistic interactive experience, the ability to move the head and body within the game world provided a level of immersion that traditional video games cannot match. User B performed well in both versions, but she performed better in the VR version and as the VR version offered a more immersive and interactive experience, User B favoured the VR version. Notably, User C, who had little to no gaming experience, spent a longer time than the other users adjusting to both the PC and VR versions of the game.

User C performed significantly better in the PC version but still preferred the VR version. Despite performing poorly in the VR version, User C appreciated the intuitive virtual interactions it provided, such as using bodily movements to evade attacks. These interactions were lacking in the PC version, influencing User C's preference. User D, who had extensive experience with traditional video games and some experience with VR gaming, achieved top scores in both the PC and VR versions. Initially, User D found the aiming in the VR version challenging due to a lack of accuracy. Although User D acknowledged that VR provided a novel gaming experience, the large viewing area of the VR headset sometimes made it difficult to see enemies accurately. The discomfort of wearing the headset for long periods of time made User D sceptical about using the VR device for a long period of time, and he, therefore, favoured the PC version.

In conclusion, User A preferred the PC version for its ease of use and comfort, while User B liked the VR version better for its immersion and realism. User C preferred the VR because, he believed that the PC version could not replace the VR version's interaction. User D performed admirably in both versions but preferred the PC version due to concerns about comfort and practicality. These observations and suggestions could be a valuable reference where game developers were trying to optimise the user experience and overall gameplay.

6.6 Associations Beyond Data

In accordance with the overall trends observed from the data collected in two experiments, it became evident that users tended to prefer VR scenes that offered richer content and more engaging interactivity. This inclination could be attributed to users' innate proclivity towards being drawn to intricate and immersive environments. In the second experiment, although users varied in their experiences and preferences, it is noteworthy that, on the whole, the four participants spent more time in the VR version compared to the PC version. Assuming these were similar games, it is reasonable to infer that the VR version possessed a higher level of appeal or potentially presented a steeper learning curve. Consequently, this could be considered a hindrance to the development of VR games. One potential avenue for future VR game development could involve reducing the difficulty of VR games or introducing optional difficulty settings to cater to a broader audience. When dealing with user feedback regarding the discomfort of virtual reality headset (VR) weight on the user experience, several factors needed to be considered, including subjective feelings and objective data. User feedback often included their subjective experiences, such as feelings of stuffiness and discomfort, which could be attributed to various factors, including the weight and material of the headset. However, quantifying these subjective feelings directly in the data could be challenging, necessitating a more in-depth analysis.

In Experiment One, I observed users attempting to grasp or pick up the same object multiple times. This is an issue that could not be discerned from the data alone. In the scenario I created for Experiment 1, I was knowledgeable about the correct methods for grasping or interacting with objects during the design and testing phases. However, participants were not pre-informed about these specifics; I only conveyed information about the functions of the buttons on the controllers. Consequently, the key takeaway here was the necessity of offering users' additional guidance or instructions to facilitate their understanding and reduce the learning curve. The sensation of stuffiness resulting from prolonged wear of a VR helmet, as mentioned by User A, might be associated with the material and ventilation of the helmet. While this issue could have significantly impact user comfort and experience, it does require further research and testing to pinpoint the exact cause. Additionally, the time required for users to acclimate to a VR headset might have varied from person to person.

Some users might require more time to adapt to the weight and pressure of the helmet, while others might adjust more quickly. This variability could be related to the user's physical strength and tolerance, and these differences need to be taken into consideration.

The ultimate goal was to enhance the user's VR experience. Based on the study's results, several improvement measures could be considered, including the development of lighter and better-ventilated helmets, the provision of more guidance on correct helmet wearing techniques and adaptation times, and the offering of adjustable helmets to accommodate the diverse needs and physical strength levels of different users. By considering both subjective experiences and objective data, we could better cater to user needs, enhance their comfort, and improve overall satisfaction.

7 Discussion

In this chapter, I describe the factors that influenced immersion and user experience in Experiment One. Additionally, I discuss the results of the comparison between two similar games in Experiment Two. Lastly, I highlight the limitations of the experiments and provided insights into future work in this field.

7.1 Perception of Engaging Visual Stimulation

Overall, the data presented in Chapters 4 and 5 suggest that incorporating detailed scenes and intricate models enhanced the level of immersion experienced by the user.

The findings from Experiment One indicated that individuals tended to find scenes that possessed higher levels of detail or incorporated more complex models and interactions to be more engaging. This finding was consistent with Bowman and McMahan's (2007) argument for the effective enhancement of a user's VR experience. Their findings suggested that, to improve the quality of VR immersion, it would be necessary to either improve the quality of the head-mounted display or to enhance the computational system that supports the head-mounted display (Bowman & McMahan, 2007).

In addition, on the feedback from the four participants, there was a correlation between immersion and presence, whereby an increased level of immersion was associated with a heightened sense of presence, which was in line with Wilkinson et al. (2021) research. The findings of their study revealed that it was essential to note that while immersion and presence were distinct concepts, technology that enhanced immersion could also contribute to enhancing presence (Wilkinson et al., 2021). Improving the display hardware or software could possibly enhance the sense of presence and complete immersion in the virtual environment. This finding was consistent with Wilkinson et al.'s (2021), the level of immersion was dependent on the representation of the scene, and therefore more detailed 3D models and greater interactivity resulted in higher levels of immersion. Data collected from the four participants indicated that the scenes that exhibited the greatest level of interactivity and successful depiction of the intended environment evoked an intensified sensation of immersion and presence. This result further supported the findings of Wilkinson et al. (2021) and Park and Woo's (2021) research on the direct relationship between the level of realism in each scene or model and the extent of immersion and presence perceived by the user.

7.2 Wireless Operation and Physical Movement

The participants provided comparable feedback after engaging in three VR games with common ground. Despite initial scepticism about the potential impact of wireless operation on the gaming experience, participants made it clear that they preferred wireless operation to wired operation. There were no cables attached to the device, so players could move around unimpeded and movements such as bending or rotating were not disturbed.

Users A and C were tested in an unobstructed environment and demonstrated higher mobility in the wireless test than those in the wired experiment. The wireless setup allowed them to examine the details of the scene with increased precision. However, Users B and C experienced difficulties executing actions requiring extensive arm movements or body rotation due to their limited physical space, rendering them unable to perform the desired arm movements or body rotations. The feedback proved that to ensure a positive VR gaming experience, the players needed access to a large amount of free space to move around. The space required for an enjoyable experience would be larger than the room needed for a conventional video game.

The third scene of Experiment One, which featured push-pull interaction, was perceived as more realistic than the automatic door opening in the first and second scenes. However, all four participants found it somewhat cumbersome. An individual experienced symptoms of motion sickness while walking, however, all participants consistently preferred more realistic or practical interactions. As suggested in this study, interactions involved in VR gaming were distinct from those in traditional gaming, which typically entailed using a mice, keyboard, or mobile device screen for input. The heightened level of immersion in VR gaming required increased physical activity, a feature not typically found in conventional video games. VR games offered users more independence and a wider range of opportunities for interaction and movement than traditional video games.

Furthermore, Users' feedback suggested that using a bulky headset led to an unsatisfactory experiential outcome. Furthermore, their feedback revealed that the pre-existing mood of individuals might had an adverse effect on their perception of presence. I found that heavy headsets and pre-existing emotional states did have an impact on user performance. Nonetheless, the pre-existing mood did not influence the sensation of complete involvement and immersion in the encounter. I concluded then that increased immersion may enhance the sense of presence, whereas a decrease in presence caused by extraneous factors might not lead to a decrease in immersion. The limited sample size of the experiments and the subjective nature of the participants' feedback gave rise to certain limitations and subjectivity in the findings of this research.

7.3 Comparison Between VR and PC Versions in Experiment Two

Based on the data analysis from Experiment Two and the interview feedback, I found that the VR version of the same game (with similar gameplay style, character controls, story setting, and modelling style) was more immersive than the PC version. Two out of four participants preferred the VR version of the game, while the remaining two participants preferred the PC version. Still, they acknowledged that the VR version offered a wider POV and allowed for a more immersive experience. However, they mentioned a tendency to lose focus on the enemies in the VR version and this was because participants believed that had too large a POV presented them with an overwhelming amount of information, making it difficult to make quick decisions when large numbers of enemies appeared. At the same time, they told me that the larger FOV that came with VR gaming gave a greater sense of immersion but also more information to process, which fitted with Crundall's (1999) argument that a larger FOV required more cognitive resources to be allocated to process more information (Crundall et al., 1999).

Even though Jennett et al.'s (2008) immersive questionnaire lacked some of the questions required for participant interviews, Jennett et al.' (2008) research questionnaire was initially intended to assess games. However, it might not be applicable for evaluating other aspects of the VR experience, such as teaching or real-life experiences. In these areas, many of the questions in the Jennett et al. (2008) questionnaire might not be able to generate valid feedback if they did not include win/lose judgements. The VR experience, admittedly, would vary depending on factors such as the user's familiarity with the technology or the hardware specifications of the VR device. These variables could greatly impact the sense of immersion or presence in the same scene. It was also worth noting that the questionnaire did not address motion sickness as a potential side effect of the VR experience. This highlighted a limitation in the existing research. During the study's design phase, a range of techniques and questionnaires were considered to effectively assess and delineate the phenomenon of immersion in gaming. I selected the questionnaire developed by Jennett et al. titled "Measuring and defining the experience of immersion in games"(Jennett et al., 2008) because to its alignment with the particular objectives and characteristics of this study. It was important to note that the IPQ (igroup presence questionnaire), which was frequently cited, was also considered. However, after conducting a thorough assessment, I concluded that the IPQ was not totally suitable for the following reasons:

Although the components assessed by the IPQ possessed inherent value in various contexts, they did not exhibit as strong alignment with the research aims of this study as the dimensions evaluated by the questionnaire developed by Jennett et al. (2008).

The limitations of the present investigation, including time constraints and participant availability, proved a challenge in incorporating an additional thorough instrument, as doing so could potentially compromise the integrity of the already obtained data. It is imperative to emphasise that the choice to exclude the IPQ was not a criticism of its validity or utility, but rather a consequence of the limits and emphasis of this study. Subsequent investigations with alternative parameters or more flexibility in their experimental design might found the IPQ as a helpful augment to their methodological framework.

Finally, the feedback from the four participants and the development of the Experiment One scene supported the idea that VR gaming offered a unique level of immersion, where the user felt constantly present in the virtual scene regardless of head movement. This was an experience that PC games cannot provide. The previously conjectured interaction of the weight simulation was verified in Experiment One, Scene 2, to improve immersion.

However, the object I used in the experiment did not precisely match the appearance and weight of the torches I created in the experimental scenes. Based on participant feedback, a cylindrical counterweight (*Figure 6*) that approximated the shape of the flashlight was found to be more effective than a normal counterweight suspended directly from the controller, as it provided a more immersive experience than using the controller alone. However, the participants also mentioned that, since the weights were not specifically designed for the controller, their instability during the experimental tests, after adding the weights, caused a shift in the centre of gravity and hindered the proper use of the controller. This issue needed to be further investigated and addressed.

The overall conclusions of this study highlighted the advantages of VR games in providing a sense of immersion. Participant feedback data and interview results suggested that VR games could provide a higher level of immersion and presence than traditional computer games. This would be of significance for the development and application of VR technology. In addition, the findings indicated the importance of environment reproduction, detail presentation and interactivity in enhancing immersion, which provided guidance for the design and improvement of VR games.

A combination of experiments and interviews was adopted in data collection in this study. Experiment One collected subjective feedback data from participants by comparing the differences across the three different VR scenes. Experiment Two further compared participants' experiences of VR and computer versions of the same game. The interviews aimed to gain insight into participants' perceptions and experiences of the VR gaming experience. I also cited existing questionnaire instruments and referenced relevant literature to support the arguments of this study.

7.4 Limitations

There were several limitations to this study. Firstly, the sample size was limited to include only four participants. Even though all four participants had different relevant gaming experiences, the limited sample size did not allow for broad inferences to be made about the views and responses of the population. Secondly, participants' feedback was subjective and might be influenced by individual differences and preferences. In addition, this study only dealt with specific types of games and specific immersion factors and other types of games and aspects of immersion might have had different effects. Therefore, further research is warranted to validate and generalise these findings.

When considering the results of Experiment One and Experiment Two, as well as the feedback from the participants, we could conclude that VR games could provide a higher level of immersion and presence than traditional computer games. In VR experiences, augmenting scene detail and interactivity, to more realistically reproduce the user's current physical environment could enhance the sense of immersion and presence. Experiment Two was a study of two games with similar graphics, story, and action, created by the same production team and released within a few months of each other. Notably, this study would be worthless if a very advanced PC game were compared to a very poor VR game, which was one of the limitations of this study.

Another limitation of my study was that I had originally planned to use multiple different head-mounted display devices to test the same game and explore the impact of different devices on immersion. However, due to limited resources, I had been forced to use only some specific equipment, which became a limitation of my thesis. This limitation presented challenges in interpreting and generalising the findings. Since only one device was employed, it was difficult to determine whether other head-mounted display devices produced different levels of immersion. Moreover, the experiments did not include potential device-specific factors affecting the overall user experience. Despite the above limitations, my study provides an initial understanding of immersion in VR gaming. By gathering feedback and data exclusively from participants using the selected device, I had successfully explored significant aspects of immersion in VR games and provided valuable insights into game design and user experience.

While this study yielded initial insights into VR gaming immersion, several limitations were evident.

The involvement of only four participants might had obscured broader perspectives, impacting the robustness of our statistical findings. Feedback, though valuable, bore inherent subjectivity; future endeavours could have benefited from standardized scales and quantitative methods to mitigate this. The research's focus on specific game genres might not captured the complete immersion spectrum, suggesting that diverse game genres should be considered in future studies. Moreover, testing with just one device restricted our insights; a variety of devices would have painted a clearer picture of device-specific effects on immersion. Nevertheless, despite these constraints, the research provided foundational understandings in the realm of VR immersion, underlining the importance of addressing these issues for more precise and reliable outcomes in subsequent studies.

Despite the study's limited scope, future research efforts would extend these findings by including a wider range of head-mounted display devices and more participants. This would help to provide a more comprehensive understanding of the impact of different devices on immersion in VR gaming, ultimately provided more informed recommendations for game developers and researchers. However, this limitation also provided direction for future research to follow and expand upon, allowing for a more in-depth study of the effects of different devices on VR game immersion.

7.5 Future Work

In the last few years, there has been a rise in smaller and more affordable VR headsets, primarily through companies like Meta or Pico. These advancements in technology have made VR gaming more accessible to a wider audience. As leading computers and high-speed Internet have developed, VR now shows tremendous potential, and the shrinking size and increasing functionality of the hardware has made VR even more popular. Furthermore, there are numerous application areas for VR technology besides gaming, with employee virtual training being one of them. VR provides interactive simulations that closely resemble real-life scenes. The benefits of virtual training include reduced risk, more opportunities for practice, and cost-effectiveness. The immersive nature of VR makes it an excellent tool for enhancing the customer experience (Galil, 2022). For instance, VR could create virtual product demonstrations or showrooms that allowed customers to experience products before purchasing. This creates an unforgettable experience and could significantly contribute to customer loyalty. Another exciting application is product design, where VR allows designers to create virtual models of products and test them in a simulated environment. This reduces the need for physical prototypes, saving time and money in the design process. Additionally, the healthcare industry could benefit greatly from VR technology, as VR could also be used for therapeutic purposes. For example, VR has been used to treat patients with phobias or anxiety disorders by exposing them to virtual environments that gradually desensitize them to their fears. This innovative approach shows promising results in helping individuals overcome their fears in a safe and controlled setting. Furthermore, VR could also be utilized for pain management during medical procedures, providing patients with a distraction from discomfort and reducing the need for strong pain medications (S. Kim & Kim, 2020). VR's immersive and interactive nature could create a more engaging and effective patient therapeutic experience.

Looking ahead, there are several future research directions to explore. One area of interest is the development of more advanced and intuitive user interfaces for VR. In VR environments, improvements in input devices, such as haptic gloves or eye-tracking systems, could enhance immersion and interaction. Additionally, exploring the potential of VR in collaborative environments, where multiple users could interact and collaborate within the same virtual space, holds promise for various industries. Another future research direction is the investigation of the long-term effects of VR on users, including potential psychological and physiological impacts. Understanding how prolonged exposure to virtual environments might affected individuals' mental health and well-being is crucial for the responsible development and implementation of VR technology. Furthermore, exploring the integration of artificial intelligence algorithms into VR systems could enhance the realism and responsiveness of virtual environments, creating more dynamic and interactive experiences for users.

As a result, the development of Extended Reality (XR) technology will likely become mainstream in the future. XR could be understood as a combination of augmented, virtual, and mixed reality. At the end of June, during WWDC, the renowned technology company Apple has unveiled their first head-mounted display device, the Apple Vision Pro. Before this launch, there was much speculation on the internet about how Apple would introduce a ground-breaking VR head-mounted display. However, Apple surpassed all expectations by unveiling its first XR head-mounted display. At the launch event, Apple gave a fascinating demonstration of the productivity boost that the Apple Vision Pro brought to the workplace, particularly in the office demo, where Apple showed off a combination of its laptops and Apple Vision Pro, which may represent an upcoming trend. This combination offered users a greater variety of options when choosing office appliances. XR technology holds immense potential for education, as it could leverage the user's natural spatial perception to effectively deliver large amounts of information and could entertain and educate individuals through games, interactive systems, and more. XR could even significantly reduce learning costs in certain subjects, such as medicine infrastructure or subjects requiring extensive practice or simulation. Gestures are dominant in interacting with XR devices because they are natural movements in real life. There were several factors to consider when designing gestures and these factors included the size of the user's hand, the user's personal gesture habits, the reach of the hand, the POV of the device, and the accuracy of gesture recognition. If a movement occurred outside the device's POV, it was not recognised, and no feedback was provided. The accuracy of gesture recognition directly impacted the gesture's precision, which had to be designed to be relatively clear in the case of ambiguous gestures. Much like the development of touch-screen phones, which initially required a stylus for interaction, they had evolved into smartphones that could recognise and respond to multiple simultaneous touch inputs.

Future XR devices will be lighter, more comfortable, with higher definition and performance. These advancements would greatly enhance the overall user experience and made XR technology more accessible to a wider audience. Additionally, future XR devices might also incorporate advanced eye-tracking technology, allowing for more intuitive and seamless interactions with virtual environments. They would also be fitted with more advanced sensors and smarter interactive devices. Innovations in feature-rich content would benefit the growth of XR, and it is expected that future developments in XR would concentrate on creating interactive and individualised experiences. Technologies that increase human-computer interaction, such as gesture recognition, speech recognition, and eye tracking, continue to advance and innovate to create more natural and effective interactions. In conclusion, future advancements in XR—whether in VR, mixed reality, or augmented reality—have the potential to reshape society through hardware innovations, enhanced human-computer interactions, and the evolving applications of artificial intelligence.

Based on the findings and insights derived from my study, there are discernible avenues for future research endeavours and investigations. The research conducted has contributed to the understanding of the components that contributed to immersion and presence in virtual reality. However, it has also generated additional enquiries and potential avenues for further investigation. This is my conceptualisation of the trajectory of my work in respect to forthcoming enquiries: One of the noteworthy observations derived from the conducted experiments pertained to the considerable importance of ensuring user comfort in the design of VR hardware. Further investigation could be conducted in the future through the implementation of prototyping and testing methodologies to explore novel ergonomic solutions. Determining the design variables that exerted the greatest influence on comfort and exploring strategies for their optimisation would be of immense value. Through the utilisation of feedback obtained from the study, it became possible to identify precise regions of discomfort and afterwards undertake the redesign of headsets in accordance with these findings.

The influence of user emotion on virtual reality immersion was emphasised in my research. Conducting a comprehensive investigation to objectively examine this association would be intellectually stimulating. This may entail the observation of users' emotional states through the utilisation of biometric measures, afterwards establishing correlations between these states and the levels of immersion experienced during different virtual reality (VR) encounters. The findings derived from this study had the potential to provide valuable guidance to virtual reality content developers in the development of experiences that effectively catered to, and perhaps controlled, the emotional state of users.

The occurrence of motion sickness among certain participants during the conducted studies highlighted the necessity for further investigation in the field of motion sickness mitigation. Considering the present study, it was recommended that forthcoming investigations be conducted to examine alternative methodologies or technologies (such as diverse refresh rates and scene stabilisation approaches) to mitigate the occurrence of motion sickness among users.

The Advancement of Interaction Techniques: The research conducted in my work had established a fundamental comprehension of the ways in which user interactions contributed to the phenomenon of immersion. One potential future direction involved the development of innovative interaction approaches or tools, which might entail the integration of haptic feedback mechanisms with intuitive control schemes. Subsequently, it would be valuable to assess the effects of these advancements on the levels of presence and immersion experienced within virtual reality environments.

The investigation into the influence of an expanded point of view (POV) on immersion implies the existence of a potential ideal range or upper threshold beyond which the widening of the POV might had a detrimental effect on immersion. A comprehensive investigation could be undertaken to examine this matter, thereby offering a set of recommendations for makers of virtual reality entertainment.

The exploration of personalised virtual reality (VR) learning environments could be a promising avenue for further investigation, leveraging the potential of VR technology in the realm of education. This prospective study would centre on the development of tailored learning experiences that cater to the unique learning styles and preferences of individual learners. By incorporating the results obtained from my research, this project could strive to optimise the levels of immersion and retention among pupils.

The findings of my study had provided valuable insights into the concepts of virtual reality (VR) immersion and presence. Additionally, these findings had opened multiple avenues for future research in this field. By leveraging the groundwork established in my research, subsequent scholars might further explore the intricacies inherent in virtual reality (VR) encounters, thus propelling the frontiers of this revolutionary technological innovation.

8 Conclusion

Immersion and presence are fundamental concepts in VR. Immersion refers to a state in which one is fully immersed and deeply engaged in the VR environment, disregarding the reality around them (Berkman & Akan, 2019). Achieving immersion and presence is crucial to creating captivating and engaging VR experiences, and this is accomplished through photorealistic graphics, high-quality audio, and intuitive controls (Freeman et al., 2017). However, creating a strong spatial awareness and physical presence in a virtual world is challenging (Steuer, 1992), and despite these challenges, VR had the potential to revolutionise various industries, including education, healthcare, and social interactions (Bailenson, 2018). One of the key benefits of VR in education is the ability to transport students to different locations and time periods, providing them with immersive learning experiences. In healthcare, VR has been used for pain management, therapy, and even surgical training. Additionally, VR had the potential to enhance social interactions by allowing people to connect and interact in virtual spaces regardless of their physical location.

This study supports previous research and contributes to understanding immersion and presence in VR. By adjusting factors such as POV, simulated manipulation, and other relevant variables, this study extends the existing research on defining these concepts and investigated the factors that influence them. Results from a range of experiments revealed that increasing image quality, texture, and mesh complexity could significantly enhance immersion (Lombard & Ditton, 1997). Additionally, a higher degree of interaction in VR environments significantly impacted the feeling of presence (Slater & Steed, 2000). These findings were consistent with previous research on presence and immersion in virtual environments (Witmer & Singer, 1998), suggesting that the quality and richness of the virtual environment served a crucial function in stimulating presence and immersion.

Furthermore, my experiments revealed that the comfort of the head-mounted display Meta- Quest 2 (Labs, 2020), its connectivity, the size of the environment in which it was used, and even the user's mood before and during the experience were all factors that influenced the sense of presence. These findings provide valuable insights for developers and manufacturers of virtual display hardware.

The findings from Experiment One consistently indicated that enhancing image quality, texture, and complexity in virtual environments had a substantial impact on the level of immersion experienced by participants. Additionally, the degree of user engagement and the immersive nature of VR technology played crucial roles in heightening the sense of presence, fostering a greater sense of authenticity within the simulated environment. These findings align with previous research, underscoring the importance of creating high-quality virtual environments that deliver immersive experiences to evoke a genuine sense of presence. The investigation into various factors influencing presence, including the comfort provided by head-mounted displays and users' emotional states, has provided valuable insights for developers and manufacturers of VR hardware. Furthermore, this research made a significant contribution to advancing immersive VR experiences by improving their appeal and creating more user-friendly interfaces. In Experiment Two, I observed that the VR version of the game resulted in a more immersive gaming experience compared to the PC version, primarily due to its wider POV. VR technology's three-dimensional interaction capabilities enhanced the overall gaming experience, setting it apart from a regular computer screen. Based on the assumptions discussed, I predicted that achieving immersion and presence in VR technology would require improved head-mounted displays, better-configured computers, and higher-quality virtual scenes. Additionally, developers of VR headsets should strive to develop high-quality software that enhances immersion while considering factors that affected the user's wearing experience, such as weight distribution.

Through extensive research on immersion and presence in Virtual Reality (VR), I have made significant discoveries regarding the various factors that contribute to creating exceptional VR experiences. The comprehensive examination of elements like POV, simulated interactions, and image quality has enriched our understanding of strategies to enhance immersion and presence in virtual environments.

A notable discovery from Experiment Two was that a wider POV in VR games exceeded the level of immersion observed in conventional personal computer (PC) games. This finding underscored the critical importance of consistently enhancing head- mounted displays and software to achieve optimal levels of immersion and presence.

However, it is essential to acknowledge the limitations of this study, as the small sample size might restrict the generalizability of the research findings to a broader and more diverse population. Therefore, future studies should aim to include a larger pool of participants to obtain a wider range of perspectives and stronger empirical evidence regarding users' attitudes and responses to VR experiences.

Two unexpected findings beyond the scope of the experiments warranted further consideration. The weight and comfort of VR headsets had a significant impact on the user experience. Comfort played a crucial role in determining whether users could comfortably wear the headsets for extended periods. Although headsets had made considerable advancements in size and weight, the experiment revealed that uneven weight distribution in headsets negatively affected the overall user experience.

Additionally, the manifestation of motion sickness during VR gaming was observed in two participants, specifically User B and User C. The unwieldy nature of the headsets and the occurrence of motion sickness led participants to request breaks and voluntarily remove the headsets. These observations provided valuable insights for the ongoing development of VR hardware technology.

Notably, the sample size of this study was limited to four participants, which restricted the generalisability of the findings. Therefore, conducting future studies with larger sample sizes would provide additional insights into how individuals with varying experience levels perceived and responded to VR experiences. Understanding the impact of these factors on presence can help developers and manufacturers enhance the overall user experience.

Additionally, considering the user's mood as a contributing factor emphasized the importance of creating a positive emotional state to maximize immersion in virtual environments.

After extensive literature research, two experiments, and careful data analysis, I have concluded that VR games inherently offer a heightened sense of immersion compared to traditional video games. This was primarily attributed to their encompassing 360-degree perspective, which immersed players within the virtual environment. In contrast to the fixed screens of traditional games, VR's expansive field of view, combined with realistic interaction simulations made possible through motion sensors, hand controllers, and even full-body tracking, allowed players to engage with the virtual world in a more intuitive and direct manner. Additionally, certain technological elements played pivotal roles: head-mounted displays enhanced visual immersion, spatial audio provided authentic soundscapes, tactile feedback devices offered sensory immersion, motion tracking ensured accurate player representation, and high-quality graphics amplified realism. This combination of features positioned VR technology at the forefront of immersive gaming, offering a depth and engagement that traditional platforms found challenging to emulate.

To fully unlock the potential of VR in the future, addressing the obstacles hindering genuinely immersive and realistic experiences was crucial. Continuous progress in display technology, graphics rendering, and haptic feedback presented exciting opportunities to enhance immersion and presence. To fully capitalize on VR's potential, developers and researchers needed focus on creating customized VR experiences that cater to various domains, such as education, healthcare, and social interactions. The profound impact of VR was widely recognized, as it had the potential to revolutionize multiple industries, transforming how individuals accessed information, received medical care, and engaged in global interactions. By leveraging feedback, developers and researchers could continuously refine VR experiences to better meet the specific needs and preferences of users in different domains. This iterative process ensured that VR applications became increasingly immersive, realistic, and tailored to enhance learning, healing, and social connectivity. As a result, the transformative power of VR can be fully harnessed to revolutionize not just a few industries, but the way we experience the world.

In conclusion, the comprehensive investigation into immersion and presence in virtual reality offered valuable insights to advance more captivating and transformative virtual experiences. These findings could be effectively applied to optimize hardware, software, and environmental elements, maximizing the potential of VR technology. This progress was expected to usher in a new era characterized by interactive digital environments that deeply engaged users. The potential for innovation in VR technology is virtually limitless, with its impact spanning across various fields. For example, in the field of education, VR technology can revolutionize traditional teaching methods by providing immersive and interactive learning experiences. Additionally, industries such as healthcare and architecture could benefit from VR's ability to simulate real-life scenes and environments, allowing professionals to train and make informed decisions in a safe and controlled virtual setting. The continuous advancements in VR technology held promise for creating a more connected and experiential world for users across different sectors.

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10 Appendix

10.1 Experiment One and Two participants' questionnaire data

Table 1: Statistics of the four participants' scores on the experimental questionnaire in ExperimentOne and Experiment Two.

User A					User B					User C					User D				
Scene 1	Scene 2	Scene 3	Superhot	SuperHotVR	Scene 1	Scene 2	Scene 3	Superhot	SuperHotVR	Scene 1	Scene 2	Scene 3	Superhot	SuperHotVR	Scene 1	Scene 2	Scene 3	Superhot	SuperHotV
4	4	5	3	5	2	3	4	4	5	3	3	4	3	4	2	3	4	3	4
3	3	4	5	5	2	4	5	4	5	2	3	3	5	5	2	3	4	5	5
3	3	3	3	5	4	5	5	4	5	2	3	3	3	5	2	3	4	4	5
1	1	1	2	5	5	5	5	5	5	1	1	1	3	5	1	1	1	4	5
5	5	5	3	5	2	3	3	4	2	3	4	5	2	4	1	1	2	4	4
3	2	1	5	2	1	1	1	5	2	2	2	1	5	2	5	5	3	5	2
5	5	5	5	5	1	1	1	1	5	3	4	4	4	4	2	2	3	3	3
3	4	4	1	5	2	3	5	1	5	2	3	4	1	4	2	3	4	1	4
2	2	2	3	1	1	1	1	4	1	2	2	2	4	2	2	2	2	4	2
1	1	1	1	1	3	2	2	1	1	3	1	1	3	2	3	1	1	3	2
2	4	5	4	5	2	3	4	3	5	2	3	4	3	5	2	3	4	2	5
3	4	4	2	5	1	2	2	1	5	2	3	3	1	4	1	1	2	1	3
2	3	3	2	4	2	3	3	2	4	2	2	3	2	3	2	2	3	2	3
2	2	2	2	3	1	2	2	2	5	1	2	3	1	4	1	2	3	1	3
1	1	1	2	1	3	4	4	2	1	1	1	1	1	1	1	1	1	1	1
4	5	5	4	4	4	4	4	5	5	3	4	5	3	3	4	4	5	4	4
2	2	2	4	5	1	2	2	5	5	1	2	3	5	5	1	1	1	4	5
1	1	1	2	3	1	1	1	4	4	1	1	1	3	3	1	1	1	1	3
1	1	1	3	3	2	3	4	3	4	1	1	1	2	3	1	1	1	2	4
5	5	5	3	3	5	5	5	2	1	5	4	5	2	2	5	5	5	2	2
4	5	5	3	3	5	4	5	3	3	3	5	5	2	3	5	5	5	5	4
2	2	2	2	2	2	3	3	2	2	1	1	1	1	1	1	1	1	1	1
2	3	4	4	5	2	4	5	3	4	2	3	5	5	5	2	3	4	4	4
2	5	5	2	2	2	3	4	2	2	1	3	4	3	3	1	1	1	3	3
2	3	4	3	3	2	3	5	4	3	2	3	3	2	3	2	2	2	3	3
1	1	1	1	1	4	5	5	3	4	1	1	1	1	1	1	1	1	1	1
2	3	3	2	2	4	5	5	4	5	2	2	3	1	1	2	2	3	4	4

10.2 Experiment One and Experiment Two scene testing video link.

Experiment One testing: https://youtu.be/MhVLDd5ZGqs

Experiment Two testing: https://youtu.be/JICehtXYcGs

10.3 The original Immersion questionnaire

To what extent did the game hold your attention?

Not at all 1 2 3 4 5 A lot

To what extent did you feel you were focused on the game?

Not at all 1 2 3 4 5 A lot

How much effort did you put into playing the game?

Very little 1 2 3 4 5 A lot

Did you feel that you were trying you best?

Not at all 1 2 3 4 5 Very much so

To what extent did you lose track of time?

Not at all 1 2 3 4 5 A lot

To what extent did you feel conscious of being in the real world while playing?

Not at all 1 2 3 4 5 Very much so

To what extent did you forget about your everyday concerns?

Not at all 1 2 3 4 5 A lot

To what extent were you aware of yourself in your surroundings?

Not at all 1 2 3 4 5 Very aware

To what extent did you notice events taking place around you?

Not at all 1 2 3 4 5 A lot

Did you feel the urge at any point to stop playing and see what was happening around you?

Not at all 1 2 3 4 5 Very much so

To what extent did you feel that you were interacting with the game environment?

Not at all 1 2 3 4 5 Very much so

To what extent did you feel as though you were separated from your real-world environment?

Not at all 1 2 3 4 5 Very much so

To what extent did you feel that the game was something you were experiencing, rather than something you were just doing?

Not at all 1 2 3 4 5 Very much so

To what extent was your sense of being in the game environment stronger than your sense of being in the real world?

Not at all 1 2 3 4 5 Very much so

At any point did you find yourself become so involved that you were unaware you were even using controls?

Not at all 1 2 3 4 5 Very much so

To what extent did you feel as though you were moving through the game according to you own will?

Not at all 1 2 3 4 5 Very much so

To what extent did you find the game challenging?

Not at all 1 2 3 4 5 Very difficult

Were there any times during the game in which you just wanted to give up?

Not at all 1 2 3 4 5 A lot

To what extent did you feel motivated while playing?

Not at all 1 2 3 4 5 A lot

To what extent did you find the game easy?

Not at all 1 2 3 4 5 Very much so

To what extent did you feel like you were making progress towards the end of the game?

Not at all 1 2 3 4 5 A lot

How well do you think you performed in the game?

Very poor 1 2 3 4 5 Very well

To what extent did you feel emotionally attached to the game?

Not at all 1 2 3 4 5 Very much so

To what extent were you interested in seeing how the game's events would progress?

Not at all 1 2 3 4 5 A lot

How much did you want to “"win”" the game?

Not at all 1 2 3 4 5 Very much so

Were you in suspense about whether or not you would win or lose the game?

Not at all 1 2 3 4 5 Very much so

At any point did you find yourself become so involved that you wanted to speak to the game directly?

Not at all 1 2 3 4 5 Very much so

To what extent did you enjoy the graphics and the imagery?

Not at all 1 2 3 4 5 A lot

How much would you say you enjoyed playing the game?

Not at all 1 2 3 4 5 A lot

When interrupted, were you disappointed that the game was over?

Not at all 1 2 3 4 5 Very much so

Would you like to play the game again?

Definitely not 1 2 3 4 5 Definitely yes